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# TWELFTH UNITED NATIONS REGIONAL CARTOGRAPHIC CONFERENCE FOR ASIA AND THE PACIFIC

Bangkok, 20-28 February 1991

Volume II. Technical Papers

# DOUZIÈME CONFÉRENCE CARTOGRAPHIQUE RÉGIONALE DES NATIONS UNIES POUR L'ASIE ET LE PACIFIQUE

Bangkok, 20-28 février 1991

Volume II. Communications techniques

UNITED NATIONS/NATIONS UNIES

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Department for Development Support and Management Services

Département de l'appui au développement et des services de gestion

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Mention of the names of firms and commercial products does not imply the endorsement of the United Nations.

The views expressed in the papers are those of the authors and do not imply the expression of any opinion on the part of the United Nations Secretariat. The papers have been edited and consolidated in accordance with United Nations practice and requirements. Minor typographical errors could not be corrected owing to time constraints.

Throughout these papers, countries are referred to by the terminology in use at the time of the activities described.

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## FOREWORD

The official records of the Twelfth United Nations Regional Cartographic Conference for Asia and the Pacific, held at Bangkok from 20 to 28 February 1991, are issued, as were those of the previous conferences, in two volumes: volume I, *Report of the Conference*,[1] and the present publication, volume II, *Technical Papers*, which contains the texts of the technical background papers submitted to the Conference by the participating Governments and organizations. The papers are grouped according to the agenda item to which they relate.

The official records of the previous United Nations Regional Cartographic Conferences for Asia and the Far East have been published as E/CONF.18/6 (Sales No. 55.I.29) and E/CONF.18/7 (Sales No. 56.I.23) for the First Conference; E/CONF.25/3 (Sales No. 59.I.9) and E/CONF.25/4 (Sales No. 61.I.8) for the Second Conference; E/CONF.36/2 (Sales No. 62.I.14) and E/CONF.36/3 (Sales No. 64.I.17) for the Third Conference; E/CONF.50/4 (Sales No. 65.I.16) and E/CONF.50/5 (Sales No. 66.I.3) for the Fourth Conference; E/CONF.52/4 (Sales No. E.68.I.2) and E/CONF.52/5 (Sales No. E.68.I.14) for the Fifth Conference; E/CONF.57/2 (Sales No. E.71.I.15) and E/CONF 57/3 (Sales No. E.72.I.20) for the Sixth Conference; E/CONF.62/3 (Sales No. E.74.I.7) and E/CONF.62/4 (Sales No. 74.I.25) for the Seventh Conference; E/CONF.68/3 (Sales No. E.77.I.12) and E/CONF.68/3/Add.1 (Sales No. E.78.I.8) for the Eighth Conference; E/CONF.72/4 (Sales No. E.81.I.2) and E/CONF.72/4/Add.1 (Sales No. E/F.83.I.14) for the Ninth Conference; E/CONF.75/5 (Sales No. E.83.I.18) and E/CONF.75/5/Add.1 (Sales No. E/F.86.I.11) for the Tenth Conference; and E/CONF.78/4 (Sales No. E.87.I.13) and E/CONF.78/4/Add.1 (Sales No. E.88.I.18) for the Eleventh Conference.

[1] *Twelfth United Nations Regional Cartographic Conference for Asia and the Pacific*, vol. I, *Report of the Conference* (United Nations publication, Sales No. E.91.I.42)

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*Sub-items on which no papers were submitted are not listed

(e) *Thematic mapping*



(f) *Special mapping (including mapping for the handicapped and the International Map of the World on the Millionth Scale (IMW)*



*Agenda item 7.* CARTOGRAPHIC DATA RETRIEVAL, ANALYSIS, DEPICTION, PRESENTATION AND PRODUCT GENERATION

(a) *Map and chart reproduction, publishing and printing*



(b) *Digital databases*



(c) *Land information systems*

## Abbreviations

| | |
|---|---|
| ACS | Automated Cartographic System |
| AMS | Advanced Mapping System |
| ASEAN | Association of South-East Asian Nations |
| ATKIS | Authorized Topographic Cartographic Information System |
| AVHRR | advanced very-high-resolution radiometer |
| BAKOSURTANAL | Badan Koordinasi Survey dan Pemataan Nasional (National Coordination Agency for Surveys and Mapping, Indonesia) |
| BDB | bathymetric database |
| BDRS | bathymetric data reduction system |
| BGN | Board of Geographic Names (United States) |
| CAD | computer-aided design |
| CAMS | computer-assisted mapping system |
| CCOP/SOPAC | Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (ESCAP) |
| CCT | computer-compatible tape |
| CDP | Crustal Dynamics Programme (NASA) |
| CEDD | Committee on the Exchange of Digital Data |
| CERCO | Commission européenne des responsables de la cartographie officielle |
| CERN | Organisation européenne pour la recherche nucléaire |
| CIDA | Canadian International Development Agency |
| CIGNET | Cooperative International Global Positioning Network |
| CNES | Centre national d'études spatiales (France) |
| CRIS | Centre de rectification des images spatiales |
| COSPAR | Committee on Space Research (International Council of Scientific Unions) |
| CRT | cathode-ray tube |
| CSIRO | Commonwealth Scientific and Industrial Research Organization (Australia) |
| DBMS | Data Base Management System |
| DCDB | digital cadastral database |
| DCW | Digital Chart of the World |
| DEM | digital elevation model |
| DFAD | digital feature analysis data |
| DGFI | Deutsches Geodätisches Forschungsinstitut (Geodetic Research Institute, Federal Republic of Germany) |
| DGK | Deutsche Geodätische Kommission (Geodetic Commission, Germany) |
| DHI | Deutsches Hydrographisches Institut (Hydrographical Institute, Germany) |
| DLG | digital line graph |
| DLM | digital landscape model |
| DLMS | digital land mass system |
| DLR | German Aerospace Research Establishment (formerly DFVLR) |
| DMA | Defense Mapping Agency (United States) |
| DMAAC | Defense Mapping Agency, Aerospace Center |
| DMAHTC | Defense Mapping Agency, Hydrographic/Topographic Center |
| DMZ | demilitarized zone |
| DNMM | Directorate of National Mapping, Malaysia |
| DORIS | Doppler orbitography and radio positioning integrated on satellite |
| DOS | Directorate of Overseas Surveys (United Kingdom) |
| DTDB | digital topographical database |
| DTED | digital terrain elevation data |
| DTM | digital terrain model |
| ECDB | electronic chart database |
| ECDIS | electronic chart display information systems |
| EDM | electronic distance measurement |
| EDP | electronic data processing |
| EEZ | exclusive economic zone |
| ERODB | European Data Base |
| EROS | Earth Resources Observation System |
| ESA | European Space Agency |
| FAA | Federal Aviation Administration (United States) |
| FAO | Food and Agriculture Organization of the United Nations |
| FIG | Fédération internationale des géomètres (International Federation of Surveyors) |

| | |
|---|---|
| FINGIS | Finnish Geographic Information System |
| GEBCO | General Bathymetric Chart of the Oceans |
| GEOKART | Organization for Surveying and Cartography (Poland) |
| GeRD | geometrical rectangular data bank (Federal Republic of Germany) |
| GLORIA | geological long-range inclined ASDIC system |
| GLOSS | global level of sea surface |
| GPS | Global Positioning System |
| GRS | Geodetic Reference System |
| GSI | Geographical Survey Institute (Japan) |
| GSJ | Geological Survey of Japan |
| GUGK | Main Administration of Geodesy and Cartography (Union of Soviet Socialist Republics) |
| HDB | hydrographic database |
| HDDT | high-density digital tape |
| HIHAN | Hydrographic Information Handling System (United States) |
| HYDLAPS | Hydrographic Data Logging and Processing System |
| IAG | International Association of Geodesy |
| ICA | International Cartographic Association |
| ICAO | International Civil Aviation Organization |
| IECA | International Engineering Consultants Association |
| IfAG | Institut für Angewandte Geodäsie (Federal Republic of Germany) |
| IFOV | instantaneous field of view |
| IGN | Institut géographique national (France) |
| IGSN | International Gravity Standardization Network |
| IGU | International Geographical Union |
| IHB | International Hydrographic Bureau |
| IHO | International Hydrographic Organization |
| IMW | International Map of the World on the Millionth Scale |
| INS | Indonesian National Spheroid |
| ISPRS | International Society for Photogrammetry and Remote Sensing |
| ITC | International Institute for Aerial Survey and Earth Sciences |
| IUGG | International Union of Geodesy and Geophysics |
| JNC | jet navigation chart |
| LADS | laser airborne depth sounder (Australia) |
| LED | light-emitting diode |
| LFC | large-format camera |
| LIS | land information system |
| LORAN-C | long-range, low-density |
| LRDC | Land Resources Development Centre (United Kingdom) |
| MASMAP | mapping and analysis with small-format aerial photography (software package) |
| MC&G | mapping, charting and geodetic data |
| MSS | multispectral scanner |
| MTLRS | modular transportable laser ranging system |
| NAD | North American datum |
| NASA | National Aeronautics and Space Administration (United States) |
| NAVD | North American vertical datum |
| NBMS | National Bathymetric Map Series (Australia) |
| NGS | National Geodetic Survey (United States) |
| NGVD | national geodetic vertical datum |
| NNSS | Navy Navigation Satellite System |
| NOAA | National Oceanic and Atmospheric Administration (United States) |
| NORDA | Naval Ocean Research and Development Agency |
| NOS | National Ocean Survey (United States) |
| ODA | Overseas Development Administration (United Kingdom) |
| OEEPE | Organisation européenne d'études photogrammétriques expérimentales (European Organization for Experimental Photogrammetric Research) |
| OICRF | Office international du cadastre et du régime foncier |
| ONC | operational navigation chart (United Kingdom) |
| OSD | Overseas Surveys Directorate (United Kingdom) |
| PPS | Precision Processing System |
| rmse | root-mean-square error |
| SAR | synthetic aperture radar |

| | |
|---|---|
| SFPT | Société française de photogrammétrie et télédétection |
| SIDA | Swedish International Development Agency |
| SIPT | Société internationale de photogrammétrie et télédétection |
| SLAR | side-looking airborne radar |
| SLF | standard linear format |
| SPOT | Système probatoire d'observation de la Terre (France) |
| TM | thematic map |
| TPC | tactical pilotage chart (United Kingdom) |
| TRANET | tracking network (United States) |
| UNDP | United Nations Development Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USAID | United States Agency for International Development |
| USGS | United States Geological Survey |
| UTC | universal time coordinates |
| UTM | Universal Transverse Mercator |
| VLBI | very-long-baseline interferometry |
| WAC | World Aeronautical Chart |
| WGS | World Geodetic System |

**Explanatory notes**

The following symbols have been used in the tables throughout the report:

Three dots (...) indicate that data are not available or are not separately reported;

A dash (—) indicates that the amount is nil or negligible;

A blank in a table indicates that the item is not applicable;

A minus sign (–) indicates a deficit or decrease, except as indicated;

A full stop is used to indicate decimals

Use of a hyphen between dates representing years, e g , 1971-1973, signifies the full period involved, including the beginning and end years

A slash between dates representing years, e g , 1980/81, indicates a crop year, a financial year or an academic year

Reference to "dollars" indicates United States dollars, unless otherwise stated

# TECHNICAL PAPERS
# PRESENTED TO THE CONFERENCE

# AGENDA ITEM 4

## Country reports on the progress made since the Eleventh Conference

### CARTOGRAPHIC ACTIVITIES IN AUSTRALIA, 1987-1990*

*Paper submitted by Australia*


#### RÉSUMÉ

Depuis 1987, le secteur de la cartographie en Australie a été fortement influencé par les divers changements apportés à la politique gouvernementale. Des changements notables ont ainsi eu lieu en 1987 : une nouvelle organisation gouvernementale, l'Australian Surveying and Land Information Group, a été formée grâce à la fusion de l'Australian Survey Office et de la Division of National Mapping. Parallèlement, le secteur public australien s'est ouvert à la commercialisation, ce qui a obligé les organismes gouvernementaux à facturer pour la première fois leurs services, et notamment les renseignements cartographiques.

Le Gouvernement fédéral et les gouvernements des Etats se sont également efforcés d'améliorer la coordination de l'information foncière, et plusieurs instances nationales ont été créées à cette fin.

Avec les progrès techniques de ces dernières années, les systèmes d'information foncière sont devenus plus complexes et plus puissants, ce qui a entraîné une augmentation de la demande de renseignements cartographiques sous forme numérique. Une proportion plus grande de ces renseignements est désormais fournie grâce aux images satellite.


#### AN OVERVIEW

Since 1987 several changes in federal Government policy have strongly influenced development of the Australian mapping industry. Indeed, 1987 was a year when several notable changes occurred. A new government organization, the Australian Surveying and Land Information Group, was formed by the merger of the Australian Survey Office and the Division of National Mapping. At the same time commercialization was introduced into the Australian public sector, requiring government agencies for the first time to charge for the services they provided, including mapping information.

Federal and state governments have also focused on improving coordination of land information and several national forums have been established to address this need.

Technological developments over the last few years have seen growth in the complexity and capabilities of land information systems and a corresponding increase in demand for mapping information in digital form. A greater proportion of these data is being supplied through satellite imagery.

#### *Australian Surveying and Land Information Group*

The Australian Surveying and Land Information Group (AUSLIG) was formed in 1987 by the merger of the Australian Survey Office and the Division of National Mapping, and it is now part of the Property Services Program in the Department of Administrative Services. AUSLIG provides government agencies, the general public and the private sector with cost-effective surveying, geodetic, mapping and land-related information services.

AUSLIG provides surveying and land-related information services on a full cost recovery basis to Commonwealth agencies and other clients on approval by the Minister. It is also required to undertake a programme of community service obligations including mapping, geodesy, production of the Australian *Atlas*, operation of the Australian Centre for Remote Sensing (ACRES), determination of offshore boundaries and coordination of land information at the federal level.

The AUSLIG work programme extends over continental Australia, its island territories, the Australian Antarctic Territory and overseas.

#### *Royal Australian Navy Hydrographer*

At the international level the Hydrographic Branch is directly involved in the work of the International Hydrographic Organization (IHO) which is developing various international standards, including "quality of data" and exchange of digital data for electronic chart display information systems (ECDIS), standards of competency for nautical cartography etc.

Australia continues to act as coordinator for the IHO's charting initiative for Area Lima (southern Indian and Pacific Oceans, including the Southern Ocean). A scheme of 1:1,500,000-scale international charting series has been drafted. In 1990 the Hydrographer held discussions pertaining to the regional aspects of the charting programme with his counterparts in New Zealand, the Solomon Islands and Vanuatu. Australia is also seeking the views of the hydro-

*The original text of this paper appeared as document E/CONF 83/INF.7.

graphic offices in the region on a proposal to form the Southwest Hydrographic Commission, under the auspices of the IHO. If this occurs, representatives would be able to meet at regular intervals to discuss mutual hydrographic and chart production problems, plan joint survey operations, and develop schemes for medium- and large-scale international chart coverage of the region.

The programme of training at the Royal Australian Navy (RAN) Training School has been well represented by the South Pacific, with participants from Malaysia, New Zealand, Vanuatu, the Solomon Islands and the Philippines. Close liaison with the Solomon Islands Hydrographic Unit continued under the Defence Co-operation Program with the exchange of personnel between the offices.

### *Royal Army Survey*

Under the Defence Cooperation Program, the Royal Army Survey (RASvy) continued to provide aerial photography, equipment, training and technical advice to countries within the Pacific region. Survey advisers are presently posted to the Solomon Islands, Vanuatu, Indonesia, and there is a small contingent in Papua New Guinea. Work continued in Papua New Guinea on a joint border survey (with Indonesia) for future 1:50,000-scale mapping, and discussions have been held with Indonesia on the resumption of cooperative mapping activities with Australia. In regard to digital data acquisition the AUTOMAP 2 computer-assisted cartographic system has proven most successful in the generation of digital data topographic products and mapping to support defence needs. The system has evolved significantly since 1986 with the procurement of new improved hardware and improved software. Planning is well under way for a replacement system capable of generating topologically structured data more suited to the introduction of geographic information systems throughout Defence.

RASvy has been involved in the Digital Chart of the World (DCW) project which was proposed by the United States Defense Mapping Agency in early 1988 as a joint research and development venture with Australia, Canada and the United Kingdom. The project aims to:

(*a*) Develop a family of standards that will enable the exchange of data;

(*b*) Produce a DCW database in accord with these standards, using Operational Navigation Charts (ONCs);

(*c*) Develop the software tools to exploit the database.

The formal DCW agreement between Australia and the United States was signed on 22 June 1990. Australia's tasks are to test data, review the draft standards and review system software design and development. It is expected that the databases developed within the DCW will become the standard for geographic information used in support of existing and developing military systems.

## National coordination

### *Australian Land Information Council*

The Australian Land Information Council (ALIC) was formed in 1986 as the peak intergovernmental forum for land information in Australia and it is responsible for the national coordination of land information. The roles of the Council are to:

(*a*) Address land information management issues at the national level;

(*b*) Support the development and implementation of national land information management guidelines and standards;

(*c*) Provide a national forum for the sharing of experiences and exchange of information on land information management at the policy level.

The members of the Council are the respective chairpersons of the Land Information Steering Committee from each Australian State and Territory, the Commonwealth, the Australian Defence Force and New Zealand.

### *Intergovernmental Advisory Committee on Surveying and Mapping*

The Intergovernmental Advisory Committee on Surveying and Mapping (IGACSM) was established in place of the National Mapping Council in 1988 by agreement between the prime minister, state premiers and the Northern Territory chief minister. At its inaugural meeting members formulated recommendations and developed agreements in relation to surveying, mapping and land information. It remains a principal objective of the Committee to provide timely and professional advice to address problems Governments face in relation to state and national surveying, mapping and land information needs, and the broader impacting environmental issues.

The broader functions relate to coordination, developing technical standards and liaison. Emphasis is placed upon exchanging information to foster consistency, maintaining links with appropriate agencies and ensuring that surveying and mapping systems are compatible with and supportive of land and geographic information systems.

To facilitate this role the Committee has established seven independent working parties with individual terms of reference. These are:

Australian Height Datum Evaluation Project Management Team

Working Party on Mapping Specifications

Working Party on Digital Exchange Format for Map and Compilation Data

Working Party on Map Accuracy and Contents

Working Party on Geocentric Datum

Working Party on Standards and Specifications for Control Surveys

Working Party on Remote Sensing

In addition, the Permanent Committee on Tides and Mean Sea Level operates separately under the auspices of the IGACSM and reports in most instances directly to members.

### *Australian Liaison Committee for Remote Sensing by Satellite*

The Australian Liaison Committee for Remote Sensing by Satellite (ALCORSS) was constituted by the Australian Government in 1978 to advise on the operation of the Australian LANDSAT Station now known as ACRES. ALCORSS was formed to provide a forum for consultation, liaison and cooperation and to advise on the efficient and effective use of remote sensing in Australia.

ALCORSS representatives are from the federal Government, the state and Northern Territory governments, private industry, the Commonwealth Scientific and Industrial Research Organization (CSIRO) and tertiary education institutions.

## Cartographic activities

### *Mapping*

*Topographic*

The National Topographic Mapping Series (NTMS) provides the basic land information framework for national development, environmental management, defence, recreation, tourism and other activities.

The 1:100,000-scale series was completed in late 1988 with the printing of the last map sheet, covering an area of land west of Alice Springs. The popular 1:250,000-scale series of Australia is also complete. There are 3,064 maps at the 1:100,000 scale and 554 at 1:250,000 scale providing a complete coverage of Australia.

The programme of small scale topographic mapping is now on a revision cycle dependent on user demand. Details of the three-year programme (to December 1993) are outlined in the new "Digital topographic data" brochure. The use of satellite imagery for rapid response and revision mapping has increased. Encouraging results have been produced from SPOT and LANDSAT scenes.

The demand for digital topographic data has dramatically increased in recent years and revised maps are now available from AUSLIG in digital format as well as in the traditional map form. Maps are also available from a network of agents across Australia.

RASvy undertakes topographic mapping of Australia at 1:50,000 scale for defence purposes with the major effort centring in the northern regions. Survey control equipment has progressed from Doppler to GPS and the concept of a total camera station is presently being developed and evaluated by the Department of Defence.

*Thematic*

Most thematic mapping is based on the NTMS and is at small scales, i.e. 1:5 million and smaller. Thematic maps of Australia have been compiled into several atlas series. The third series of the *Atlas of Australian Resources* was recently completed with the publication of its sixth volume, *Vegetation*, which contains a systematic description of vegetation types over the entire continent and examines vegetation change over the past 200 years.

The atlas contains two new Australian vegetation maps showing Australia's vegetation cover in 1788 and 1988. The map of "Natural vegetation" shows the state of vegetation around the time of European settlement in 1788 and was mapped from current botanical reconstructions and historical descriptions.

The "Present vegetation" map is the first to show the present vegetation cover of the entire continent. It was compiled from satellite imagery, interpreted in conjunction with a large number of botanical survey records and reports.

The other editions of the atlas are on the topics of soils and land use, population, agriculture, climate, and geology and minerals. Maps included in these volumes are provided in the traditional printed format but are also available as digital data so that maps can be used in computer-operated systems. In future, editions of the atlas will be a comprehensive and timely series of single-sheet atlas maps.

In addition to the atlas series on Australian resources atlases have been published on themes such as the electoral geography of Australia which provides a consolidated report of all Commonwealth electoral redistributions since Federation, and explains the reasons behind the changes to electoral division boundaries. A factual atlas on Australian resources for the visually impaired and an atlas of Australian peoples are a few more examples of this type of educational publication which have been produced.

*Image mapping*

Full colour satellite image maps are being produced at various scales ranging from 1:25,000 to 1:2,500,000 for Antarctic research, aviation, environmental management and mining.

The process used is named 'SIMAP'. It involves printing a high quality image directly from digital data. This innovative process is very cost effective, particularly when compared to traditional methods (including producing maps from satellite image prints).

*World Aeronautical Chart (WAC)*

Maps of 1:1 million scale have been produced showing topographic base information for the whole of Australia. This is a major project which involves updating maps on a regular 2-5 year cycle.

### *Hydrographic charting and bathymetric mapping*

*Hydrographic surveying*

During 1989 and 1990 four new Survey Motor Launches were commissioned in the RAN Hydrographic Service. The Hydrographic Data Logging and Processing System (HYDLAPS) is installed on each of these 38-metre long catamaran hulled vessels and is based on the Qubit TRAC V/CHART V configuration, utilizing Hewlett Packard 9000 series computers. Installation of HYDLAPS has also been carried out on the survey ships *Moresby* and *Flinders*, in the Hydrographic Office and the Hydrographic School.

In May 1989, BHP Engineering Pty. Ltd. was awarded a $40M contract to produce and trial an operational system for the laser airborne depth sounder (LADS). When fitted in a F27 aircraft, LADS will measure water depth in the range of 0-50 metres, obtaining a 10 × 10m grid of soundings over an approximate area of 130 sq km in a typical four-hour flight. Flight trials are expected to commence in early 1991.

*Hydrographic Information System*

The Hydrographic Information System was formally accepted into the Hydrographic Branch in September 1989. Project definition and development is continuing, and the work in progress includes:

(*a*) Final development and documentation phase of the Chart Management Database;

(*b*) Entry of existing manuscript survey indexes and testing of the Survey management database scheme;

(*c*) Categorization of survey data rendered in terms of initial quality assessment;

(*d*) Completion of software developed to transform survey data between spheroids;

(*e*) Definition of management procedures in the handling of digital data. Links are being established between the HIS and the chart production system AUTOCHART (Automated Charting System).

*Charts*

Australia has to date published 376 charts from a planned total of 728 contained within its internationally accepted area of charting responsibility. The correction of published chart stock, normally managed by hand correction services, has been successfully enhanced by the application of screen printing methods. A total of 160 published charts, requiring 550 corrections (issued by Notices to Mariners) and involving 76,275 chart copies, have been corrected by screen printing, ensuring that navigational information has been accurately and promptly issued to the marine community.

*Sailing directions*

A decision has been made to commence the publication of *Sailing Directions in Australia,* covering the area of Australian charting responsibility. It is intended to have nineteen volumes, 12 of which will cover the Australian mainland and the Tasmanian coasts. Three volumes will cover the Coral and Tasman Seas, the Southern Ocean and the eastern part of the Indian Ocean. Four volumes will be devoted to Papua New Guinea waters.

### *Aerial photography and photogrammetry*

Developments in Australia over the last three years include the SATMAP System developed by Wild Australia from research done by the University of New South Wales. This allows for topographic and thematic mapping from overlapping SPOT satellite imagery using a Wild BC2 analytical plotter. Analog images produced from an image writer, either full frame or partial, are used as diapositives for restitution.

In airborne photogrammetry, there is an increasing use of analytical and digitized-analog plotters for map production. There are two Australian companies—QASCO Analytical Systems, which effect analog-to-analytical conversions of Wild B8 plotters; and ADAM Technology, which provides a similar service for the B8's and Jena Topocarts. ADAM have also developed their own analytical plotters, the ASP 2000, which utilize full-size diapositives, and the MPS 2, which has been designed for economical mapping from small-format cameras.

The Australian Surveying and Land Information Group (AUSLIG) is using an inflight calibration method, using linear features to determine lens distortions. Based on the plumbline method of calibration, the procedure allows for a total system of calibration.

Several projects are under way to link GPS equipment and camera systems to provide camera station coordinates. Investigations are continuing in an attempt to also acquire camera attitude parameters. The results of these investigations are expected to reduce ground control requirements.

There is an ongoing programme of aerial photography acquisition for national coverage, with colour photography being the norm, and an increasing use of colour infra-red photography for environmental monitoring.

### *Satellite imagery*

The federal Government, state governments, universities and research organizations in Australia have all developed remote sensing facilities. The government centres, although primarily established to service the public sector, also include substantial commercial components.

AUSLIG's Australian Centre for Remote Sensing (ACRES) has been upgraded so that it now has the capability to receive and process LANDSAT-5 thematic mapper (LS5-TM) and SPOT HRV (high resolution visible) multispectral (XS) and panchromatic (PA) images of Australia. Both TM and SPOT images are characterized by their high ground resolution of 30m for TM and 20m and 10m respectively for SPOT.

In addition to its range of raw data and partially processed products, ACRES is now able to produce geocoded data. Such products have the pixels uniquely and systematically aligned along the axes of a reference coordinate system with known position and scaling, specifically a cartographic projection.

The ground coverage of the geocoded data set is selected in order to match that of the 1:100,000-scale map sheet format of the National Topographic Map Series (NTMS). Typically colour photographic negatives are generated at 1:500,000 scale and then enlarged five times to 1:100,000 scale although the same data are available on magnetic media.

Preliminary tests with LANDSAT-TM data have shown that a useful match between satellite image and existing map can be obtained. Such a simple comparison could play an important role in revision. Examples of geocoded images are being generated and their usefulness manually evaluated. It is considered that the concepts developed through manual processing could be translated to a digital process.

A number of airborne and ground reception developments have also been taken up by private industry. The developments have in turn spawned specialized image processing systems such as the "fast delivery processor" for ERS-1 data and the CSIDA system for NOAA data.

A number of image analysis systems, for example MicroBRIAN, DISIMP (Device Independent Software for Image Processing), ER Mapper and A-Image, are developed and marketed in Australia. Australia is also a leading supplier of ground-based remote recorders and loggers.

### *Land information systems and management*

An important trend in land information management in Australia in the past two years has been the growth in demand for data in digital formats. Digital cadastral databases are well advanced in most jurisdictions and these are often used as a base for other databases being developed by government agencies, for a wide range of applications including land tax and valuation; land title and administration; mining, forestry and agriculture; utility services; and local government rating, planning and development.

The developments occurring in land information systems used by Australian government agencies are well illustrated by the ACTILIS project, described below.

*Development of an integrated land information system*

In April 1989 a task force was established by the Australian Capital Territory (ACT) Government to review the concept of an ACT integrated land information system (ACTILIS), specify requirements and functions of system components, introduce data administration procedures and policies for land information and begin to market information products.

The principal components of ACTILIS are a Central Property Register (CPR) and an upgraded Digital Cadastral Data Base (DCDB). The development is designed to build on existing systems operated by the ACT Government and considerable effort is being expended to computerize land records and coordinate procedures.

The integrated database will incorporate text and spatial data sets from various agencies which provide and use land data. The first stage of the Central Property Register will include data from the land titles register (which is currently being automated), rates, building and lease management.

The DCDB (a spatial record of the cadastral database for the ACT) upgrades the existing survey and planning systems. The high quality of survey coordinate data makes it possible to implement a continuous deposited plan using the DCDB. Considerable savings in survey and title registration should accrue from this development.

ACTILIS is planned as a government commercial venture. It is proposed that the CPR and DCDB will provide a platform to sell value-added information products to industry and the public. The next two years will see the implementation of Stage 1 ACTILIS and completion of the automation of the titles register. Rating and utilities systems are to be upgraded and it is expected that automation of critical building data will occur within three years.

Lease management data is already automated and will be improved over this period. Simplification and automation of lease documents is proposed as an adjunct to a development application register and tracking system, which will be operational from 1991.

In 1989 the ACT, in cooperation with AUSLIG, initiated a study of the feasibility of establishing legal coordinates in the ACT. A further review conducted by AUSLIG identified options for upgrade of the cadastre to improve the network and to maximize benefits from the coordinate system. Implementation of the system is currently being considered by the ACT Government in the light of these reports and a recent cost-benefit analysis of its introduction.

*Geographical names*

Geographical names application and standardization is the responsibility of the states and territories. They own and control both the data and the writing systems. The Commonwealth Government is, in land mapping, a user of the geographical names supplied by the states and territories. The Hydrographic Survey names the sea and territorial shelf and beyond the "three-mile" line. Apart from this exception the Commonwealth Government does not generally apply or standardize geographical names.

In 1984 the Committee for Geographical Names in Australia (CGNA) was formed in order to coordinate geographical names application and standardization across Australia and increase international liaison. The Committee is a national body consisting of representatives of geographical names authorities, related mapping organizations and invited experts.

Australia was recently admitted to membership of the United Nations Group of Experts on Geographical Names for the Asia, South-East, and Pacific, South-West, Division and hosted a meeting of the Division for the first time in August 1990.

Australia's immediate priorities lie in implementing the recommendations of the United Nations Conference on the Standardization of Geographical Names so as to facilitate national and international standardization. This will involve preparation and publication of toponymic guidelines and of a national gazetteer.

Draft toponymic guidelines were tabled for members' consideration at the 1990 CGNA Conference.

Preparation and publication of a national gazetteer will require consolidation of individual state, territorial and hydrographic survey gazetteers.

## NEW DEVELOPMENTS IN SURVEYING AND MAPPING IN CHINA, 1987-1990*

*Paper submitted by the People's Republic of China*


### RÉSUMÉ

Depuis la onzième Conférence cartographique régionale des Nations Unies pour l'Asie et le Pacifique, les activités menées par la Chine dans le domaine des levés et de l'établissement des cartes ont progressé sous divers aspects. On a eu fréquemment recours aux calculs électroniques, à la télémétrie laser et à la télédétection. On a créé et mis partiellement en œuvre le Système national d'information foncière de base. Le Bureau national de topographie et de cartographie, en organisant ses sources et celles de la profession des géomètres et des cartographes et en donnant la priorité à la planification, a accompli plusieurs missions consistant à établir des fonds de carte à l'échelle de 1/10 000, ainsi que des tâches de levé et d'établissement de cartes pour l'étude des ressources du sol. Il a également réalisé plusieurs projets importants de levé et d'établissement de cartes tels que la création du Réseau national de nivellement de second ordre et du Réseau national de gravimétrie de premier ordre. Au cours des années à venir, trois tâches fondamentales devront être accomplies : *a*) révision générale des cartes topographiques à 1/50 000; *b*) levés cadastraux pour tout le pays; et *c*) mise en place d'un réseau géodésique spatial national de grande précision utilisant des technologies spatiales modernes.


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Since the Eleventh United Nations Regional Cartographic Conference for Asia and the Pacific took place in 1987, there have been new developments in surveying and mapping activities in China. Electronic computation technology, laser-ranging technology and remote sensing have been comprehensively used, and the National Land Fundamental Information System has been established and partly applied in practice. During the reporting period, the National Bureau of Surveying and Mapping (NBSM) of China, by organizing its resources and those of the surveying and mapping profession, and giving priority to planning, has accomplished missions of basic mapping at scale 1:10,000 and surveying and mapping tasks for land resources investigation. A number of important surveying and mapping projects were completed, such as the establishment of a national second-order levelling network, and a first-order gravity network. In the coming years, three kinds of key surveying and mapping missions are planned:

(*a*) Overall revision of the topographic maps at 1:50,000 scale;

(*b*) Nationwide cadastral survey;

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(*c*) Establishment of a high-precision national space geodetic network with modern space technology.

### Organizational structure

Surveying and mapping institutions in China are separated under more than 30 departments and distributed in provinces and administrative districts with a total staff of about 300,000 persons. According to mapping tasks and organizational systems, they fall into three parts:

(*a*) The National Bureau of Surveying and Mapping (NBSM) includes surveying and mapping bureaux in provinces and autonomous regions, and surveying and mapping institutions in municipalities directly under the central Government and in cities with independent development plans. It is mainly responsible for the general administration of the surveying and mapping profession and for the execution of basic survey and special survey tasks nationwide;

(*b*) The Surveying and Mapping Bureau, under the Headquarters of the General Staff of the Liberation Army, includes surveying and mapping institutions of the greater military areas and the arms of the services. They are mainly responsible for mapping activities for military purposes;

(*c*) Surveying and mapping institutions under the departments of economic construction. They are mainly engaged in special surveying and mapping activities required by their departments.

NBSM of China was set up in 1956 with the approval of the National People's Congress. It is a functional department of the State Council of China in charge of surveying and mapping work all over China. The main responsibilities of NBSM are: working out guidelines, policies and laws and regulations of nationwide surveying and mapping work; overall planning and development of surveying and mapping tasks; organizing the implementation of national surveying and mapping tasks; establishing surveying and mapping standards of the country; issuing national fundamental geographic information data; training surveying and mapping personnel for all levels; organizing international surveying and mapping exchange and cooperation. At present, in addition to the surveying and mapping bureaux in provinces, autonomous regions and municipalities directly under the central Government, surveying and mapping administration institutions have been established in some of the prefectures, cities and counties of China.

### Geodesy

After the China Gravity Basic Network (CGBN 85) was established in 1985, the national first-order gravity network was completed in 1989. The network consists of 195 stations measured with LCR-FG and LCR-D relative gravimeters. The distance between stations is about 300 kilometres and the mean error of the gravity difference of connected measurement is less than $\pm 25 \times 10^{-8}$ $ms^{-2}$. Eight national gravimetric calibration bases were established in the past years in Beijing, Xi'an, Lushan, Chengdu, Fuzhou, Kunming, Lanzhou and Urumqi.

Marine gravimetry was carried out in offshore and intermediate sea areas. The profile measurement was also made in the western and southern Pacific. During the reporting period, 500,000 kilometres of marine gravity measurement line was completed with point accuracy $\pm 3 - 4 \times 10^{-5}$ $ms^{-2}$.

In cooperation with Finland and Germany, 18 absolute gravity stations were measured in China with JILA G-5 and JILA G-3 absolute gravimeters. The purposes of the measurements were first to find the non-tidal changes of the gravity values and next, to compare the results with those measured by the absolute gravimeters made in China and in Italy (IMGC).

The new astronomical longitude network of China was completed by the end of 1990 after eight years of astronomical determination work. The computation of the network is estimated to be completed in 1991. In order to meet the requirements of astronomic positioning in geodetic survey, the determination was made on those stars in the China Geodetic Star Catalogue (CGSC) which were frequently used for geodetic survey in China. The CGSC has been compiled in the past years and will be finished by the end of 1991. The star catalogue is composed of 4,082 stars from the declination -30 to +80 with an accuracy Ma = $\pm 0^{s}.004$ and Ma = $\pm 0''.1$.

Measurement of crustal deformation in China was done in close connection with seismological research and other methods of disaster prediction and prevention. The main objects of deformation measurement were plate tectonic motion, crustal deformation within a plate, and movement of active faults. In addition, the monitoring measurement was also made in some areas for land subsidence, cliff collapse and landslide, relative rising and flowing of the mean sea level along the coastal areas, and deformation of large projects.

During the reporting period, the main achievements were:

(*a*) A decision was made to remeasure the national first-order levelling with more accurate methods, with an interval of 10 to 15 years in order to obtain information on the nationwide crustal vertical deformation;

(*b*) 20 key monitoring zones for the vertical deformation were established in the whole country, with the repeated grid precise levelling as a main method with an accuracy of ±0.4mm/km;

(*c*) The monitoring measurement of the movement of 40 active fault zones was continued with vertical movement measurement as well as horizontal movement measurement. The vertical movement was measured by repeated precise levelling at short sides, and the horizontal movement was measured mainly by so-called fixed-point sides-measurement by EDM. Owing to progress in research on meteorogically effected errors, the accuracy of the side measurement was rather stable, reaching $10^{-6}$ magnitude, and could be consistent with the accuracy of the vertical movement measurement;

(*d*) The *Atlas of Modern Crustal Movement of China* was compiled from 1987 and will be published in late 1991. The *Atlas* is composed of maps of crustal movement speed rate in the country and in provinces; national and regional active structure (fault) movement; crustal deformation of main earthquake areas; and land subsidence of main cities in China.

Establishment of the National Geodetic Database was started during the reporting period. At present, the first phase had been completed, i.e. retrieval system of the horizontal control network database was set up.

Progress was also made on space geodesy, in addition to the above-mentioned conventional geodetic work. Positioning technology with the Global Positioning System (GPS) was keeping pace with positioning technology with NNSS, and was playing an important part in geodetic positioning work. In addition to the GPS receivers made in China, there are about 70 receivers of various types, imported.

On static positioning, GPS technology was mainly used for the establishment of control networks of cities, photographic control points in difficult areas, and control survey of engineering projects and mining projects. On dynamic positioning, GPS technology was mainly used for the navigation of ships and the aerial magnetic survey.

On Satellite Laser Ranging (SLR), the third-generation SLR systems in Wuhan and Changchun were installed and under operation. In addition to the Shanghai station, there were three officially operational SLR stations in China. The accuracy of the single ranging for the Shanghai SLR station was ±5 cm and that for Wuhan SLR Station was ±3 cm. At present, the SLR station in Beijing is under experiment and will be in operation in 1991.

According to the plan, the VLBI network in China is composed of three VLBI stations in Shanghai, Kunming and Urumqi. The Shanghai VLBI Station, consisting of a 25-m radio telescope, MK III recording terminals and micro VAX and HP-1000F computers as a complete system at one station, had carried out 63 connected measurements with a decade of VLBI stations of nearly 10 countries since January 1989. The VLBI stations in Kunming and Urumqi were under construction.

### Photogrammetry and remote sensing

At present, in China, all medium and small-scale mapping (from 1:5,000 to 1:50,000) is carried out by aerophotogrammetry, and most large-scale mapping (from 1:500 to 1:2,000) for cities and towns is done by aerophotogrammetric methods. In China, there are sufficient technical sources and equipment for the required aerophotography for mapping at scales 1:500 to 1:50,000. Every year, some 300,000 sq km are photographed for mapping purpose. Furthermore, large areas of aerial remote sensing are done for various purposes, such as geological investigation and mineral exploration, forestry investigation, urban resource and environment analysis, line selections of railways and highways, village and town planning, agricultural resource investigation, flood control and disaster relief, water resource exploration and mining construction. In the past four years, areas photographed for mapping purposes totalled more than 1,400,000 sq km and the photographed areas for other purposes were over 200,000 sq km. For 1:500- to 1:10,000-scale mapping, the photographic scale was generally one third to one sixth of the mapping scale, with the flight line following the central line of map sheets, and in general one photograph for one sheet of maps. For 1:25,000- and 1:50,000-scale mapping, the photographic scales selected were between 1:35,000 and 1:100,000 in accordance with different situations in different areas.

In mapping production, the layout of control points for block adjustment was generally used for field control. The horizontal coordinates of field control points were measured with conventional distancing traverse and theodolite intersection methods by the use of medium- and short-distance EDM instruments and various theodolites. The vertical coordinates were measured by the methods of levelling connections, triangulation elevation lines and traverses. In some difficult areas, GPS receivers were used for field control points. For feature investigation, office and field interpretation combined, or field investigation only, were used according to different areas. Office densification for control points was carried out by the on-line or off-line aerial triangulation block adjustment, whose software had functions of gross error detection and systematic error correction. Plotting was made with precise stereoplotters or analytical plotters.

Various kinds of survey and mapping instruments were made in China, including medium- and short-distance EDM instruments and analytical plotters. With 16 ZS-1 orthophotoprojectors, made in China, around 7,000 sheets of orthophotomaps were produced. 14 UX series analytical plotters, designed and manufactured in China, were used in production and played an important role in mapping production especially in large-scale mapping. Various theodolites and levels made in China not only met the requirements of surveying at home, but also could be exported to other countries.

In the past years, conventional aerophotogrammetric methods were continuously improved and developed, such as refinement of the existing software for block adjustment, expansion of the utilization ranges of conventional analog plotters, improvement of technological procedures of mapping, establishment of a high-precision camera experiment site for improving photogrammetric accuracy, and improvement of the photography materials. At the same time, a lot of effort was placed on photogrammetric digitization and automation; for example, analog plotters were modified into devices with digital mapping functions, several research results were obtained in new technology, such as automatic image matching and pattern recognition, primary experiment and research was made in real-time photogrammetry and airborne GPS experiments were done for decreasing the field control points.

For large-scale mapping at scales 1:500, 1:1,000 and 1:2,000 with aerophotogrammetric methods, not only analytical plotters and high-precision stereoplotters were used, but normal stereoplotters were also used through the use of ground marks, the method of transformed bundles of rays, and improvement of technological processes of mapping. Furthermore, the digital mapping system with integration of office field-work was developed for making large-scale city maps, cadastral maps and setting up the corresponding map database.

According to the different economic conditions and requirements in each region, cadastral survey was carried out in cities and towns by various methods, some with total station tachymeters for data collection and automatic cadastral mapping, and some with conventional plane-tables for making cadastral maps. A large number of experiments were made especially for making cadastral maps by photogrammetric methods. Of the completed cadastral maps, 60 percent were made with photogrammetric methods.

Great achievement was made in remote sensing technology in China in the past years. Spatial remotely sensed information was applied for the analysis and investigation of land-use status, for estimation of agricultural output and for prediction of insect plagues. Various remote sensing information was used for analysing and interpreting geological structures, which provided strong evidence for mineral findings and geological exploration. Aerial remote sensing was directly used for monitoring large-area ocean environment. Aerial remote sensing information increasingly played an important role in urban planning, in environment analysis and protection, and in other fields. For flood control, real-time remote sensing monitoring systems for flood prevention were set up in some important parts of Yongding River, Huanghe (Yellow) River, Changjiang (Yangtze) River and Huaihe River. Progress was also made in finding forest fires by means of space remote sensing information. Two national resource satellites were launched successfully, and a large number of wide-area and effective remote sensing information obtained. DIPNET image processing systems were successfully developed. Some experiments were made for revising medium- and small-scale topographic maps with spatial remote sensing information.

## Mapping and map publication

During the reporting period, the main mapping tasks were provision of topographic maps and image maps at scales 1:10,000 and 1:25,000 for detailed investigation of the land resources of the whole country; large-scale topographic maps required for urban planning and construction; and cadastral maps for cadastral management in cities and towns. In map publication, besides the continued compilation of topographic maps at various scales, more than 1,000 kinds of thematic maps on geology, meteorology, history, medical science etc. were compiled and published.

The main tasks for mapping and map publication completed during the reporting period were:

### *Topographic mapping*

In China, there are topographic maps at scales from 1:500 to 1:1,000,000. In the past four years, 80,000 sheets of topographic maps were surveyed and compiled.

*Large-scale topographic maps*

In China, these mean topographic maps at scales larger than 1:10,000; they are used for urban planning, municipal construction and engineering projects. Such maps are generally made by photogrammetric methods. During the reporting period, there were completed over 40,000 sheets of topographic maps at scales 1:500, 1:2,000; 1,000 sheets of topographic maps at scale 1:5,000; and 30,000 sheets of topographic maps at scale 1:10,000. These were produced by surveying and mapping organizations of China for urban planning and construction in more than 150 cities and for engineering projects such as highway construction, tube-line selection and building, and factory and mining construction.

*Medium-scale topographic maps*

These are topographic maps at scales between 1:25,000 and 1:100,000, and they are the basic maps used by national institutions in urban planning, land resource investigation, and development of agriculture, forestry, water conservancy and electricity. These maps are mostly made by compilation and partly by photogrammetric methods. In the past years, more than 1,000 sheets of topographic maps at scale 1:25,000 were made for some large engineering projects such as Gezhouba Dam, diverting water from Luanhe River to Tianjin City etc. Over 900 sheets of topographic maps at scale 1:50,000 were surveyed and revised in some areas. With the new map norms and specifications, over 100 sheets of topographic maps at scale 1:100,000 were newly compiled and revised in some provinces and autonomous regions.

*Small-scale topographic maps*

Topographic maps at scales 1:250,000, 1:500,000 and 1:1,000,000, are mainly produced for economic departments of China for use in general and regional planning, natural resource investigation and exploitation, and distribution of industry and agriculture. Maps at scale 1:200,000, consisting of 1,675 sheets,were completed in 1970s. Since such maps covered fewer areas with more sheets and were inconvenient to use, a decision was made by the State in 1984 that the map scale would be changed to 1:250,000. Now, all 800 sheets of 1:250,000 maps have been published. These newly compiled 1:250,000 topographic maps give fundamental information. Recompilation of 1:500,000-scale topographic maps was started in 1988; it is now almost complete and the maps will soon be published. The simple edition of 1:1,000,000 topographic maps in Pinyin (Chinese phonetic spelling) will come out in the near future.

*Revision of 1:50,000 topographic maps*

The 1:50,000-scale topographic maps of China were maintained and revised three times, with the third-generation maps already 10 years old. In 1990 NBSM decided to start the fourth generation revision of these topographic maps and at the same time establish the economic edition of the 1:50,000-scale map series, which would consist of five types of map editions: line maps, image maps, landform-type maps, land-use status maps and maps for international cooperation. The revision would be done separately, by office compilation, partial revision, and new mapping methods according to the different situations of different areas and the time of original mapping.

### *Image map making*

In China, image maps were started for research and experiment in 1958 and, since 1977, have been popularly used as a new kind of map. During the reporting period, more than 30,000 sheets of large-scale photographic image maps were made for land planning, resource investigation and agricultural division in parts of the provinces and municipalities.

### *Cadastral surveying and mapping*

Cadastral surveying and mapping were started in China in 1988. According to a primary estimation, the cadastral tasks for 477 cities, 1,936 counties and 1,148 towns of China amount to 40,000 sq km for cadastral mapping at scales 1:500 to 1:2,000. During the reporting period, over 9,000 sheets of cadastral maps were done for large cities such as Shanghai and Tianjin, and for parts of medium and small cities, making up 4.5 per cent of the total tasks for cadastral maps of the country.

### *Compilation of thematic maps*

To meet the needs of economic planning and management, education, scientific research and tourism, more than 1,000 kinds of thematic maps have been compiled and published since 1987. These include various general physical maps; all kind of socio-economic maps; some large cartographic products and plastic relief maps, for example, general physical maps such as the *National Physical Atlas of the People's Republic of China* and *Ecological Environment Atlas of Beijing and Tianjing Areas*, geological maps such as *Geological Maps of Quinghai-Xizang Plateau and Adjacent Areas* and the *Lithosphere Atlas of China;* ocean maps such as the *Comprehensive Atlas of the Coast Zones and Ocean and Sea Resource Investigation of China;* soil maps such as *Soil Atlas of China;* population maps such as *Population Atlas of the People's Republic of China;* economic maps such as *National Economic Atlas of the People's Republic of China* and *Atlas of Chinese Industry Distribution;* history maps such as *National History Atlas of the People's Republic of China;* and other maps such as *Atlas of Chinese Post Codes* and *Atlas of Schistosomiasis of China.*

### *Compilation of the National Atlas*

The *National Atlas of China* has been compiled twice. The second edition was started in 1981. The *Atlas* is in quarto size and divided into five volumes. Compilation of the *General Atlas* volume has been completed and will be published soon. The volume on *Agriculture* was published by the China Cartographic Publishing House in 1989. The *Physical Atlas, Economic Atlas* and *History Atlas* volumes are still under compilation.

### *Compilation of tactile maps*

To meet the needs of 7,000,000 blind and weak-sighted persons, NBSM decided in 1987 to organize research and preparation of the *Tactile Atlas of China*. After three years' work, compilation of the *Atlas* was completed, and it will be published with 325 maps. There are 60 dot-shape tactile symbols representing the position and distribution and independent elements, 20 line-shape tactile symbols representing objects distributed in line or strip forms, and ten area-shape tactile symbols representing the natural phenomena and social, and economic phenomena that occupy rather large areas and scope.

### RESEARCH AND DEVELOPMENT

In China, there are 23 research institutions for surveying and mapping with over 4,200 research staff. Of these, 10 are research institutions with 879 research staff in the system of NBSM. In the past years, NBSM established in succession the Research Institute of Surveying and Mapping Standardization; the Research Institute of Surveying and Mapping Economics and Management; and the Centre for Quality Supervision, Inspection and Testing of Surveying and Mapping Products. It also established the National Institute of Surveying and Mapping Scientific Information within the Research Institute of Surveying and Mapping of NBSM in Beijing, thus further improving the research and development system.

Since 1985, NBSM has set up a development fund for surveying and mapping sciences and technology, and has worked out a contract system of research projects together with corresponding management regulations. Meanwhile, great attention was paid to the combination of research projects and production from the setting-up to the completion of research projects. In the four-year period from 1986 to 1989, NBSM completed 785 research and development projects, of which, 16 obtained patents and 210 were recommended for popular application. Many projects achieved remarkable social and economic results. During the four years, 324 research projects won prizes, 4 of them State level prizes, and 95 prizes of provincial or ministry level.

On the development of surveying and mapping production techniques, the scheme for national first-order levelling adjustment was successfully used in the entire net adjustment of the first-order levelling network, with 93,000 km levelling lines. The research results of the 18-23 multispectral photographic technique, the on-line aerial triangulation technique and the four-colour printing technique were already applied in production. The research results of the scheme for the precise levelling remeasurement technique, the analytical-orthophoto projection technique, the new technology for large-scale mapping, and the reproduction techniques for remote sensing images and series maps, would be applied soon in surveying and mapping production.

On advanced research and development of new techniques and new products for surveying and mapping, the JZ-3 analytical plotter was in batch production and the JX-4 analytical plotter was under development. The DIPNET remote sensing and cartographic image processing system was selected in the international bidding for the World Bank loans and DIPNET series systems will be developed. The PR universal interface for computers was on sale all over the country The auto-correlation software for full digital mapping system was completed, and the digital mapping technique was officially applied in production of some survey organizations and would be recommended to the whole country gradually. The National Land Fundamental Information System began to take shape with a database of 1:1,000,000-scale National Digital Terrain Model (DTM) established, which played an important role in the project "National Food Control and Disaster Prevention Real-time Monitoring System". The precise laser alignment technique was successfully applied in the construction of the Beijing Positron and Negatron Strike Project and received a State prize. Some of the analog plotters were modified into digital mapping devices and most of the analog plotters in the country would be modified. An experiment on reforming the map printing technique was under way. The GPS positioning technique was applied in the establishment of control networks in some cities and in the connected positioning for the islands of the South China Sea of China, and played an important role in the departments of oil, geology, seismology, urban construction and surveying and mapping. Some research projects were under development, such as the geographic information systems of 1:250,000-scale maps of Liaoning Province, the 1:50,000-scale digital cartographic database of Hainan Province, the computer-aided cartographic and automated compilation system, and the national retrieval and management system for surveying and mapping information and archives.

On fundamental construction and basic research of surveying and mapping technology, the Ningxiang Remote Sensing Experiment Site in Hunan, the Taiyuan Photographic Dynamic Experiment Site in Shanxi and the National Calibration Center for Electro-Optical Distance Meters in Beijing, was established. The third-generation satellite laser-ranging system made in China for the Fangshan Satellite Observation Station in Beijing was under final experiment. Three national open key laboratories had begun to take shape, i.e. the Laboratory on Surveying, Mapping and Remote Sensing Information Engineering in Wuhan Technical University of Surveying and Mapping, the Laboratory on Dynamic Geodesy in the Institute of Geodesy and Geophysics, the Academy of Sciences of China, and the Laboratory on Resource and Environment Information System in the Geographic Institute, of the Academy of Sciences. Some research projects on basic theory were under development and practical results obtained; for example, the intelligent expert cartographic system, integrated geodesy, and the basic theory of GPS application and experiments of aerial triangulation with GPS.

In accordance with the unified plan of the country, NBSM drew up a development plan on surveying and mapping science and technology for 1991-1995, which set up basic aims and key tasks for surveying and mapping science and technology for the next five years. The basic aims are: (a) reforming conventional surveying and mapping techniques; (b) developing modern surveying and mapping techniques; (c) exploiting specially practical surveying and mapping techniques. The key tasks are:

(*a*) Modification of the conventional technique into digitization with new technology;

(*b*) Research on the development of a national precision spatial dynamic positioning network and an orbit determination network and their application;

(*c*) Continued research and application of the fundamental land information system and special geographic information systems;

(*d*) Setting up of the professional system of satellite remote-sensing application;

(*e*) Development of marine survey techniques;

(*f*) Research on computer stereo-vision and real-time photogrammetric techniques for industrial automatic control;

(*g*) Research on surveying and mapping standardization and scientific management;

(*h*) Research on surveying and mapping basic theory and its relation to intersected sciences and disciplines.

## EDUCATION AND TRAINING

### *High-level education*

During the reporting period, the number of institutes, professions and students were similar to that in the past years. Wuhan Technical University of Surveying and Mapping is a main base for training high-level personnel for surveying and mapping in China. In the past four years, Technical University enrolled every year about 60 post-graduate students, 750 graduate students and 400 adult students. Within the total number of the enrolled students, were a number of students for each specialty; students of engineering survey, land management and cadastral survey increased, while students of geodesy decreased. While keeping the scale of education, the university paid more attention to training students with production capability and improving practical teaching. On the one hand, students were arranged for practical training in production units, generally in the last-term before graduation; on the other hand, the practice sites of the university were improved. At present, the Technical University has maintained and reformed the two practice bases of the university.

On training of post-graduate students, there are specialties entitled to confer Doctor's and Master's degrees. In addition to the two specialties (geodesy, and photogrammetry/remote sensing) having the right to confer Doctor's degrees, the engineering survey specialty of the university has had the right to confer Doctor's degrees since 1990.

In 1989, the Technical University started to receive foreign students. A one-year course was offered to four students from Pakistan, Sri Lanka and Mongolia in 1989. Five students were received in 1990 from the ESCAP remote-sensing programme and the United Nations Space Commission for a one-year course. Now, the University has the capability for receiving foreign students on specialties of geodesy, photogrammetry and remote sensing, engineering survey and cartography.

In China, higher education institutions are not only education centres, but also centres of research and development. Wuhan is one of the key universities of China, specializing in photogrammetry and remote sensing as a national key specialty. The national key Laboratory on Surveying, Mapping and Remote Sensing Information Engineering, set up in the university, will become an important base for scientific research and it will be open to surveying and mapping experts from China and other countries.

By the end of 1990, the Technical University had completed a project of the Second Development Programme for Chinese Universities with World Bank loans. With loans of $US 5,000,000, a computer system and modern survey instruments and equipment were purchased, teaching staff were sent to other countries for study tours, and foreign experts were invited to lecture at the university. The education Centre for Urban and Rural Survey, Planning and Management, established jointly by the Technical University and the International Institute for Aerial Survey and Earth Sciences (ITC) of the Netherlands, was continued with a group of teaching staff from ITC for lectures and joint research in Wuhan.

### *Middle-level education and staff training*

There is only one special technical school for surveying and mapping in China, i.e. Zhengzhou Technical School of Surveying and Mapping under NBSM, which mainly trains technicians for surveying and mapping production. At present, the school has specialties of geodesy, photogrammetry, cartography, engineering survey and cadastral survey, with 250 students enrolled every year. There are also more than ten technical schools under other departments and provinces, which have surveying and mapping specialties. At the same time, NBSM has eight middle technical schools for surveying and mapping staff, which enrol technical workers from survey departments.

In China, the surveying and mapping staff education is divided into diploma education, certificate education, on-the-job training and continued engineering education, these have formed an adult education system at different levels, multi-ways and multi-standards.

## INTERNATIONAL EXCHANGE AND COOPERATION

In the past four years, the surveying and mapping departments of China have further developed and strengthened the exchange and cooperation relations with surveying and mapping departments of many countries. NBSM has signed agreements on scientific and technical cooperation with survey departments of countries such as Finland, Germany, Pakistan, United States of America, and has established technical and information exchanges with more than 30 countries. Some cooperation projects have reached remarkable results, for example, cooperation on cadastre between NBSM and DSE (German International Development Foundation), cooperation on the length standard baseline, and absolute gravimetry and remote sensing image processing between China and Finland. NBSM sends yearly from 40 to 50 delegations or groups to other countries for visits, technical study tours, joint research projects and various meetings and symposia, and receives more than 100 specialists and scholars from other countries to China for visits, lectures, joint research, technical exchange and training.

The Chinese Society of Geodesy, Photogrammetry and Cartography continues to participate in various activities of international professional bodies. In April-June 1990, supported or organized by the Society, the following meetings were held in Wuhan: the meeting of the Executive Committee of the International Cartographic Association (ICA); the Eighth International Symposium on Geodetic Computation of the International Association of Geodesy (IAG); and Commission III of the Symposium of the International Society for Photogrammetry and Remote Sensing. The 58th meeting of the International Federation of Surveyors (FIG) will be held in Beijing on 20-25 May 1991.

Exchange and cooperation relations with survey departments of all countries in the world will continue to be maintained and scientific and technical exchanges and collaborations with survey experts and specialists from all countries will be further developed.

## PROGRESS MADE IN THE FIELD OF SURVEYING AND MAPPING IN CYPRUS, 1987-1990*

*Paper submitted by Cyprus*


### RÉSUMÉ

Ce rapport décrit les activités nationales de topographie et d'établissement de cartes thématiques, de remembrement et de gestion des terres, de constitution de bases de données numériques dans les domaines juridique, budgétaire et cadastral, d'enseignement et de formation, et de normalisation des noms géographiques.


Cyprus is the third largest island in the Mediterrenean Sea with an area of 9,251 sq km (3,572 sq miles) It lies in the north-eastern corner of the Mediterranean basin, at a cross point of three continents: Europe, Asia and Africa. Over 100 years ago, in 1878, when the British took over the administration of Cyprus, one of the first steps taken by the Government was the survey and mapping of the island. Owing to its strategic position, Cyprus has always been a favorite subject for cartographers, and its cartography has followed closely the history of map-making even from the beginning; indeed, its geography and cartography was of as much importance as its possession by rival powers at different times. Now, and since 1974, 40 per cent of the total territory of Cyprus is occupied by Turkish forces.

### TOPOGRAPHICAL MAPPING

For the completion of mapping of the unoccupied part of Cyprus by National Topographical Mapping at scale 1:5,000, an area of about 350 square miles remains. Efforts are in progress to perform airphotography of the whole part of the unoccupied area of the island with the object of completing the unmapped area and revising the existing map series.

### THEMATIC MAPPING

The following new editions of maps were prepared and published by the Department of Lands and Surveys.

(*a*) Following the decision of the third meeting of the Mediterranean and Black Seas Hydrographic Commission to allocate to Cyprus the production of INT 3604 at scale 1:250,000 (350 N>), this chart was produced by the Department of Lands and Surveys in 1984, based on the International Hydrographic Organization (IHO) specifications and submitted to the Fifth conference of the Mediterranean and Black Seas Hydrographic Commission in 1986. This chart replaced the original one produced in 1982 by the same Department under the national series number DLS 26;

(*b*) The first Approach Chart for Cyprus was prepared for Vasilikos port in 1990;

(*c*) The Department of Lands and Surveys always provides its assistance to the Department of Civil Aviation in the production of several charts for civil aviation purposes as well as to all ministries, government departments and organizations, as follows:

- (i) The aeronautical chart of Cyprus at scale 1:500,000, produced for the first time in 1987; the chart is prepared under the International Civil Aviation Organization (ICAO) specifications;
- (ii) The Aerodrome Obstacle charts-ICAO, Type A (Operating limitations) and the Aerodrome Ground Movements charts—ICAO, for the two international airports of Cyprus, Larnaca and Paphos;
- (iii) 30 multicoloured geographical maps, prepared for the Ministry of Education to be included in geography books for elementary and secondary schools;
- (iv) Two street names/maps of two communities at scale 1:5,000;
- (v) Two separate tourist maps at scale 1:5,000, prepared for two respective areas;

(*d*) The following maps were revised:

- (i) Road net of the military maps at scale 1:50,000, English edition;
- (ii) Road net of the Joint Operations Graphic (Air) map, English Edition, scale 1:250,000;

(*e*) Progress was made in the revision and production of:

- (i) Topographical map at scale 1:100,000;
- (ii) Administration and Road Map at scale 1:250,000, Greek and English editions;
- (iii) Lefkosia East and Lefkosia West (2 sheets) Town Plans (street names maps) at scale 1:750,000.

### LAND CONSOLIDATION

The enactment of land consolidation in Cyprus started in 1969. Up to 1987, 26 communities were completed, involving some 7,136 new units of land. From 1987 to 1990, 6 communities were completed, involving some 991 new units of land; and 18 other communities are in progress for completion.

### LAND MANAGEMENT

Following the directions of the Government of Cyprus, a group of experts, called in 1989 from Australia, prepared and submitted information on technology strategy for the Department of Lands and Surveys. The long-term aim is the development of a fully integrated set of land records for Cyprus—in effect, an efficient Land Information System for the State.

In brief there will be three databases in the Department of Lands and Surveys, which will form an integrated system.

#### *Legal/Fiscal DataBase*

The main functional areas to be supported and the facilities to be provided in the initial implementation of the system are listed below.

(*a*) Computerization of the major document registers;

(*b*) Storage and maintenance of land register data in digital form;

(*c*) Automatic generation of certificates of registration to facilitate the examination of documents;

*The original text of this paper appeared as document E/CONF 83/INF 40.

(*d*) Availability of data at lodgement counters to facilitate the examination of documents;

(*e*) Storage of property details and land values in digital form;

(*f*) Ability to produce an inventory of State-owned land;

(*g*) On-line access by all branches of the Department of Lands and Surveys to a wide range of departmental data;

(*h*) Production of a variety of management and statistical reports.

In addition to the functions mentioned above, the database will be designed to support computer-assisted evaluation techniques.

The Legal/Fiscal DataBase will be integrated with the Digital Cadastral DataBase (DCDB) and the Survey DataBase (SDB).

*Survey DataBase*

The proposed Survey DataBase would be built over many years. Initially the bulk of the data would come from a proposed general resurvey of Cyprus. The database would continue to grow as all new surveys were entered. Access to survey data would be provided for surveyors and the wider LIS. The community would be centred on the Survey Database.

Integration will permit the display of the legal/fiscal information in graphical form. This will facilitate the production of a wide range of thematic maps for valuation and land managements purposes.

*Digital Cadastral DataBase*

The recommended strategy for creating the DCDB is summarized as follows:

(*a*) Digitize a large portion of the chain survey-based plans;

(*b*) Do not digitize the unsound survey-based plans;

(*c*) Digitize a subset of the plane table survey-based plans, but enter chain survey data in these areas from the field books;

(*d*) Build the DCDB progressively from a combination of digitized plans, chain survey field-book data, and new survey data. The system would supply the Department of Lands and Surveys with the geographic/spatial tools to create, maintain and generate products from a database of the cadastral boundaries of Cyprus.

EDUCATION AND TRAINING

Cyprus is faced with shortage of trained staff and, of course, financial resources. Offers will be welcomed for technical assistance in the fields of hydrography and nautical charting, land information systems, cartography and geographical names, from any who have the means to assist us.

GEOGRAPHICAL NAMES

The geographical names of Cyprus have an old history from a cartographic as well as a cultural point of view. The task of collecting, standardizing and establishing the romanization of those names was entrusted to the Cyprus Permanent Committee for the Standardization of Geographical Names, which was set up on 21 April 1977 by decision No. 15769 of the Council of Ministers. The Committee constitutes the only competent national geographical names authority. In collaboration with the Department of Lands and Surveys and the Cyprus Research Centre the Committee collected, standardized and romanized the main geographical names, some 2,000, and published the *Concise Gazetteer of Cyprus* in 1982. The *Gazetteer* is based on the Cyprus Topographical Map at scale 1:100,000.

In 1987 the *Complete Gazetteer of Cyprus* was completed and published. It contains about 67,000 entries and is based on the cadastral plans at various scales as well as on other sources such as the 1:50,000 maps and the National Topographical Series at scale 1:5,000. Also three Administration and Road Maps at scale 1:250,000, with standardized names, were prepared by the Department of Lands and Surveys and were published in 1987, one in Greek, one in Turkish (as both languages are the official languages of the Republic of Cyprus) and one in English in roman script. The gazetteer and maps were submitted and approved by the fifth United Nations Conference on the Standardization of Geographical Names, held in Montreal, Canada, in 1987. The Aeronautical Chart—ICAO of Cyprus, which also was prepared by the Department of Lands and Surveys in 1988 uses the standardized names.

FUTURE PROGRAMMES

The Department of Lands and Surveys has the task of revising the names on existing editions of maps in order to conform to the accepted new transliteration system.

## ETAT D'AVANCEMENT 1987-1991, ET PRINCIPALES INTERVENTIONS RÉGIONALES*

*Document présenté par la France*

### SUMMARY

This report provides brief information on cartographic work carried out by France in 1987-1990 in 15 countries and territories of the Asia and Pacific region.

TERRITOIRES DU PACIFIQUE OU ASSOCIÉS

*Nouvelle Calédonie :*

Réseaux de base :

1989 : Réalisation des réseaux de géodésie et de nivellement pour l'île de Lifou

Cartographie : A l'aide de la prise de vue aérienne réalisée en 1985

18 cartes à 1/50 000 ont été révisées et éditées au 31 décembre 1990.

11 autres cartes de la même série sont en cours de rédaction.

*Wallis et Futuna :*

Edition en 1987 des cartes à 1/25 000, référence 4 902 et 4 901 W.

*The original text of this paper appeared as document E/CONF 83/L 38

*Polynésie* :

Les cartes suivantes ont été éditées depuis le précédent rapport d'activité :

1988 : Carte de Tahiti et des environs 1/100 000, référence 513

1989 : Carte de Tahiti en relief, référence R1 TAH

*Territoires Australs* :

Cartographie des îles des Apôtres, des Pingouins, de l'île aux Cochons, référence 4450 C

## MOYEN-ORIENT

*Oman*

1989 : Réalisation de 12 feuilles à 1/50 000 pour Ministry of Petroleum and Minerals

1990 : Réalisation de 5 feuilles à 1/50 000 et 4 feuilles à 1/20 000 pour National Survey Authority

*Yemen*

1989 : Réalisation d'une carte "au trait" au 1/50 000 et au 1/100 000 sur la région d'Ibb par restitution photogrammétrique d'un couple stéréoscopique SPOT (feuille pilote)

1990 : Signature d'un contrat de géodésie de premier ordre (300 points GPS) et de nivellement de précision (3 500 km)

*Arabie Saoudite*

1990 : Fin des travaux cartographiques sur le Rub al Khali

1989/90 : Classification de thèmes urbains à partir d'images satellitaires (LANDSAT-MSS)

*Iran (République islamique d')*

1989/90 : Formation pour le traitement et interprétation de données satellitaires à Iranian Remote Sensing Center (IRSC), Téhéran

## ASIE DU SUD-EST

*Bangladesh*

1989 : Réalisation d'une carte "au trait" au 1/50 000 par restitution photogrammétrique d'un couple stéréoscopique SPOT (feuille pilote)

1989/90 : Réalisation de 200 spatiocartes SPOT dans le cadre du Plan de contrôle des crues (Flood Action Plan)

*Chine*

1989/90 : Traitement d'images SPOT sur la région de GUNSU dans le cadre de la coopération scientifique franco-chinoise

*Indonésie*

1987-1989 : Développement et mise en œuvre d'une base de données dans le cadre d'un projet de planification et d'évaluation des ressources naturelles (LREP)

*Malaisie*

1989/90 : Réalisation d'une cartographie topographique et d'occupation des sols dans l'État de Sabah

*Inde*

1989/90 : Stage de perfectionnement en reproduction et tirage pour 8 techniciens du Survey of India

*Thaïlande*

1987-1989 : PVA dans le cadre du Land Titling Project, years 3, 4 et 5 (40 000 photos, 4 échelles)

1990/1991 : PVA dans le cadre du Land Titling Project, year 7 (45 000 photos, 4 échelles)

*Brunéi Darussalam*

1991 : Développement et mise en œuvre d'une station de traitement d'images satellitaires à l'Université Brunéi Darussalam

# NATIONAL REPORT ON SURVEYING AND MAPPING*

*Paper submitted by Germany*


## RÉSUMÉ

Ce rapport décrit les activités théoriques et pratiques menées entre 1987 et 1990 dans les domaines de la géodésie, de la photogrammétrie et de la cartographie.


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### GEODETIC RESEARCH ACTIVITIES

In the collection of observation data from geodetic space techniques, the Fundamental Station Wettzell plays a central role. Several observational methods are employed to contribute to different geodetic and geodynamic projects, especially for determining and monitoring global and national reference systems and for contributing to coordinated international projects for detecting and monitoring global and regional plate tectonics and the variations in earth rotation parameters.

The main activities in Wettzell during the reporting period were:

(*a*) Operation of the fixed Nd:YAG satellite laser ranging system. This system contributed regularly to international programmes such as the Crustal Dynamics Project and the International Earth Rotation Service, by observing the satellites LAGEOS, Starlette and Ajisai;

(*b*) Installation of the new Nd:YAG laser-ranging system WLRS, which is designed to have the dual capability of ranging both to satellites and to the moon. This system is in the testing phase. Observations to satellites and to the moon have been made;

(*c*) Operation of the 20-metre radio telescope, which is primarily dedicated to geodetic very long baseline interferometry (VLBI). This system contributes mainly to the International Radio Interferometry Survey (IRIS) project, making 24-hour observations to determine changes in the earth rotation rate and the position of the pole. Additional observations are made for one hour each day along with one of the United States stations, with the objective of detecting higher frequency variation in the earth's rotation rate. Sporadic observations are also made every month in support of the Crustal Dynamics Project of the United States National Aeronautics and Space Administration (NASA);

(*d*) Continuous operation of a Global Positioning System (GPS) tracking station, as part of the Cooperative International Global Positioning Network (CIGNET). The objective of this international project is to provide orbital information to non-military user participants.

Further observations have been made by the modular transportable laser ranging system MTLRS-1 and by various GPS receivers:

(*e*) MTLRS-1 has been used for co-location observations in Wettzell, in Greenbelt, Maryland, United States of America and at Matera, Italy. Along with its Netherlands and United States counterparts, MTLRS-2 and TLRS-1, it has made observations in 1986, 1987 and 1989 in Italy, Greece and Turkey as a contribution to the WEGENER-MEDLAS Project. Crustal motions in the Central and Eastern Mediterranean have been determined and a fiducial network of points for later densification with GPS has been established. In 1988 and 1990 at three sites in the United States, observations within the scope of the NASA Crustal Dynamics Project have been performed;

(*f*) The group has participated in several GPS campaigns designed to test and to optimize the use of this system of geodesy, especially over long baselines, e.g. for investigating the application of GPS to earth rotation (Wettzell, Simeis/Crimea, UdSSR and Ankara/Turkey). Several GPS campaigns have been performed, e.g., for the following:

(i) Installation of geodetic reference systems (EUREF, Turkey);

(ii) Monitoring of geokinematics in Turkey and Greece (WEGENER-MEDLAS);

(iii) Monitoring of sea-level change (BALTNAV).

A two-way observation system, PRARE, operating in the S- and X-bands, was developed in the Federal Republic of Germany and will be flown for the first time on board the ERS-1 satellite scheduled to be launched by the European Space Agency (ESA) in 1991. PRARE is designed to observe range (10 cm) and range rate (0.1 mm/sec). The data will be accumulated on board and dumped to a central ground computing facility when the satellite is over the horizon of the ground receiving station.

There has been considerable activity in the area of orbital computation and point positioning computation by both long-arc and short-arc methods. Studies have continued on the determination of improved gravity fields from satellite observations. Analyses have addressed satellite-to-satellite tracking and satellite gravity gradiometry.

The use of inertial instrumentation has been tested at three institutions with the objective of deriving evaluation procedures for remote or underdeveloped areas and for special applications such as engineering survey and physical geodesy (determination of the deflection of the vertical and gravity).

Gravity measurements were performed at several stations of the German first-order gravity network and at Wettzell with an absolute gravity meter (system Faller/USA). The mean observed differences were 6 $\mu$gal. For the first time ever, observations with the superconducting gravimeter at the earth tide station in Bad Homburg demonstrated the influence of earth rotation effects on gravity observations. Observations taken at the VLBI-sites Wettzell and Richmond, Florida, United States, enable a comparison of earth rotation parameters derived both by VLBI methods and by superconducting gravity meters. In Antarctica, a 9-metre radiotelescope is being installed. It is dedicated to geodetic VLBI and to ERS-1 image recording.

### PHOTOGRAMMETRY RESEARCH ACTIVITIES

In photogrammetry and remote sensing, research activities are increasingly concentrating on the development of digital image recording and processing procedures. They extend not only to reconnaissance and control of the earth, but also to the fields of regional policy, engineering survey, and close-range photogrammetry. Space-related information

*The original text of this paper, prepared by the Institut für Angewandte Geodäsie (IfAG), appeared as document E/CONF 83/INF 14.

systems can be considered as a global objective; they require a transfer of technology between the research and development fields and the operational application field.

Many university institutes and other research facilities are active in the above-mentioned fields. Their main activities are concentrated on: digital image recording (Stuttgart, München, Oberpfaffenhofen), data processing and editing (Hannover, Berlin, Karlsruhe, Frankfurt am Main, Oberpfaffenhofen). The use of "additional data" in image processing is also of increasing importance. DPS (Stuttgart) and altimetry data are here of particular interest. A space-related information system for Antarctica (GIA) has been started (Frankfurt a.M.). Some institutes work on radar image data processing (Oberpfaffenhofen, Hanover, Stuttgart, Karlsruhe, Frankfurt a.M.)

The German ERS-1 ground segment consists of processing and archiving facilities at Oberpfaffenhofen (D-PAF) and the synthetic aperature radar (SAR) data download facility on the Antarctic Peninsula. Among the SAR projects carried out in conjunction with ERS-1 are the *Radarmap of Germany* and *Interrelation of Ocean, Ice and Atmosphere in the Antarctic* (OEA).

The ESA satellite activities in photogrammetry and remote sensing in Germany can be found in the national report of the German Society for Photogrammetry and Remote Sensing.

In the field of extraterrestrial research, Germany will participate in the projected Mars-'94 programme of the USSR with the High Resolution Stereo Camera (HRSC) Experiment ("Three-Line-Geometry"), and the Wide Angle Optoelectronic Stereo Scanner (WAOSS) Experiment.

## CARTOGRAPHIC RESEARCH ACTIVITIES

In cartography, research work has been performed mainly in the field of automation. Digital cartographic data today are not only used for computer-assisted map production, but also as a topographic base of geographic information systems (GIS). Such systems are needed for planning and for statistical, navigational, ecological and military purposes. Thus, the demand for such data by official and private institutions has dramatically increased in recent years, and the high costs of data acquisition therefore are much better justified now than in the times of merely cartographic application.

In view of this situation, the Working Committee of the Survey Administrations of the states of Germany created the project, "Authorized Topographic-Cartographic Information System" (ATKIS). Some of the members have started to realize its value and plan to finish a first version of the most urgent information needs by the end of 1994.

The essence of ATKIS is to convert the content of the official topographic maps into digital form, supplement them by attributes of general interest, structure them according to modern topological and object-oriented theories of spatial data models and offer them to the public in a standardized digital exchange format. ATKIS comprises so-called digital Landscape Models (DLMs) with precise, symbol-independent information and digital cartographic models (DKMs) derived from them by cartographic generalization and displacements, as required by the dimensions of the cartographic symbols. Since up to now there is no method of automatic generalization, there will be separate and rather independent DLMs for the scales 1:25,000, 1:200,000 and 1:1,000,000. Their content is described in detail in a feature class catalogue, which models the landscape by simple and complex objects defined by feature class, names, attributes, coordinates and references to other objects. The data are captured from air photos and from existing map foils; e.g., in the case of the DLM of scale 1:200,000, for each map sheet the 17 foils of the existing official map series of that scale are scanned. These data are then updated digitally in raster mode, using a procedure that replaced manual map revision at the Institute of Applied Geodesy (IfAG) some years ago, and which ensures that only the newest data enter the following processing steps. These comprise interactive and fully automatic editing of the revised raster data, their transformation into vector data, interactive correction, adding of attributes and data structuring according to the complex data model of ATKIS.

In some cases, also, methods of cartographic pattern recognition are used to speed up data capture. Thus with the railways ten different feature classes may be distinguished automatically using symbol characteristics such as line width, area, skeleton-topology etc. And with the contour lines the height values are assigned before vectorization of the raster data using a method called "flooding", in which the different height layers between the contour lines are automatically filled with pixels of different colours starting from seed-points in the valleys and proceeding layer by layer, until the summits of the mountains are reached.

After automatic extraction of the different feature classes several methods of desymbolization are applied to reduce their geometry to the simple forms suitable for their incorporation into a Digital Landscape Model.

The methods described use three different hardware and graphic base software systems one after the other as in an assembly line. Scanning, vectorization and raster batches occur on a Scitex Response 280 installation, interactive raster and vector editing on a Kartoplan PC-based RASCON system, and attribute processing and data structuring using ESRI's ARC/INFO software.

For the Digital Landscape Model 1:25,000, however, manual digitizing methods prevail, and photogrammetry plays an essential role for the capture of those feature classes, for which a high accuracy standard has been defined. In this context systems like ALK-GIAP (AED-Graphics), SICAD-ATKIS (Siemens) and PHOCUS (Zeiss) are used, which stand for a number of other suitable choices.

Considering the large number of systems for automated cartography and geographic information systems on the market, a survey of current hardware and software was conducted at IfAG and published in the *Kartographisches Taschenbuch* of the Deutsche Gesellschaft für Kartographie. It shows that the proper choice is not a constant, but depends on a number of parameters following from the specific characteristics of the task at hand and of the institution fulfilling it.

## PRACTICAL CADASTRE, CARTOGRAPHY, PHOTOGRAMMETRY AND SURVEYING

National survey activities are addressed primarily to maintenance of the state networks of horizontal and vertical control stations. Despite the application of modern survey techniques, electronic measurement systems and the use of electronic computers for reducing observational data, the maintenance of these networks can no longer be carried out within a reasonable time frame.

Starting from an overall scientific diagnosis of the network, work has commenced on improvement of the horizontal control survey positions, and experiences with GPS gave very successful results. A complete resurvey of the precise levelling network has been carried out by the state survey authorities, though the computation of the results is in progress. Each line of the Unified European Levelling Network has been renewed. During these resurveys it was demonstrated that some of the automatic levels are affected systematically by the magnetic field and all levelling lines observed with these instruments were resurveyed. Further research addresses the scale factor of the levelling rods and vertical refraction effects.

The densification of the national networks by conventional means has been continued. The automated flow of data from the field to the control data file has been realized in most cases. Following the establishment of the German primary gravity network, densification is being performed to give one station every four kilometres.

Topographic surveys are performed by means of aerial photogrammetry and, in so far as necessary, using tachometric procedures for base maps at scales of 1:5,000 and in some areas in southern Germany 1:2,500. More than two thirds of this map series is currently being produced in either final or provisional editions. Owing to the large scale and the detailed representation of both planimetry and heights, this map series serves as a basis for a multitude of applications. Some states produce orthophotomaps at a scale of 1:5,000 as a supplement to the 1:5,000 base map series. The whole series of orthophotomaps has been completed for Nordrhein-Westfalen and will be renewed in a four- to six-year cycle.

Prior to completion of the 1:5,000 map series, the 1:25,000 topographic map is used to identify topographic changes and therefore constitutes the basis for the preparation and revision of all the derived scales. The series 1:25,000 is available in its entirety.

The state survey offices have work out concepts for the digital registration of official topographic/cartographic information systems (ATKIS). It is projected that data acquisition with the approximate content of a topographic map 1:25,000 for the first stage will be available in the period 1990 to 1995.

In addition to the basic map series 1:5,000 the official map series comprise topographic maps published by the state survey offices at scales: 1:25,000, 1:50,000 and 1:100,000.

In addition to line maps, more satellite image maps have been produced, e.g. multi-sensor image maps of 1:50,000 and smaller scales, mainly by merging LANDSAT-TM data with SPOT-pan data (performed in Berlin, Frankfurt a.M. and Oberpfaffenhofen).

In accordance with an agreement between the Federal Administration and the Survey Administration of the States, IfAG publishes the following:

General topographic map 1:200,000

General map 1:500,000

International Map of the World 1:1,000,000

Maps for air traffic control and for military purposes

Dependent on the demand, special maps (combined sheets, maps of towns and their environment, district maps etc.) and thematic maps are derived from the foregoing series. Compilation and reproduction of regular topographic map series and thematic maps are carried out using modern techniques and materials.

The Survey Administration decided upon a nominal concept for the automation of the property cadastre and the tax roll. Automation, aimed at storing the property information on the land parcels in digital form, has been carried out since 1977. In this way, data files will be established for planimetry, coordinates and the measured elements. The future course of this work will see these data files integrated with the pertinent data from the tax roll and the property register (descriptions of the land parcels and the legal conditions applicable to them). This work has proceeded to different stages in the various states.

Many investigations are being performed with respect to German re-unification, e.g. the unification of the vertical, horizontal and gravity datums.

In April 1991 a GPS campaign will be started in Germany to establish a new German reference system (DREF). It will be part of the European Reference System (EUREF) which is based on the datum of the ITRF 1988, represented by the coordinates of the VLBI and SLR Stations in Europe.

## SURVEY AND MAPPING ACTIVITY IN INDONESIA, 1987-1990*

*Paper submitted by Indonesia*

### RÉSUMÉ

La National Land Agency a été organisée en 1989 comme organisme chargé des questions topographiques et cartographiques. Le rapport décrit les activités qu'elle a menées dans les domaines suivants : administration foncière, enregistrement de la propriété foncière et des titres de propriété, cartographie de l'utilisation du sol, création d'une base de données cadastrale, gestion de l'information foncière, etc.

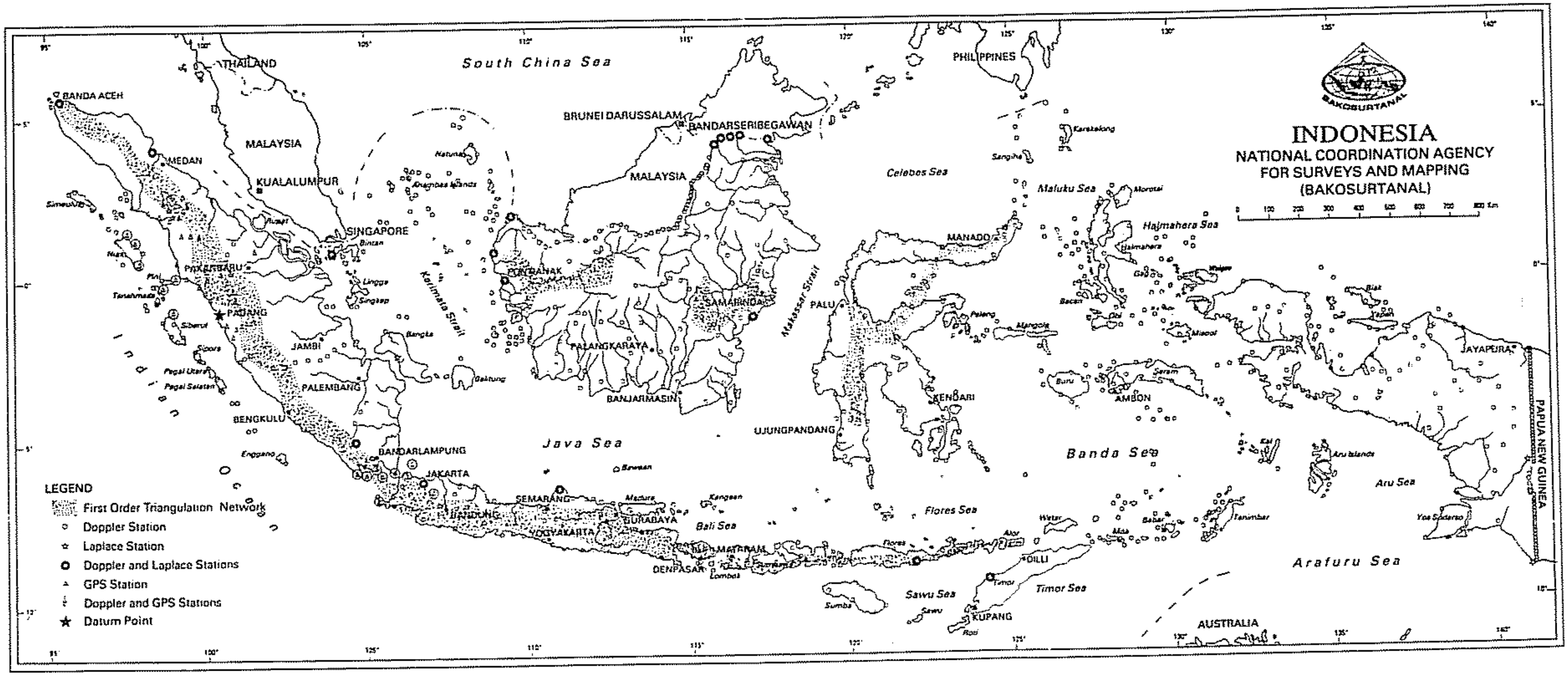
#### Mapping organizations

In 1989, from among the existing mapping organizations reported in previous Conferences, the Directorate General of Agrarian Affairs, under the Ministry of Home Affairs, was reorganized as a non-ministerial government agency and was named the National Land Agency (Badan Pertahanhan Nasional, BPN).

The new agency, like other non-ministerial government agencies, or specialized agencies, is directly responsible to the President of Indonesia. Its mandate is the same as that of the former Directorate General: that is, it is responsible for land administration, registration of land ownership and land titling, land-use mapping, establishment of the cadastral database and land information management.

*The original text of this paper appeared as document E/CONF.83/INF.29

Figure I. Distribution of national geodetic control



## Geodetic activities

### *Horizontal control*

By the end of 1990, the total number of Doppler controls were 1,258, comprising Doppler controls for national base mapping; for the demarcation of the international boundaries Indonesia-Malaysia and Indonesia-Papua New Guinea; for the demarcation of provincial boundaries; and for the unification of urban mapping controls with the national geodetic system.

For monitoring the crustal deformation along the Sumatera Fault Systems, the Global Positioning System (GPS) has been used since 1989. About 42 GPS positionings have been made, mostly at or excentric to the old triangulation stations, established between 1884 and 1929. This campaign, known as GPS-GPS (Global Positioning System for Geodynamic Project of Sumatera) will be repeated every year for the duration of one month.

Figure I shows the distribution of horizontal control (Doppler, GPS and Laplace stations) in Indonesia.

### *Vertical control*

As previously reported, the Java precise levelling network undertaken since 1980 was completed in 1987. Continuation to the island of Bali was also completed in 1989. A total number of 1,728 benchmarks were established with a total of 5,287 levelling line-kilometres.

The second-order levelling, as started in Sumatera, West Kalimantan and South Sulawesi in 1987, and fieldwork were completed in 1990 except for a small re-levelling of certain loops in Sumatera. A total number of 3,095 benchmarks were established with a total of 13,257 levelling line-kilometres.

Concurrently, tide gauges have been established for the provision of mean sea-level heights for the adjustment of the levelling networks and for the definition of height datums. For this purpose, 14 tide gauges were connected to the levelling networks. Another 10 tide gauges were installed for the purpose of monitoring sea levels and tides, seven of which were maintained by the Research and Development Center for Oceanology of the Indonesian Institute of Sciences, and three by the National Coordination Agency for Surveys and Mapping (BAKOSURTANAL).

An important refinement in the formulation of a mathematical model for the levelling adjustment is the adjustment of geopotential numbers instead of raw levelling data. For this purpose, gravity measurements were made along the levelling lines.

## Gravity control network

The purposes of the gravity control networks in BAKOSURTANAL are (a) for correction of levelling heights to orthometric heights; (b) for geoid computation; (c) to support geophysical exploration; and (d) to monitor gravity changes in time in connection with plate tectonics.

During the last four years (1986-1990) BAKOSURTANAL's priorities have been given to gravity measurements along the levelling lines (gravity profiles), establishment of first-order gravity network at airports, and establishment of calibration lines.

The needed precision of gravity control for levelling and for geoid computation is 1 milligal (mgal). In geophysical exploration precision depends on the kind of exploration. The general network gives a base for possible further extension. For plate tectonics the gravity changes should be measured as accurately as possible, preferably to 0.01 mgal. This is only achievable when procedures on the calibration lines are followed.

To support BAKOSURTANAL's activity three modern Lacoste Romberg gravimeters of geodetic type were purchased, which can reach 0.1 mgal precision without too much extra effort.

Figure II shows the national levelling network with the distribution of tide gauges and first-order gravity stations, while gravity profiles for levelling correction follow the levelling routes.

## Map production

The national base mapping programme has made some progress since the last report. Highlights are given below.

*1:50,000-scale base mapping.* A total of 566 sheets at 1:50,000 scale of part of Kalimantan (183 sheets) and the whole of Sulawesi (383 sheets) have been contracted out, since 1988, to three private consortiums under World Bank funding. Some of the requirements of the Government for foreign companies to participate in the international tender were:

(*a*) that such companies should be associated with an Indonesian private mapping company in a sort of consortium to secure the strengthening of and transfer of technology to the Indonesian private company;

(*b*) that all works (photogrammetric plotting, cartographic construction, field completion and reproduction) should be done in Indonesia, BAKOSURTANAL providing the contractors with aerotriangulated models;

(*c*) that the consortium use Indonesian workforce as much as possible, especially at the level of operators, technicians and surveyors.

At the time of the present report, the mapping contracts are at the stage of manuscript and field completion for 70 per cent. It is expected that the base maps of the above-mentioned areas will be published between June 1991 and the end of the year.

A total of 16 map-sheets of the surrounding islands of Sulawesi, covering the islands Selayer, Muna, Buton and Peling, was completed by BAKOSURTANAL with in-house capacity from 1987 to 1988.

For the relatively flat areas in South Kalimantan, contoured annotated photo-maps will be published. Out of 120 sheets covering this area, BAKOSURTANAL has completed a total of 49 sheets; the rest are expected to be published by March 1991.

*1:25,000-scale base mapping.* Since 1988, production of new topographic base maps of Java and Bali at scale 1:25,000 were commenced at BAKOSURTANAL. 30 sheets were produced within two years using 5 stereoplotters, and it is projected that 40 map-sheets every two years will be produced, starting in 1990.

Starting in April 1990, a number of 50 map-sheets have also been contracted out to Indonesian private companies, comprising the works from photogrammetric plotting to printing of maps. These maps are expected to be published by March 1991. This is the start of involvement of Indonesian private companies in systematic topographic mapping in the country, which has not been the case in the past.

For relatively flat areas in Java, a total of 60 sheets will be produced as photo-maps by simple rectification.

**Figure II. National levelling networks, distribution of tide gauges and first-order gravity stations**

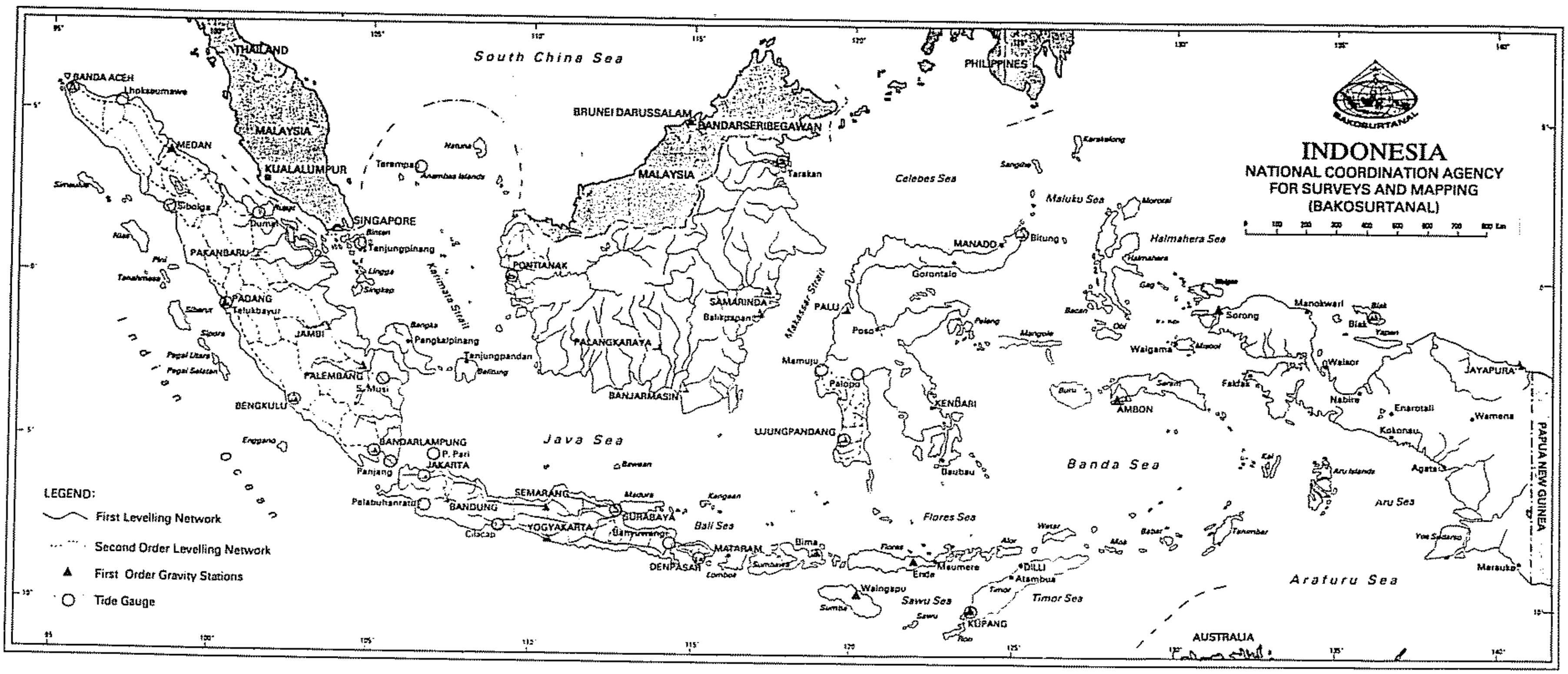


Table 1. National base-mapping programme: Indonesia

| Region | Basic scale | Sheets | Availability, 1 Jan. 1991 |
|---|---|---|---|
| 1. Sumatera | 1:50 000 | 856 | 523[a]<br>600[d] |
| | 1:250 000 | 58 | 58[a]<br>49[d] |
| 2. Kalimantan | 1:50 000 | 822 | 145[a]<br>182[b]<br>49[c]<br>261[d] |
| | 1:250 000 | 51 | 21[d] |
| 3. Sulawesi | 1:50 000 | 436 | 16[a]<br>320[b] |
| 4. Maluku | 1:100 000 | 113 | 94[a] |
| 5. Irian Jaya | 1:100 000 | 209 | 94[a]<br>54[d] |
| | 1:250 000 | 40 | 15[d] |
| 6. Java and Bali | 1:50 000* | 345 | 345[a] |
| | 1:25 000 | 877 | 60[a]<br>90[b] |
| 7. Nusa Tenggara | 1:50 000 | 192 | — |
| 8. Timor Timur | 1:50 000 | 25 | — |
| 9. Indonesia | 1:250 000 | 292 | 242[e] |
| | 1:1 000 000 | 34 | 33[a] |
| Total | | 4 350 | 3 251 |

*Reprinted United States Army Map Service maps.
[a]Printed line-maps.
[b]In manuscript stage.
[c]Photo-maps
[d]SAR planimetric maps
[e]JOG maps.

The line-maps produced are still the conventional line-maps using photogrammetric plotting. At BAKOSURTANAL a start has been made to produce digital topographic maps straight from photogrammetric compilation, with editing in the ARC/INFO system. Future contracts to private companies will be specified to digital mapping after BAKOSURTANAL gains experience in this field.

*Radar maps.* In addition to the airborne synthetic aperture radar (SAR) coverage reported in the previous Conference, during the period from March to August 1989 a total of 440,000 sq km in Sumatera were covered by airborne SAR. From this imagery, 49 sheets at 1:250,000 scale and 600 sheets at 1:50,000 scale of unannotated radar planimetric maps were produced and printed in February 1989.

Figures III and IV show the mapping coverage as at 1 January 1991.

### Aerial photography and radar survey

An SAR survey was continued in Sumatera in 1989 to produce, respectively, 1:250,000 and 1:50,000 SAR planimetric maps from digital mosaicking of SAR strips. Specifications for SAR survey were the same as previously reported, i.e., X-band, 6-metre resolution, 7 look. The number of sheets produced are shown in table 1.

In addition to the aerial photography coverage reported previously, new aerial photography at larger scales has been conducted during the period of this report, i.e. at scales from 1:50,000 to 1:15,000, using BAKOSURTANAL's Taurus King Air aircraft. These aerial photos were taken for filling in gaps of the mapping photography taken during the 1980s as well as for the preparation of transmigration project sites in Sumatera, Kalimantan, Sulawesi and Irian Jaya.

Figure V shows the new aerial photo coverage shown from 1987 to 1990.

### Geographical names

Collection of geographical names has been carried out concurrently with the progress of field completion of the 1:50,000 and 1:25,000 base mapping programmes. As at 1 January 1990, a total number of 40,000 names were collected in South Kalimantan and Sulawesi and 4,000 names in Java.

A toponymic database has been developed at BAKOSURTANAL. Since all efforts have been directed towards names collection and inputting into the database, no new gazetteers have been produced since the last report.

Under the auspices of the United Nations Group of Experts on Geographical Names, Indonesia hosted the Workshop cum Training in Geographical Names of the Asia, South-East, and Pacific, South-West, Division in Cipanas, West Java, from 16 to 28 October 1989. This was the second such training course Division organized by Indonesia, after the successful first pilot course in toponymy was held in 1982. A separate report of this recent Workshop cum Training Course on Toponymy will be submitted to the present Conference.

### Regional Physical Planning Programme for Transmigration and the *National Atlas*

Since 61.4 per cent of the Indonesian population live on 7.3 per cent of the total land area, i.e., Java and Bali, a national programme of transmigration of population from the above densely populated islands to the sparsely populated outer islands has been conducted since the first five-year national development plan in 1969.

Transmigration planning is structured on three levels. Phase I is the initial selection of large areas, in which it is hoped that development for transmigration settlements might take place. Phase II consists of semi-detailed field studies to verify which parts of the selected areas have potential, and Phase III comprises detailed surveys which are required for site planning.

Before 1983, a high proportion of areas selected in Phase I were subsequently rejected during Phase II field studies. This was identified as a critical weak link in the planning process. The Department of Transmigration recognized the deficiency and invited the Land Resource Development Centre, now called Land Resource Department (LRD) of the United Kingdom to assist the Government of Indonesia, through the Department, to strengthen the Phase I planning, with the specific objective of reducing substantially the site rejection at Phase II.

The programme, started in 1983, is called the Regional Physical Planning Programme for Transmigration.

For the above purpose a number of maps have to be prepared, and for this reason the programme team works closely with BAKOSURTANAL; hence, the office moved to the premises of BAKOSURTANAL in Cibinong for easy access to basic data and facilities. The following three types of maps were produced systematically for the whole country at 1:250,000 scales:

(*a*) Land Systems/Land Suitability map, referred to as "Land System Map";

(*b*) Present Land Use/Forest Status map, referred to as "Land Use Map";

(*c*) Land Status/Recommended Development Area map, referred to as "Land Status Map".

Figure III. Mapping coverage as at 1 January 1991: Indonesia

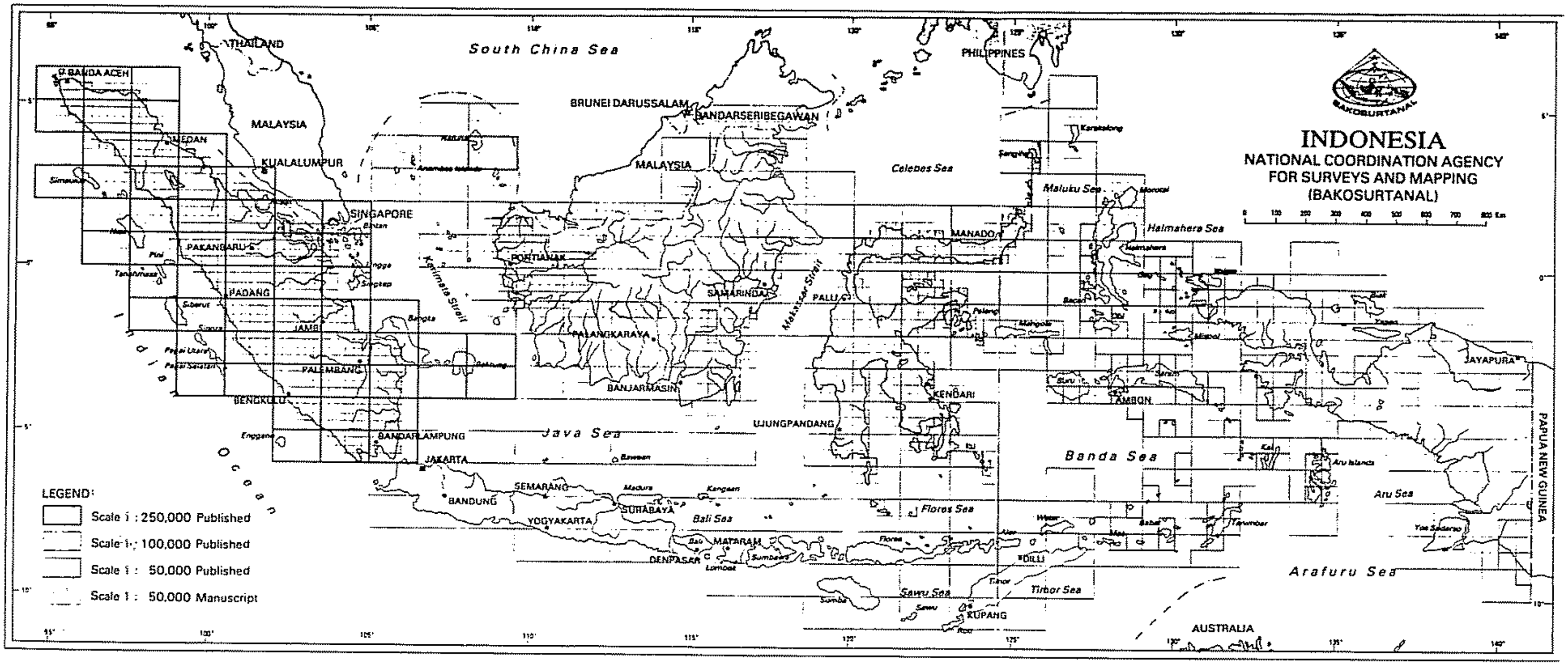


Figure IV. Mapping coverage as at 1 January 1991: Java Madura

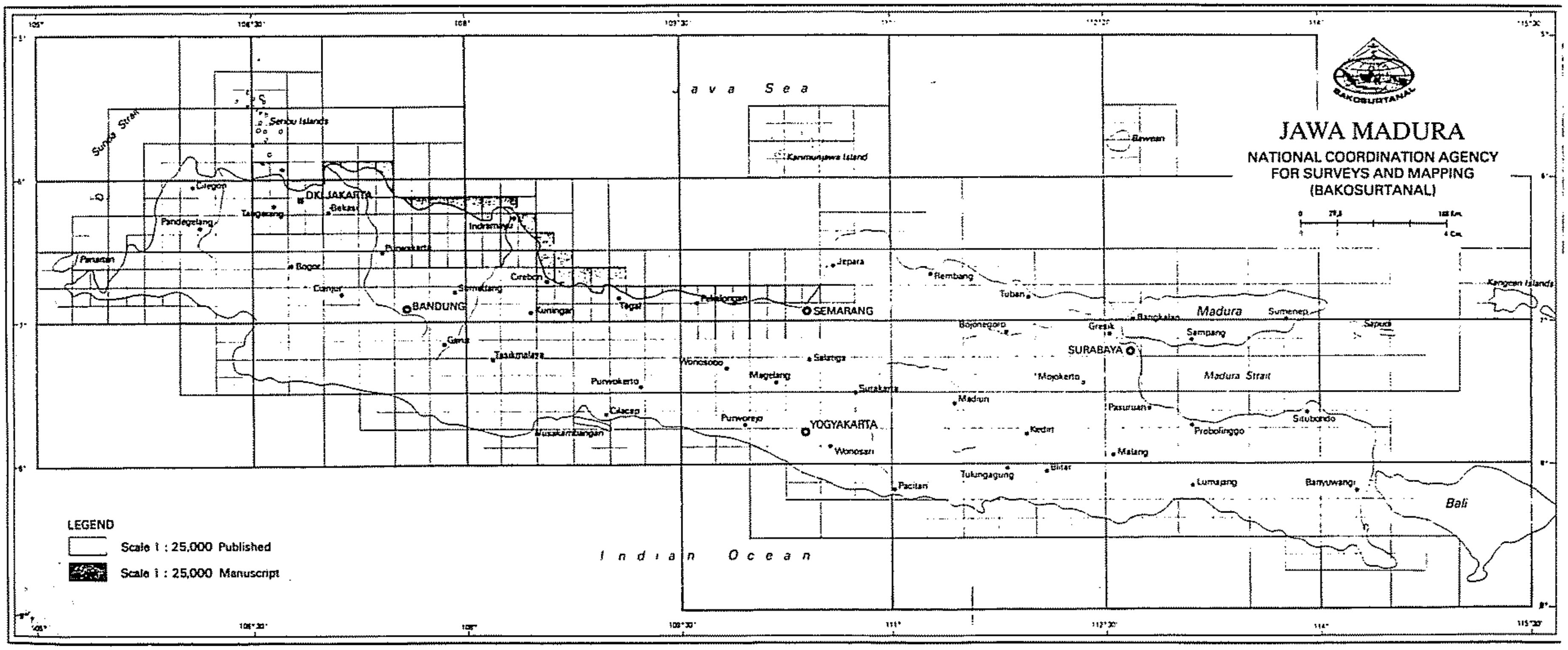
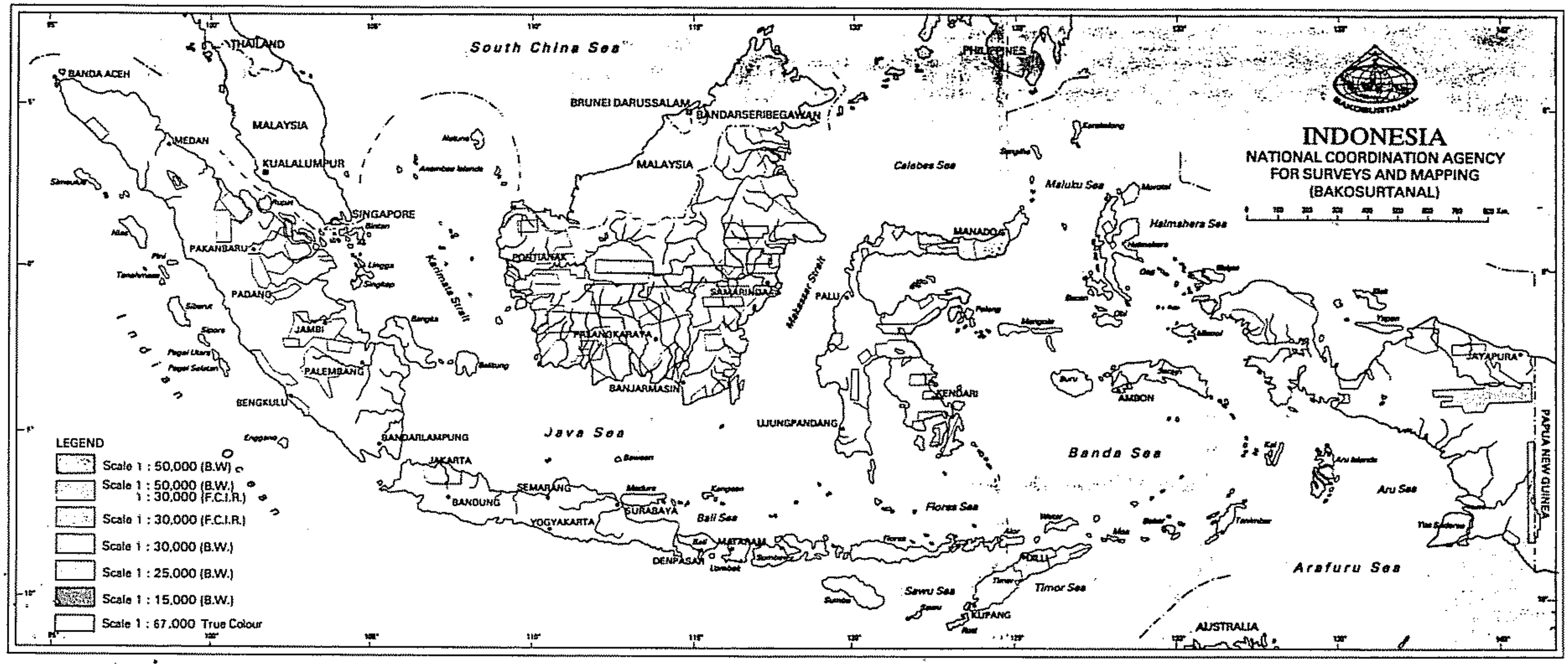


Figure V. Aerial photography coverage, 1987-1990



Even though the primary target is to prepare a study of the outer islands where the transmigrants will be resettled, the task of the team also includes study of the islands of Java and Bali where the transmigrants originate, in which socio-demographic aspects are important for national overview of the transmigration programme. Also, it includes environmental aspects, identification of areas liable to flooding and landslides, zones of volcanic hazards, earthquake-prone areas etc.

The whole country is covered by 237 map-sheets at 1:250,000 scale. Planners concerned with national issues need to view the whole country at a time but the handling of map-sheets covering the countries at 1:250,000 scale for any given theme is cumbersome and not conducive to clear analysis. There was, therefore, a need for synopsis, specifically to enable a broad view to be taken of the nation's land resources, their qualities, limitations and distribution. This had led to the publication of a *National Atlas* which gives an overview of the Indonesian land resources at scale 1:2,500,000, comprising 14 themes, namely: Geology; Mineral and Energy Resources; Mean Annual Rainfall; Agroclimatic Zones; Groundwater Potential; Physiographic Types; Physiographic Regions and Potential Development Areas; Soils; Land Cover and Suggested Revised Forest Zoning; Land Use and 1982 Forest Classifications; Environmental Hazards; Transmigration Sites Settled Before End of the Fourth Five-Year National Development Plan (April 1989); Population Distribution; and Regional Development.

Each theme covers two sheets, the western part and the eastern part of Indonesia, respectively, joined together and folded, so that the *Atlas* has a dimension of 92 cm × 60 cm.

### Development of national digital topographic database

The creation of a national digital topographic database, (NDTDB) has been emphasized at BAKOSURTANAL to support the national programme for the inventory of natural resources. Although immediate needs enforce the collection of digital data on an ad hoc basis, BAKOSURTANAL's strategy is to make use of whatever data are available and initiate the systematic creation and maintenance of NDTDB so that it can be used continuously by potential users.

The concept of the object-oriented database, which forms the basis for many GIS operations, and its interface with digitized graphics (map-sheet based) was implemented on the ARC/INFO system.

The objectives of the NDTDB are:

(*a*) To support map-updating activities;

(*b*) To improve responsiveness to demands for topographic information in digital form;

(*c*) To provide the base upon which a series of spatial analysis and GIS operations in the Land Resource Evaluation and Planning (LREP) project can be performed.

The need for rapid availability of digital coverages for Sumatera initiated mass digitizing activities at BAKOSURTANAL for the conversion of existing maps to a digital form. The data required for this purpose was mainly collected from the 1:250,000-scale national topo-maps series whenever possible (i.e., available and up-to-date); otherwise the most recently produced 1:50,000-scale base-maps. These are assembled to form the 1:250,000-scale maps. No generalization of the data collected from the 1:50,000-scale maps took place.

Considering the needs of the inventory programme, it is recognized that the most practical near-term approach is to extend the current activities to other major islands in order to extend these databases to nationwide coverage by mass digitizing of existing 1:250,000 Transmigration Programme maps.

As a long-term policy, however, data entry into this database is to be at larger scales (i.e., 1:50,000- and 1:25,000-scale base-maps) using photogrammetric stereo-compilation, digitizing of existing base-maps, and the use of SPOT imagery for updating the information.

For the purpose of the LREP project, the suitability of the collected data needs to be investigated in terms of:

(*a*) Its completeness, resolution, accuracy, data structure and organization;

(*b*) Further data to be collected;

(*c*) Further processing and re-conditioning of data.

This requires very intensive map quality assessment activities and close cooperation between the various resource producing agencies involved in the production and/or the use of geo-referenced information.

## CARTOGRAPHIC WORK IN JAPAN, 1986-1989*

*Paper submitted by Japan*

### RÉSUMÉ

Au Japon, les opérations de géodésie fondamentale sont exécutées essentiellement par l'Institut géographique et par le Département d'hydrographie. Des cartes sont produites par l'Institut géographique, par le Département d'hydrographie, par l'Office national du cadastre, par le Ministère de l'agriculture, des forêts et des pêches et par le Service des levés géologiques.

Les principales activités récentes entreprises au Japon, en fait de levés géodésiques, sont les suivantes : contrôles géodésiques précis, détection de la subsidence de la croûte terrestre aux fins de la prévision des séismes, opérations de nivellement dans les zones de subsidence, observations géodésiques par satellite pour le contrôle du bon fonctionnement du réseau géodésique et pour la détermination de la position exacte d'îles isolées, observations astronomiques pour l'établissement de stations de Laplace et pour la compilation d'almanachs et d'éphémérides pour la navigation, mesures de la gravité pour l'éta-

*The original text of this paper appeared as document E/CONF 83/L.10

blissement de cartes des anomalies gravimétriques et observations géomagnétiques pour l'établissement de cartes géomagnétiques.

Indépendamment de ces activités géodésiques, de grands travaux géodésiques qui intègrent le réseau géodésique japonais au système géodésique mondial sont entrepris par l'Institut géographique japonais, au moyen du système d'interférométrie à très longue base (VLBI), et par le Département d'hydrographie, au moyen du satellite géodésique AJISAI.

L'Institut géographique japonais procède à des levés ayant pour but de réviser les cartes de base nationales à l'échelle du 1/25 000, ainsi qu'à la préparation de cartes topographiques dont l'échelle varie entre 1/2 500 et 1/3 000 000 et de plusieurs cartes thématiques, notamment des cartes d'utilisation des sols et des cartes d'état des sols. L'Institut géographique publie aussi différents types de cartes topographiques, dont l'échelle va du 1/2 500 au 1/3 000 000. Indépendamment des cartes générales, l'Institut géographique établit plusieurs autres cartes thématiques, telles que les cartes d'utilisation des sols et les cartes d'état des sols. En 1990, l'Institut géographique a publié l'édition révisée de *l'Atlas général du Japon*, publié pour la première fois en 1977.

L'Office national du cadastre a procédé à un levé cadastral. L'échelle des cartes du cadastre va du 1/250 au 1/5 000.

Le Ministère de l'agriculture, des forêts et des pêches établit des cartes pédologiques des terres cultivées et boisées, et il existe désormais des cartes pédologiques couvrant l'ensemble des forêts du domaine public.

Le Service des levés géologiques produit des cartes géologiques à l'échelle du 1/50 000 et des cartes géologiques et sédimentologiques des plates-formes continentales à l'échelle du 1/200 000.

Pour concourir à la sécurité de la navigation, le Département d'hydrographie publie diverses cartes nautiques, bathymétriques et marémétriques.

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In Japan, most cartographic work is carried out under the auspices of a Survey Law, by which it is efficiently coordinated and standardized and overlapping is avoided. There are two categories of survey: the *basic survey*, which is nationwide and executed by the Geographical Survey Institute; and *public survey*, for special projects or local governmental projects, carried out by appropriate governmental or public organizations, such as the Forestry Agency, the Geological Survey of Japan and the National Land Agency. Various kinds of hydrographic charts are prepared by the Maritime Safety Agency of the Hydrographic Department.

### Geodetic work

Fundamental geodetic work is principally executed by the Geographical Survey Institute (GSI) and the Hydrographic Department (HD).

The Japanese national geodetic network consists of 1,000 first-order, 5,000 second-order, 32,700 third-order and 59,000 fourth-order triangulation points, and 20,000 km of precise levelling routes. Fourth-order triangulation points are still being added, mainly for cadastral surveys.

#### *Precise Geodetic Network Survey Project*

The GSI started the Precise Geodetic Network Survey Project in 1974 in order to switch over from its old geodetic data, obtained by conventional methods, to more precise new geodetic data obtained by trilateration, using optical electronic distance measurement (EDM). The geodetic framework of the project is classified into two networks. One is a primary precise geodetic network, composed of 6,000 first- and second-order triangulation points, and the other is a secondary precise geodetic network, composed of 32,700 third-order triangulation points.

The new data can serve not only as a revised framework for mapping, but also for earthquake prediction and research on crustal movement in Japan.

#### *Levelling*

The GSI completed the seventh revision levelling survey along the first-order levelling routes throughout Japan in 1987 and started the eighth revision survey in the same year. About 2,000 km of revision surveys are being carried out every year.

In addition to the revision survey, the GSI is conducting 1,000 km of relevelling annually in the specified observation areas and the intensified observation areas designated in the National Earthquake Prediction Project; furthermore, 12,000 km of relevelling is performed annually in and around ground subsidence areas along the coast by the GSI, in cooperation with local governments.

All the tidal data obtained at 105 tidal stations registered with the Coastal Movement Data Center are compiled and published every year.

HD is carrying out cross-sea levelling and the observation of vertical deflection annually in the Izu Syoto, which is a tectonically active area in the seas about Japan. It provides data for elucidation of the crustal structure of this locality.

#### *Satellite positioning*

GSI has been using a Navy Navigation Satellite System (NNSS) to: (*a*) detect the possible distortion of the geodetic network of Japan; (*b*) determine the geodetic coordinates of islands isolated from the mainland; (*c*) study the geotidal height; (*d*) connect the geodetic network to those of other countries. HD also is engaged in satellite positioning.

In order to measure the precise position of the mainland and islands of Japan in the World Geodetic System, HD has continuously conducted a satellite laser ranging (SLR) observation of LAGEOS at the Shimosato Hydrographic Observatory since 1982, and has constantly determined the positions of more than 40 off-lying islands by means of the translocation observation of NNSS since 1974.

Prior to the launching of the Japanese geodetic satellite AJISAI on 13 August 1986, a new branch, named the Satellite Geodesy Office, with 16 staff members at present, was established at the Department in April 1986 to conduct the whole satellite-based geodesy including the above two observations. In 1986 and 1987, some new observation facilities were introduced, such as the transportable side-locking radar (SLR) systems, the fixed and transportable satellite cameras as well as a computer system named the Satellite Data Reduction System. At the same time, three new members were added to the staff of Shimosato Hydrographic Observatory.

With these new staff members and by using the new equipment and the fixed SLR system at the Observatory, in 1988 the Department started a new five-year project to determine the precise position of 10 major islands from the simultaneous observation of AJISAI. The observations were performed in 1988 at Titi-sima (the largest of the Bonin islands) and Isigaki Sima, and in 1989, at Minami-Tori Sima (Marcus Island), Okinawa Sima and Tusima. Observations at Oki Syoto and Minami-Daito Sima are planned for 1990.

Both of these SLR observations are supported by cooperative research under the umbrella of United States–Japan cooperation in the field of space development. The research is related to the Crustal Dynamics Project conducted by the National Aeronautics and Space Administration (NASA).

The obtained data were analysed by the successive passes orbit revising technique (SPORT), developed at the Department to determine the relative positions of these major islands referred to Shimosato with precision to 7 mm uncertainty for the baseline length of about 2,000 km in the case of Minami-Tori-sima.

In order to watch the crustal deformation for middle-size (about 50 km) baselines in the Sagami Bay, which is well known as the nest of big earthquakes, the Department started a continuous monitoring, at least a one-day session each week since February 1990, of GPS geodetic survey for the triangle of Izu-Osima, Manazuru and Turugi-saki.

*Astronomical observation*

GSI carries out the observation of the astronomical azimuth, latitude and longitude to establish Laplace stations in the primary precise geodetic network.

HD also carries these observations for the purpose of preparing the Japanese ephemeris (the most precise almanac in Japan), the nautical almanac, the abridged nautical almanac etc. Observations are made of occultation of stars by the moon at the hydrographic observatories at Tokyo, Shirahama, Shimasato, and Bisei, and grazing occultation at two places in Japan.

*Very long baseline interferometry survey*

Since 1986, GSI has been conducting mobile VLBI observations with the cooperation of the Communications Research Laboratory (CRL), Ministry of Post and Telecommunication. The VLBI system visited Miyazaki in 1986 and 1988, and Chichi-sima in 1987 and 1989, and from the results of the Chichi-sima experiments, the motion of the Philippine Sea plate was successfully detected. The GSI will continue the operation of the VLBI system to detect crustal deformation; control the precise geodetic network; and establish Global Positioning System (GPS) satellite tracking stations.

*Gravity survey*

Gravity surveys are executed on land by GSI and at sea by HD. The GSI is repeating fundamental and first-order gravity surveys at fundamental and first-order gravity stations to detect gravity changes associated with crustal movements. Since 1984, an absolute gravity measuring system has been operated for the fundamental gravity survey.

GSI also continues second-order gravity surveys at levelling and triangulation points. These data are concentrated on the preparation of Bouguer anomaly and free air anomaly charts provided for the study of geoidal height in and around the islands of Japan and for the study of underground structures.

HD has been conducting gravity measurements. For the purpose of detecting crustal deformation of the Izu Islands in the Minami Kanto district, precise over sea levellings by measuring gravity and with the usual optical trigonometric methods are conducted in the Izu Islands every year. These observation data are used to delineate vertical crustal movement related to earthquake and volcanic eruption.

*Geomagnetic survey*

GSI has been conducting continuous land geomagnetic and aeromagnetic surveys, the former at 105 first-order geomagnetic stations at about three-year intervals. The data obtained are used for compilation of magnetic charts at scales 1:2,500,000 for D (declination) and 1:4,000,000 for H (horizontal intensity), I (inclination), Z (vertical intensity) and F (total intensity) components.

GSI is preparing to revise D, H, I, F, component charts in 1992, using the data obtained from the period between 1952 and 1990, which were reduced to the common epoch 1990.0.

In addition to these, GSI is carrying out an aeromagnetic survey to revise the aeromagnetic total intensity chart published for 1975.

HD conducted landmagnetic and aeromagnetic surveys on and over the Japanese islands and its surrounding waters. In order to maintain the safety of a vessel or an aircraft using a magnetic compass, magnetic variations and annual changes must be shown on the nautical and aeronautical charts. For that, the Department regularly conducts geomagnetic observations and measures magnetism and annual variations by means of airborne magnetic surveys on and around Japan and land magnetic surveys at the regular observation points every five years.

At the time of the volcanic eruption of Izu-Osima island in November 1986, repeated airborne magnetic surveys were conducted to detect magnetic change and magnetic structure of the volcano. For the purpose of volcanic prediction of the Izu Islands, airborne magnetic surveys for that area were also carried out.

*Unmanned survey craft*

In order to make it possible to carry out hydrographic surveys in dangerous areas, such as those where submarine volcanic eruption is likely to occur, HD developed in 1988 a remote-controlled unmanned survey craft. The craft, nicknamed "MANBO", proved its practical capability of hydrographic survey, when a submarine volcano erupted off the Izu Hanto (peninsula) in July 1989.

For the earthquake prediction programme, one of the most important objectives is to make geophysical observations of the sea-bottom. In response to this, some development schemes to observe crustal deformation at the sea-bottom were launched in 1989, in cooperation with the Japan Hydrographic Association. The operation and improvement of the unmanned survey craft was also conducted in relation to this project

TABLE 1 GEODETIC WORK: 1986 TO 1989

| | *1986* | *1987* | *1988* | *1989* | *Total* |
|---|---|---|---|---|---|
| Primary precise geodetic network | 736 | 592 | 544 | 464 | 2 336 |
| Secondary precise geodetic network | 129 | 142 | 119 | 103 | 493 |
| Fourth-order triangulation | 1 268 | 1 156 | 1 122 | 1 103 | 4 649 |
| Satellite laser ranging | | | | | |
| Inland (HD since 1982) | | | | | 1 |
| Islands (HD) | | | 2 | 3 | 5 |
| Satellite Doppler positioning | | | | | |
| Inland (GSI) | 2 | 15 | 9 | 36 | 62 |
| Islands (GSI) | 1 | 2 | 10 | 9 | 22 |
| (HD) | 5 | 0 | 9 | 11 | 25 |
| Korea | | | | 4 | 4 |
| Laplace station | 1 | 1 | 1 | 1 | 4 |
| Astronomical observation | 6 | 5 | 5 | 5 | 21 |
| Gravity survey | | | | | |
| Fundamental | 3 | 2 | 2 | 1 | 8 |
| First-order | 29 | 24 | 30 | 140 | 223 |
| Second-order | 159 | 158 | 113 | 5 | 435 |
| High density (km$^2$) | — | — | — | 324 | 324 |
| First-order geomagnetic survey | 30 | 22 | 27 | 28 | 107 |
| 12th Whole Japan Magnetic Survey Project (HD) | | | | 2 | 2 |
| Aeromagnetic survey | | | | | |
| Land(GSI) (km$^2$) | 64 700 | 60 360 | 78 200 | 0 | 203 260 |
| Land/sea(HD)(km) | 5 000 | 5 000 | 2 000 | 18 000 | 30 000 |
| First-order revision levelling (km) | 2 511 | 2 218 | 2 253 | 2 144 | 9 166 |

### *The earthquake prediction programme*

*HD surveys for the earthquake prediction programme.* In order to obtain data and information necessary for the prediction of earthquakes, the Department has been carrying out surveys and investigations for submarine topography and active sea-bottom structures in specific areas off Miyagi and Fukushima (scale: 1:100,000) in which large-scale earthquakes have occurred before, as well as on Sagami-Nankai Trough (scale: 1:50,000), which is designated as the Intensive Observation Area for earthquakes.

For this purpose, magnetic and gravity surveys were also conducted around the Izu-Bonin island arcs and other plate boundaries. Total intensity magnetic anomaly and free-air gravity anomaly maps were made for elucidation of sea-bottom structure. Free-air gravity anomaly is also used to calculate the precise geoid.

## TOPOGRAPHIC MAPPING

### *Medium-scale topographic maps*

The national base-map series, a topographic map covering the entire country of Japan at 1:50,000 scale, was begun in 1895 and completed in 1925.

About 40 years later, the 1:25,000-scale topographic map was adopted by the GSI as the national base map, replacing the 1:50,000-scale map under a medium-scale topographic map development programme. The map encompassing the whole country of Japan was completed in 1983.

GSI has been conducting a revision survey and re-compilation of these maps, utilizing the following principles:

(*a*) Revision of the 1:25,000 maps is conducted at intervals of 3 years (urban areas), 5 years (intermediate areas) or 10 years (mountainous areas), depending on the extent of unit change in the map sheet;

(*b*) The 1:50,000 scale sheets are revised simultaneously with the revision of the corresponding 1:25,000 scale topographic maps;

(*c*) The projects to interpret the extent of the changes are carried out by Regional Survey Departments of the GSI, which are located at 10 locations throughout the country.

### *Large-scale topographic maps*

GSI initiated the National Large-Scale Topographic Mapping Project in 1960, in order to cover 190,000 sq km of flat areas of the country. The Forestry Agency also began promoting a similar project in mountainous areas, for the purpose of producing a Basic Forest Map as a basis for surveying of forests. That project was completed in 1980, and currently the Forestry Agency is promoting revision work of the existing Basic Forest Map.

Until 1974, local public organizations had been producing large-scale urban planning base maps with their own standards. Since 1975, GSI and the City Bureau of the Ministry of Construction have standardized the 1:2,500-scale urban planning mapping process by promoting the 1:2,500-map cooperative project, in which GSI will take aerial photographs and do aerial triangulation, and local public bodies will make maps. Around 50,000 sq km of urban planning area have been mapped according to the standard, and these maps, in principle, are revised every five years.

In 1983, GSI began producing a 1:10,000-scale topographic map for urban areas utilizing the existing 1:2,500-scale maps.

Table 2 shows the amount of large- and medium-scale topographic mapping work undertaken during the past four years.

Basic forest mapping work done during the same period is shown in table 3.

TABLE 2 LARGE- AND MEDIUM-SCALE TOPOGRAPHIC MAPPING
(*Square kilometres*)

| | *1986* | *1987* | *1988* | *1989* |
|---|---|---|---|---|
| 1: 2 500 New edition | 18 | — | 6 | 13 |
| Revision | — | — | — | — |
| 1: 5 000 New edition | 544 | 653 | 338 | 145 |
| Revision | — | — | 48 | — |
| 1: 5 000 Photomap | 268 | 252 | 192 | 120 |
| 1:10 000 New edition | 797 | 821 | 718 | 524 |
| Revision | — | 91 | 494 | 698 |
| 1:25 000 Revision | 42 382 | 40 396 | 42 389 | 38 652 |
| Recompilation | 3 140 | 2 328 | 1 840 | 1 099 |
| | | (*Number of sheets*) | | |
| 1:50 000 Revision | 89 | 117 | 112 | 181 |
| Recompilation | 7 | 3 | 6 | 4 |

TABLE 3. BASIC FOREST MAPPING
(*Square kilometres*)

| | *1986* | *1987* | *1988* | *1989* |
|---|---|---|---|---|
| 1:5 000 photomaps | 6 481 | 5 991 | 5 558 | 5 222 |
| 1:5 000 BFM revision | 1 500 | 1 331 | 1 814 | 1 653 |

### *Small-scale maps*

Small-scale maps published by GSI as of end 1989 are shown in table 4.

The International Map of the World on the Millionth Scale (IMW) is compiled by utilizing standard international map symbols. Preparation of this map requires close cooperation with the various countries of the world, so that the map symbols, method of preparation etc., are prepared in compliance with the requests of the United Nations, in order to reflect the results of the study of the international map of Japan.

### *Geographical information and digital mapping*

#### *Digital national land information*

In order to promote effective use of land resources, GSI started data collection of digital national land information in cooperation with the National Land Agency in 1974. Various categories of information, such as elevation, coast-lines, rivers, roads, railways, political boundaries, land use etc., have been collected from 1:25,000, 1:50,000 and other smaller-scale maps and filed onto magnetic tape under each category.

The information has been used not only for the planning of national land, but also for city, water use, environmental assessment planning and other various applied fields.

#### *Detailed digital land-use data*

GSI has been collecting data on detailed digital land use since 1981 under a survey project on the trend of housing land use, on which to prepare detailed information on present housing and possible future housing lots in the urban areas of Tokyo, Osaka and Nagoya.

Ten-metre grid base (mesh) land-use data, taken during different periods, along with associated data, have been collected in order to classify and analyse the present and possible future state of change of housing land use.

#### *Digital cartographic data from a 1:25,000-scale map*

In 1984, GSI began another digital map information collection project to collect data for fundamental categories of 1:25,000-scale cartographic maps, namely, contour lines, political boundaries, roads, railways and water edge lines.

TABLE 4. STATUS OF SMALL-SCALE MAP PREPARATION

| *Title* | *Sheets* | *Size (cm)* | *Colours* | *Remarks* |
|---|---|---|---|---|
| 1:200 000 scale regional map | 130 | 46 × 58 | 6 | Layered edition |
| 1:500 000 scale district map | 8 | 788 × 1 091 | 9 | |
| 1:500 000 scale district map | 8 | " | 4 | |
| 1:1 000 000 scale IMW | 3 | " | 12 | |
| 1:1 000 000 scale NIPPON | 3 | " | 4 | |
| 1:3 000 000 scale Japan and surroundings | 1 | " | 12 | Layered edition. Hill shading edition |
| 1:100 000 scale composite map | 2 | " | 4 | Tokyo and vicinity Shikotsu. Toya and vicinity Osaka and vicinty |

The objective of the project is to prepare a digital cartographic database from a 1:25,000-scale map for automated map compilation and production, and for dispensing and providing basic data of geographic information systems digital data services.

#### *Digital mapping*

In Japan, private surveying companies, as well as GSI, have been developing the technique of producing maps from aerial photographs by the digital process. With this effort, a manual for digital mapping standards, focused mainly on large-scale digital mapping, was proposed by GSI in 1988. Since then, most large-scale maps have been produced conforming to the proposed standard. Large-scale digital maps of 900 sq km were produced by digital mapping last year.

#### *KDB data base*

In Japan, digital map data have been produced and used in the field of urban planning, utility management, navigation etc. by public organizations and private companies. In these circumstances, the effective and proper use of survey data of digital maps is indispensable. To avoid duplication and maintain accuracy, GSI began the Kokudokihonzu (Japanese expression of National Large Scale Map) Data Base (KDB) project in 1989. In this project, the digital map data, scaled from 1:500 to 1:10,000, produced by basic or public survey, will be stored in KDB and opened to the public.

#### *Geographic information database*

In 1990, the GSI started preparation of the project "Geographic Information Database". The aim of this project is to construct a basic database of various kinds of geographic information and present it in various forms suited to a wide range of users' needs, by applying the geographic information system. The skeletal structure of the database is the position and the place-name of each item of geographic information on the digital base map, which is digitized from the 1:200,000-scale regional map series. This project is at the stage of system designing, and is planned to be operational after 1992.

## THEMATIC MAPPING

GSI is engaged in various kinds of thematic mapping in cooperation with other governmental organizations for the purpose of presenting basic geographical information for regional development, disaster prevention etc. Table 5 shows some typical thematic maps prepared and published by GSI during the period April 1986–March 1990.

Besides these maps, GSI has compiled various thematic maps resulting from geographical research, e.g. land condition maps of volcanoes and maps related to some particular natural disaster.

## *NATIONAL ATLAS OF JAPAN*

The first edition of the *National Atlas of Japan*, compiled by GSI, was published in 1977, and has been widely ac-

TABLE 5 THEMATIC MAPS

| *Type of map* | *Scale* | *Sheets* |
|---|---|---|
| Land-use map | 1:25 000 | 14 |
| Land condition map | 1:25 000 | 13 |
| Land condition map of coastal areas | 1:25 000 | 5 |
| Lake chart | 1:10 000 | 6 |
| Ground elevation map | 1:10 000-1:50 000 | 3 |

claimed. The GSI continued its revision according to the latest statistics and other materials, and the *National Atlas of Japan (Revised edition)* was published on 30 November 1990. This A2-sized *Atlas* consists of 218 pages and contains 235 thematic maps. About 40 per cent of the maps were prepared by a computer-assisted system. Both Japanese and English editions were prepared.

### NATIONAL LAND SURVEY

The National Land Survey of Japan is being carried out under the direction and guidance of the National Land Agency (NLA). The objective of the Survey is to contribute to the promotion of effective use and conservation of national land, and to reveal the present condition of national land, such as land ownership and its utilization. It is expected to be based on the National Land Survey Law, which was enacted in 1951 when the survey was initiated. Three major items form the core of the survey: the cadastral survey, the land classification survey and the water use survey.

#### *Cadastral survey*

The cadastral survey aims at clarifying the location, boundary, ownership, lot number, acreage, and current status of land use of each parcel. Local governments, such as prefectural and municipal governments, carry out the survey. They transact such affairs as planning and supervising the project and contracting with a surveying company. The NLA plays a role in the survey by giving local governments a 55 per cent subsidy on the total cost and also some technical guidance. The executive body only has to share one thirtieth of the total cost, since a special grant is given to the Survey by the Japanese Government. Because of present austere budget conditions, there has been a sharp curb in the progress of the survey. 2,500 sq km or more is the acreage that the cadastral survey has completed annually over the past five years. The progress of this survey at the end of 1989 is as follows:

Completed cadastral survey: 98,543 sq km (1951-1989)

Progress ratio: 35.0 per cent (of target acreage of 285,500 sq km)

The cadastral survey consists of the following stages: supplementary survey, detailed on-the-spot survey, measuring the acreage of each parcel, and making atlases and books. The supplementary survey comprises the control point survey, which is the setting up of control points for cadastral surveying. Establishment of these control points is carried out by GSI. Scales of cadastral atlases differ from case to case depending on the mean acreage of a parcel. Scales of 1:250, 1:1,000, 1:2,500 or 1:5,000 are used, of which scales 1:500 and 1:1,000 are the most common. The required accuracy of measurement is classified into six types depending on the land-use pattern. For a residential area, for example, the highest degree of accuracy is demanded. The accuracy level for a forest area is the lowest.

Copies of cadastral maps and books are bound to be sent to registry offices after having been checked for accuracy and having obtained the legal approval of the National Land Survey, from the Minister of the National Land Agency, or, in some cases, from the prefectural governor, to replace the old maps, which were prepared about 100 years ago and are still used for levy and land registration.

The cadastral survey had not been well promoted, and in an attempt to correct this, the acceleration law, named the National Land Survey Promotion Law, was enacted in 1962. Under this law, a target acreage to be covered by the survey for a period of 10 years was clearly established. The survey is now proceeding into its fourth ten-year plan stage (1990-1999). According to the plan, the target acreage is 49,200 sq km. For more effective transaction of survey affairs, a personal computer system was introduced in 1984.

#### *Land classification surveys and water-use surveys*

A land classification survey is the survey of topographical and geological features, soil and present land use, the results to be included in atlases and books. A water-use survey aims at investigating the basic statistics of a river, such as annual rainfall, discharge and present water utilization for farming or drinking, and groundwater.

In the land classification survey, a computerized mapping method has been developed in which a specific device is controlled by a computer, and a coloured map drawn. By this method, one can easily identify various kinds of data related to land classification.

The above-mentioned surveys are published in atlases and books, as follows:

(*a*) Land classification maps (showing geomorphological features, surface geology, soil, present land use, land-use capability), overlays (such as slope classification) and an explanatory data book;

(*b*) Land conservation maps (indicating natural conditions, present land use and vegetation, natural disasters, land-use tendencies in designated areas, control and designated area for disaster prevention, valuable natural and cultural assets distribution, basic conservation) and explanatory data book;

(*c*) Water-use maps and a descriptive catalogue of available information on major river systems;

(*d*) Ground-water data ledger.

### SOIL MAPS

Soil maps in Japan are roughly divided into two categories; cultivated lands and forest lands. They are prepared by the Ministry of Agriculture, Forestry and Fisheries.

A 1:50,000 scale map series of soil types and products of cultivated lands has been prepared by the Agricultural Administration Bureau since 1959, covering the entire area of cultivated land, 51,000 sq km.

A 1:20,000-scale map series of soil types in national forests has been prepared by the Forestry Agency since 1947. 65,000 sq km were covered by this series. The agency has also prepared a 1:50,000-scale map series of soil types for many private forests.

### GEOLOGICAL MAPS

Most geological maps are published by the Geological Survey of Japan (GSJ), Agency of Industrial Science and Technology.

TABLE 6 LAND CLASSIFICATION AND WATER-USE MAPS (1951-1989)

| | *Scale* | *Coverage* |
|---|---|---|
| Land classification map | 1:200 000 | 380 000 sq km |
| | 1:50 000 | 241 000 sq km |
| | 1:2 500-1:5 000 | 4 370 sq km |
| Land conservation map | 1:200 000 | 118 400 sq km |
| | 1:50 000 | 4 800 sq km |
| Water-use map | 1:50 000 | 72 river systems |
| | 1:25 000-1:50 000 | 2 regions |

A series of basic geological maps at 1:50,000 scale (after a series at 1:75,000 had been published since 1952 by the GSJ) and 412 sheets, along with explanatory texts, had been published up to the end of 1989. The Japanese islands are covered by 1,267 sheet maps at 1:50,000 scale in which 811 sheet maps, including those at 1:75,000 scale have been published. Thus, 64 per cent of the islands is covered by geological maps at large scale. Over four years, from 1986 to 1989, compiled sheets at 1:200,000 scale were published, two of which were revised editions. One compiled sheet at 1:500,000 scale was published.

In addition to these geological maps, various kinds of geological and geophysical maps are distributed by GSJ, as follows:

1 computer-generated geological map of Japan, 1:2,000,000

2 hydrogeological maps, 1:50,000

7 marine geological and sedimentological maps, 1:200,000

3 geological maps of volcanoes, 1:25,000; 2 are revised editions. In addition, a geological map of Mt. Fuji was revised and eruption of Oshima island in 1986 was published

2 neotectonic maps, 1:500,000

1 geologic map of oil and gas fields

1 aeromagnetic map of Miyakojima island and its surrounding area, 1:200,000

1 gravity map of north Honshu, 1:200,000

1 geological map of geothermal area of north-east Honshu, 1:100,000

Geologic maps of Tama Hills, Tsukuba Science City and surrounding area and Lake Biwa as special series of geological maps.

## Marine geology

GSJ has been engaged in marine geological and geophysical investigation of the seas surrounding the Japanese islands, the Central Pacific and the Antarctic, chartering the geological survey vessel *Hakurei-maru* (1821 gross tons) and other boats. The investigation comprises basic studies of marine geology, mineral resources and geophysical prospecting, and lacustrine and coastal sedimentological study.

Special efforts have been given to such research projects as pollution

International cooperation is actively promoted in the fields of marine geology and mineral resources.

## Hydrographic work

### *Hydrographic surveying and charting*

Hydrographic survey and charting works done in the period are shown in tables 7-10.

TABLE 7. HYDROGRAPHICAL SURVEYS

| *Type of survey* | *1986* | *1987* | *1988* | *1989* |
|---|---|---|---|---|
| Harbour | 10 | 10 | 9 | 7 |
| Updating | 220 | 209 | 222 | 217 |
| Passage | 0 | 0 | 1 | 2 |
| Coastal | 1 | 2 | 2 | 4 |
| Oceanic | 1 | 1 | 2 | 2 |
| Basic maps of the sea | 7 | 7 | 7 | 7 |
| Earthquake prediction | 1 | 3 | 3 | 5 |

TABLE 8. NAUTICAL AND OTHER CHARTS PRODUCED

| *Type of chart* | *1986* | *1987* | *1988* | *1989* |
|---|---|---|---|---|
| New charts | | | | |
| Nautical charts | 12 | 11 | 8 | 10 |
| Miscellaneous charts | 0 | 0 | 0 | 0 |
| Basic maps of the sea | 29 | 34 | 28 | 20 |
| Aeronautical charts | 1 | 0 | 0 | 0 |
| New editions | | | | |
| Nautical charts | 61 | 48 | 57 | 47 |
| Miscellaneous charts | 2 | 5 | 2 | 15 |
| Basic maps of the sea | 2 | 4 | 2 | 3 |
| Aeronautical charts | 3 | 3 | 4 | 3 |
| TOTAL | 110 | 105 | 101 | 98 |
| Reprints | 13 | 7 | 11 | 8 |

TABLE 9. CLASSES OF BASIC MAPS OF THE SEA

| *BMS Series* | *Scale* | *Coverage* | *Size* | *Type* |
|---|---|---|---|---|
| In coastal waters | 1:10 000<br>1:50 000 | Within 12 miles of the coast | Full | Bathymetry; submarine structure |
| Continental shelf areas | 1:200 000 | Continental margin | 1/2 | Bathymetry; submarine structure; total magnetic intensity; gravity anomaly |
| Ocean areas | 1:500 000 | Ocean area | Full | (Planned) |

TABLE 10. CHARTS ISSUED AS OF MARCH 1989

| Type of chart | Number of issues |
|---|---|
| Nautical charts | 992 |
| Miscellaneous charts | 107 |
| Basic maps of the sea | 726 |
| Aeronautical charts | 25 |
| TOTAL | 1 850 |

The International Charts of the International Hydrological Organization (IHO) for which Japan has responsibility as the producer nation have been published; i.e. six charts of the 1:3,500,000 series and one chart of the two 1:10,000,000 series.

### *Oceanographic activities*

*Ocean current observation*

HD has been conducting routine observation of ocean currents in adjacent seas of Japan by using survey vessels, patrol vessels and aircraft. Obtained data are compared with those from drifting buoys and the analytic results of infrared photographs taken from artificial satellites to be synthetically analysed for the understanding of fluctuations in sea conditions.

*International cooperative research of western Pacific waters*

The international cooperative research of the western Pacific Waters (WESTPAC) is a regional project of the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). It aims to study and monitor variations of oceanographic structure, fluctuations in ocean living resources etc. in the western Pacific, as well as to train personnel engaged in oceanographic activities in coastal countries of the western Pacific region. Japan has been participating in the project since it was initiated.

*Sea ice observation*

On the coast of the Sea of Okhotsk in Hokkaido and in waters to the west of Hokkaido, a great quantity of drift ice is a serious obstacle to navigation or fishery every winter. In order to prevent marine accidents caused by drift ice, HD has been observing the distribution and movement of drift ice by using aircraft and patrol vessels during the sea-ice season, from December to April every year.

*Observation of tide, coastal currents and tidal streams*

In order to obtain basic data for the safety of maritime traffic, utilization and development of coastal areas, determination of chart datum, prediction of earthquakes, and the like, HD has been carrying out tide and tidal stream observations and ocean current observations.

*Survey of marine pollution*

HD regularly makes surveys of marine pollution in major bays and waters around Japan.

The Department has conducted seawater sampling in areas around Japan twice a year (summer and winter). Sampling of seawater and sea-bed sediment are also made in A zones once a year to analyse for oil, PCBs (polychlorinated biphenyls), heavy metals etc. According to the findings obtained so far, the pollution level was rather low in those sea areas and no increase of pollution has been observed in the last ten years.

In order to understand how discharged pollutants have spread from major bays to the ocean, HD conducts sampling of seawater and sea-bed sediment in such bays as Tokyo Bay to make a chemical analysis for oil, PCBs, heavy metals etc. The results of observations revealed that the pollution level of seawater was rather low, while that of sea-bed sediment was slightly high in the inner part of such bays. In either case, however, the pollution level has shown no fluctuations in the last several years.

HD has also been conducting surveys for artificial radioactive nuclides in seawater and sea-bed sediment in areas around Japan. After the Chernobyl reactor accident on 26 April 1986, the increase of caesium-137 in seawater, particularly in the Japan Sea, was observed. But in and after 1987, caesium-137 lowered to the same level as before the accident. According to the findings obtained so far, no progress in pollution has been observed.

### *Marine survey for delimitation of sea areas under Japanese jurisdictions*

*Survey of coastal areas*

In order to cope with the situation of extending the territorial seas to 12 miles, establishment of 200-mile exclusive economic zones (EEZ) and the need to delimit sea areas falling under the Japanese jurisdiction by taking into account the adoption of the UN Convention on the Law of the Sea, HD is carrying out detailed surveys of low tidal lines, topography and geological structure of the sea-bed in coastal areas, particularly in those important areas around baselines defining the Japanese territorial sea.

OTHER PUBLISHING ACTIVITIES

| Type of publication | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|
| New publications | | | | |
| Sailing directions (including supplements) | 1 | 3 | 2 | 1 |
| Special publications | 21 | 20 | 20 | 20 |
| New edition | | | | |
| Sailing directions (including supplements) | 5 | 4 | 4 | 4 |
| Special publications | 2 | 3 | 3 | 4 |
| Notices to Mariners | 3 770 | 3 457 | 3 845 | 4 442 |
| Japan Navigational Warnings | | | | |
| (Japanese) | 2 135 | 1 988 | 2 063 | 2 266 |
| (English) | 974 | 638 | 679 | 799 |
| NAVAREA XI Navigational Warnings | 1 338 | 1 284 | 1 301 | 1 424 |
| Information on ocean conditions | | | | |
| Quick bulletin of ocean condition | 24 | 24 | 24 | 24 |
| Ocean current forecasting | 25 | 51 | 51 | 51 |

*Survey of continental shelf areas*

HD is carrying out hydrographic surveys south of Japan by using the large-type survey vessel Takuyo equipped with modern survey instruments such as a narrow multi-beam echo-sounder in order to obtain basic data required for the promotion of utilization and development of the continental shelf areas of Japan.

*Promotion of marine geodetic survey*

Nautical charts of each country are constructed according to the country's own geodetic system. With the recent development of the geodetic satellite survey technique, however, a difference in geodetic systems has become a problem. Accordingly, the IHO recommends that the meridians and parallels given on the chart should be shown on the basis of the World Geodetic System (WGS). Therefore, in Japan also, it becomes necessary to locate the mainland and remote islands on the basis of WGS, and the Maritime Safety Agency has been conducting geodetic satellite observations by laser ranging to the geodetic satellite LAGEOS, in conjunction with NASA, in order to obtain the precise location of the mainland on the basis of WGS.

*Realtime and Non-Realtime Information Supply Service*

In order to disseminate information on matters required for the safety of ship traffic, Notices to Mariners are issued in printed matter, while the Japanese Navigational Warnings and the navigational warnings (NAVAREA XI Navigational Warnings) by the Worldwide Navigational Warning System (WWNWS) are transmitted by radio.

In addition, information concerning conditions of the sea areas around Japan is supplied as "Surface Current State of the Seas Adjacent to Nippon", issued to preserve the safety of sea traffic and the economic operation of ships.

*Notices to Mariners*

Notices to Mariners carry information for maintaining nautical charts up-to-date and information contributing to the safety of navigation and efficient operation of ships. The Notices are issued once a week. Information includes changes in aids to navigation, construction works at sea such as the construction of the Kansai International Airport, firing exercises being conducted by the Defense Agency etc.

*Navigational Warnings*

Japanese Navigational Warnings, covering a broad area warning system, are sent by radio three times a day, giving emergency notices for the safety of Japanese ships navigating in the waters from the western part of the North Pacific Ocean to the Persian Gulf and foreign ships navigating around Japan. Since 1986, particularly urgent Navigational Warnings are broadcast at any time, without delay, to improve realtime quality.

NAVAREA Warnings are a worldwide navigational warning system, and information on the waters for ocean-going ships is sent by radio through this system. The world sea area is divided into 16 areas, and Japan is designated as Coordinator of the XI area (western part of the North Pacific Ocean and South-East Asian waters) disseminating information as NAVAREA XI Warnings four times a day and, in addition, issuing weekly summaries of NAVAREA XI Warnings as printed matter. Information carried by the Navigational Warnings includes submarine volcanic eruptions, drifting of capsized vessels, firing exercises etc.

*Information on surface current state of the seas*

"Quick bulletin of ocean conditions" is provided on the first and third Fridays of every month. It concerns the state of surface currents and sea ice of the seas adjacent to Japan and is issued as printed matter, facsimile or radio broadcast.

"Ocean current forecasting" is supplied every Friday by means of facsimile illustrating the forecasted Kuroshio current and other main currents in the adjacent waters of Japan.

*Provision and supply of marine data and information*

Since the acquisition of marine data and information is costly both in money and time, utilization of such data should be further promoted not only for the primary purpose but also for the secondary and tertiary purposes. From this point of view, for 25 years HD has been engaged in collecting, managing and supplying marine data and information to form a comprehensive marine data bank established in accordance with a resolution adopted by the IOC and a report made by the Oceanic Technology and Science Council of Japan. The Oceanographic Data and Information Division of HD is registered with IOC, under the International Oceanographic Data Exchange (IODE) project promoted by IOC, as the Japan Oceanographic Data Center (JODC). As the Japanese representative organization in the field of oceanographic data exchange, it takes an active part in international exchange of marine data and information.

## INTERNATIONAL ACTIVITIES

*International Hydrographic Organization (IHO)*

IHO Commissions, Committees and Working Groups in which Japan has been participating are as follows:

Finance Committee (FC)

Chart Standardization Committee (CSC)

Committee on Electronic Chart Display and Information Systems (COE)

Commission on Promulgation of Radio Navigational Warnings (CPRNW)

Committee on the Exchange of Digital Data (CEDD)

Working Group on Technical Aspects of the UN Law of the Sea Convention (TALOS WG)

Ad Hoc Working Group on the revision of S.P. 23

FIG/IHO Technical Assistance Coordination Committee (TACC)

Working Group on Ocean Plotting Sheet

Working Group on Standards for the Release of Tidal Data to Commercial Organizations

*Intergovernmental Oceanographic Commission (IOC) of UNESCO*

The HD participates in international conferences held by the IOC as one of the Japanese technical organizations. As mentioned previously, the Oceanographic Data and Information Division (Japan Oceanographic Data Center (JODC)) of the Department is designated as a Japanese representative organization in the field of oceanic information exchange, and it is also in charge of the Responsible National Oceanographic Data Center (RNODC), which manages the data obtained from international projects such as the IOC Subcommission for the WESTPAC Programme and the Joint IOC-WMO Working Committee for the Integrated Global Ocean Services System (IGOSS) programme.

*International Lunar Occultation Center*

The HD conducts astronomical observation under the international cooperation and makes efforts to improve the accuracy of such almanacs as ephemerides. From April 1981, upon the request of the International Astronomical

Union (IAU), the Department took over the activities performed by the Royal Greenwich Observatory as the International Lunar Occultation Center and started to collect and analyse, in a homogeneous manner, observations about occultation obtained from all over the world.

*Japan-China Joint Research of the Kuroshio*

Since 1986, in cooperation with researchers and scientists from China and as part of the Japan-China Joint Research of the Kuroshio, HD has been carrying out observations of the changing mechanism of the Kuroshio in the East China Sea and the southern seas of Honsyu. These observations were made for the purpose of clarifying the characteristics of the Kuroshio and its flows in the Tokara Strait, as well as the processes originating the Tsushima Warm Current. Survey vessels are used four times a year, once in every season, and more than 10 observation lines have been set. Mooring arrays are deployed to obtain long-term consecutive data in these areas. The flow of Kuroshio is tracked by using satellite-tracked drifting buoys (ARGOS).

## LA CARTOGRAPHIE EN RDP LAO*

*Document présenté par la République démocratique populaire lao*

Shortly before the Eleventh United Nations Regional Cartographic Conference for Asia and the Pacific, the National Geographical Department of the Lao People's Democratic Republic, in cooperation with the Department of Geodesy and Cartography of the Soviet Union, compiled and published topographic maps at scales 1:100,000, 1:200,000, 1:500,000 and 1:1,000,000, covering the entire territory of the Lao People's Democratic Republic; and at scales 1:10,000 and 1:25,000, covering 1 per cent of the country's territory.

Since the Eleventh Conference, activities in the field of topographic cartography have been at a stand-still for financial reasons. The most urgent requirement in the area of thematic mapping is the preparation of educational maps. The National Geographical Department has published physical and administrative maps of the Lao People's Democratic Republic, a political map of the world (in Lao) and an administrative map of the Vientiane prefecture.

In addition to the National Geographical Department, other national organizations, assisted by foreign experts, have used remote sensing to prepare land-use maps, agro-ecological maps and other maps of the southern parts of the country.

There is a growing need for maps to meet the requirements of national development. Currently, the main obstacle to the preparation of large-scale topographic maps is the lack of qualified staff, instruments, equipment and, lastly, technical expertise.

*The original text of this paper, prepared by Boualay Sayasane, Département géographique national, appeared as document E/CONF 83/INF 39

Peu avant la onzième Conférence, le Département géographique national de la République démocratique populaire lao en coopération avec la Direction générale de la géodesie et cartographie de l'Union sovietique, avait établi et publié des cartes topographiques de différentes échelles tellesques: 1/100 000; 1/200 000; 1/500 000; 1/100 0000 couvrant l'ensemble du territoire de la république; et échelles 1/10 000 et 1/25 000 couvrant 1 percent du territoire du pays.

Dès la onzième Conférence, les activitiés concernant la cartographie topographique semblent être paralysés par des conditions financières. Les travaux de la cartographie thématiques demandés sont les cartes pour l'éducation. Le Département géographique national avait publié:

(*a*) les cartes physiques, administratives de la République démocratique populaire;

(*b*) une carte politique du monde ( langue lao );

(*c*) une carte administrative de la préfecture de Vientiane.

A part du Département géographique national, il y avait d'autres organisations nationales avec l'aide des experts étrangers qui avaient utilisé la méthode de Télédétection pour établir les cartes d'occupation du sol, cartes agro-écologiques etc dans certains régions du sud.

Les besoins des cartes pour le développement national sont devenus de plus en plus intensifs. Les problèmes posés de nos jours, pour la production des cartes topographiques à grande échelle, seconcernent les personnels qualifiés, les instruments et l'équipement et finalement la connaissance de la technologie.

## CARTOGRAPHIC ACTIVITIES IN MALAYSIA, 1987-1990*

*Paper submitted by Malaysia*

### RÉSUMÉ

Le Département de topographie et de cartographie de Malaisie, qui relève du Ministère du développement foncier et coopératif, est l'organisme responsable des levés cadastraux et des activités géodésiques et cartographiques de Malaisie. Il apporte son appui au secteur de la défense et favorise le développement économique et social en fournissant des cartes précises et des informations topographiques en temps voulu afin de répondre aux besoins des divers utilisateurs.

Le Département, qui a à sa tête un directeur général, se compose de deux éléments : la Division du cadastre et la Division de cartographie, officiellement dénommée Direction de la cartographie nationale de Malaisie. Les activités de cette dernière sont notamment les suivantes : créer et tenir à jour un réseau géodésique national; produire et mettre à jour des cartes topographiques, politiques, urbaines et routières du pays; réaliser des photographies aériennes et les diffuser; dispenser des conseils techniques sur les frontières maritimes et sur la délimitation des frontières internationales communes.

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The Department of Survey and Mapping, within the Ministry of Land and Co-operative Development of Malaysia is the single agency responsible for cadastral surveying, geodesy and mapping of the country. It provides support for the nation's defence, as well as for its economic and social development by providing accurate maps and timely survey information to meet the various user requirements.

The Department has two components; the Cadastral Survey Division and the Mapping Division, which has the official name of Directorate of National Mapping, Malaysia (DNMM). DNMM's activities include establishing and maintaining a national geodetic network; production and maintenance of topographical, political, town and road maps of the country; flying and distributing aerial photographs; providing technical advice on maritime boundaries, and demarcation and survey of the common international boundaries.

#### CARTOGRAPHIC-RELATED ACTIVITIES

##### *Geodetic network*

Peninsular Malaysia is unique in that cadastral and geodetic surveys are carried out on a combination of different datums, different ellipsoids and different projections. Each state in Peninsular Malaysia has its own coordinate system based on the Cassini Soldner Projection, while national mapping is based on the Rectified Skew Orthomorphic Projection. In Peninsular Malaysia the geodetic networks used for cadastral surveys are the PERAK (1886) and ASA (1899) systems, while the geodetic network used for mapping is the Malayan Revised Triangulation (MRT 68). The network consists of 77 geodetic, 240 primary, 837 secondary and 51 tertiary stations.

East Malaysia uses the Borneo Triangulation (1968) for controlling both its cadastral and mapping surveys. Both types of surveys are also plotted on the Rectified Skew Orthomorphic Projection. There are 113 primary, 535 secondary and 1251 tertiary stations on this network.

##### *Levelling network*

The entire precise levelling network of Peninsular Malaysia was first undertaken in 1912 and completed in 1967. The levelling network consisted of two lines of precise levels running over the whole of the country, one on the west coast and the other on the east coast. These two are joined by an E-W line through the middle of the country. No orthometric corrections were applied and no homogeneous adjustments of the whole network was ever attempted. The datum was derived from 365-day tide gauge observations at Port Swettenham (now Port Kelang), carried out in 1910-1911.

A new exercise to re-level the existing network and to replace or relocate all missing benchmarks commenced in 1985. This project is being carried out in conjunction with a Tidal Observation Project, to establish a national geodetic vertical datum (NGVD) for Peninsular Malaysia.

The levelling network consists of a 3,630 kilometres (km) of precise levelling and 15,000 km of second-order levelling, which will be connected to the tide gauge stations. The progress of survey from April 1986 to October 1990 is 3,420 km (94 per cent) for precise levelling and 12,659 km (84.4 per cent) for second-order levelling.

##### *Motorized levelling*

Motorized levelling was introduced in 1988 under the cooperative project with SWEDSURVEY of Sweden. Using this technique, it is hoped that the re-levelling network project could be completed in a much shorter time. As of October 1990, 1,050 km of motorized levelling has been completed.

##### *Gravity survey*

The earliest documented record of gravity measurement was one conducted by the French in 1954 during gravity ties between Paris and Antarctica, using the western geographical C°, Nr42 EQ gravity meter.

In 1962, two technical officers from the Geographical Survey Institute of Japan conducted gravity surveys along the Kuala Lumpur-Singapore road highway using Worden gravity meter model 346.

The 1381st Geodetic Survey squadron of the United States of America, as part of the West Pacific Calibration Line Survey in 1966, established gravity stations in Peninsular Malaysia and Singapore using La Coste & Remberg gravity meter.

Subsequently when the International Gravity Standardization Net of 1971 (IGSN-71) was established, four stations in Peninsular Malaysia were included in this network. Of the

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*The original text of this paper, prepared by Abdul Majid Bin Mohamed, Department of Survey and Mapping, appeared as document E/CONF 83/INF 37 four stations, only one station, IGSN-71 02631A in the University of Malaya in Kuala Lumpur has withstood the test of time.

*Peninsular Malaysia Gravity Standard Network, 1989*

Work on the 1989 gravity network was done in two phases. The first phase, the first-order gravity network, was initiated in August 1988 and completed in July 1989. The gravity network is shown in figure I. The second phase set up a more dense network of gravity stations at 1-5 km intervals. Up to October 1990, 87 per cent of this phase was completed, covering a total distance of 3,850 km with 1,230 stations and 131 loops. The observations were conducted using a La Coste Romberg Model G-888 gravity meter.

*Gravity data processing and documentation*

Adjustment of the first-order gravity was carried out by the method of least squares and has been completed. The total distance involved is 4,160 km, with 158 stations and 41 loops. Adjustment of the second-order gravity is about 30 per cent completed. Documentation is provided in the form of hard copy and diskettes.

### *Tidal Observation Project (tide-gauge)*

The Tidal Observation Project was initiated in 1981, to establish a network of permanent tide gauge stations around Peninsular Malaysia with the primary objective of establishing the national geodetic vertical datum for Peninsular Malaysia (NGVD).

By November 1986, a total of 12 tide gauge stations were established at salient selected points around the country. The location of the 12 tide gauge stations are shown in figure II.

| | |
|---|---|
| Pulau Langkawi | Johor Bharu |
| Penang | Tanjung Sedili |
| Lumut | Pulau Tioman |
| Pelabuhan Kelang | Kuantan |
| Tanjung Keling | Cendering |
| Kukup | Genting, Tumpat |

The tidal observation data collected have been used extensively by both the Department and other client agencies for the following purposes:

(*a*) Analysis of tidal constituents;

(*b*) Study of the tidal phenomena;

(*c*) Publication of the Annual Tidal Observation Record (since 1984);

(*d*) Publication of the Annual Tidal Prediction Tables (since 1986).

A total of eight (8) suitable sites have been identified in Sabah and Sarawak for tidal stations and are scheduled for implementation in the Sixth Malaysia Plan (1991-1995).

### *Global Positioning System*

In 1989, with the cooperation of SWEDSURVEY, the Department carried out Global Positioning System (GPS) observation in the southern part of Peninsular Malaysia. A total of 108 points were observed, consisting of existing Doppler, geodetic, primary, secondary and new monumented stations. Four sets of ASHTECH receivers were deployed and the technique of phase measurement was used. Processing of data was done in Malaysia, while final adjustment was carried out in Sweden.

The final geodetic coordinates were given on the WGS 84 datum. Transformation parameters using the Moloduski Badekas Model were also determined between the MRT 68 and WGS 84 datums.

### *Aerial photographs*

Aerial photography at scale 1:40,000 was done during 1984-1990, covering most of Peninsular Malaysia. The aerial photographs are used by the Department for the compilation of standard mapping of Peninsular Malaysia, Series L7030, at scale 1:50,000, and by various other land/resources related agencies for their own planning and interpretative requirements. Besides this, aerial photography at scales ranging from 1:10,000 to 1:20,000 was carried out for various towns.

For land development projects, under the Federal Land Development Authority (Felda) a total area of approximately 90,456 hectares was photographed at 1:20,000 scale. Aerial photographs for special projects were also taken at various scales ranging from 1:5,000 to 1:25,000.

## MAP PRODUCTION

### *Map compilation*

The process of map compilation using conventional cartography has always been the standard technique adopted by this Department. With the introduction of the computer assisted mapping system in 1988, digital map compilation techniques were introduced into the standard operational procedure. Currently, both techniques are running in parallel; and it is envisaged that in the very near future digital compilation techniques by CAMS will dominate map compilation work in the Department.

### *Computer-assisted mapping system (CAMS)*

The computer assisted mapping system (CAMS) was acquired under the fifth Malaysia Plan (1986-1990) with the objective of expediting map production capacity. CAMS is designed to automate aerial triangulation, photogrammetric compilation and the manual cartographic drafting technique. CAMS was implemented with the following specific objectives:

(*a*) To expedite map production capacity of the national topographic mapping series commensurate with an ideal map revision cycle period;

(*b*) To facilitate the production of other purpose maps for civilian and military use;

(*c*) To create a national topographic and cartographic database.

*Product of CAMS*

The CAMS System produces reproduction materials conforming to map specification of the National Topographic Mapping Series in the form of colour separates, and digital feature-coded map data in the form of magnetic tape, according to the Malaysian Standard Feature Code.

### *Mapping progress*

*Standard topographic series maps*

Topographic maps are classified as medium-scale maps in the series of L7010, L7030, L8028, T738 and T735. These maps are multi-coloured, with the standard map-sheet size of 70×90 cm (map neatlines of 60×60 cm). (Table 1.)

*Large-scale town maps*

Town maps in Peninsular Malaysia come under the series L905, with scales varying from 1:3,000 to 1:12,500 depending on the mapping area. The large-scale town maps of series L808 covering Kuala Lumpur and environment are published on a scale of 1:10,000. Standard map sheet size is 80 × 90 cm with map neatlines of 60 × 60 cm. (Table 2.)

Figure I. Peninsular Malaysia gravity standardization network, 1989

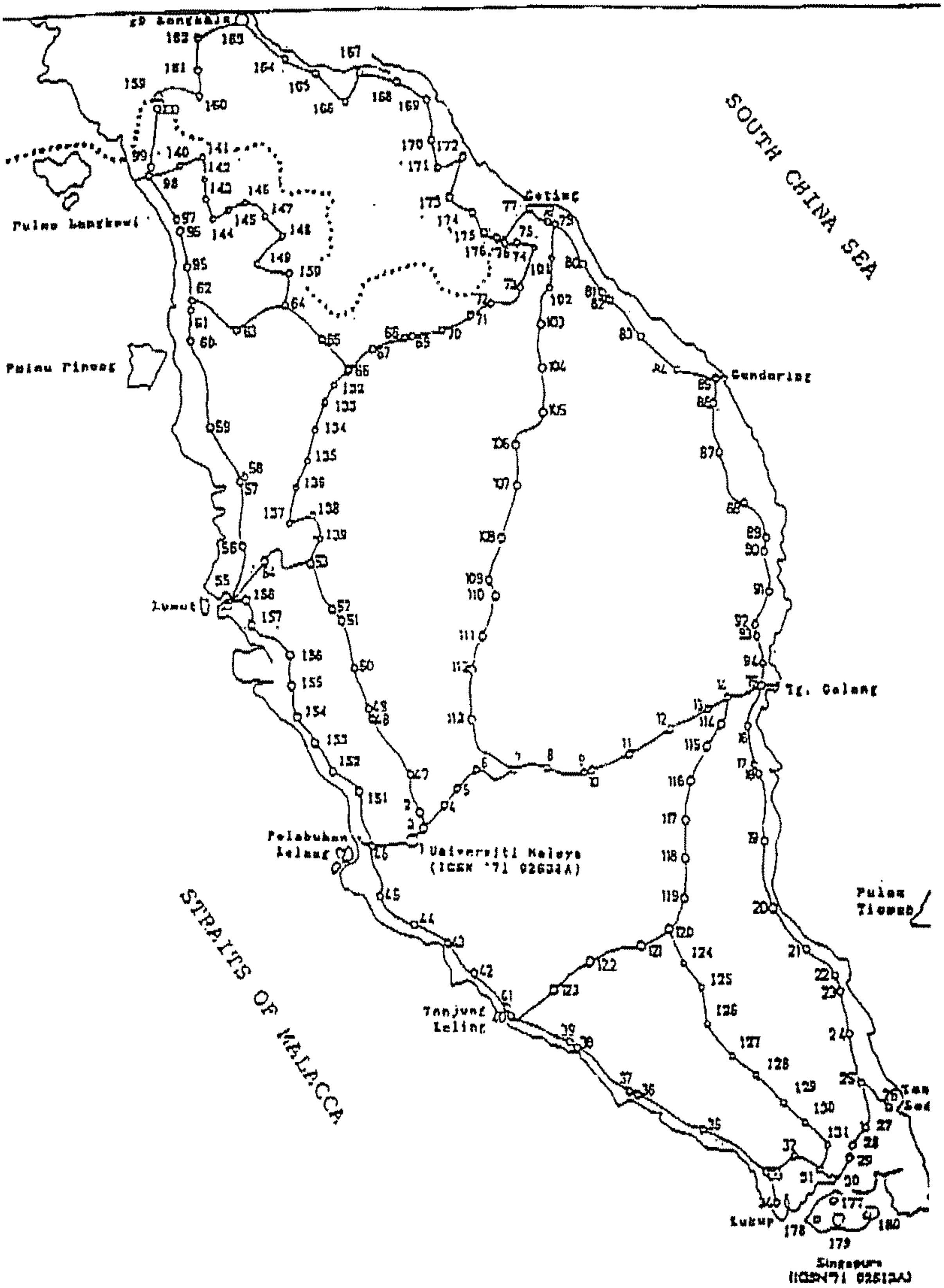

**Figure II. Location of tidal stations in Peninsular Malaysia**

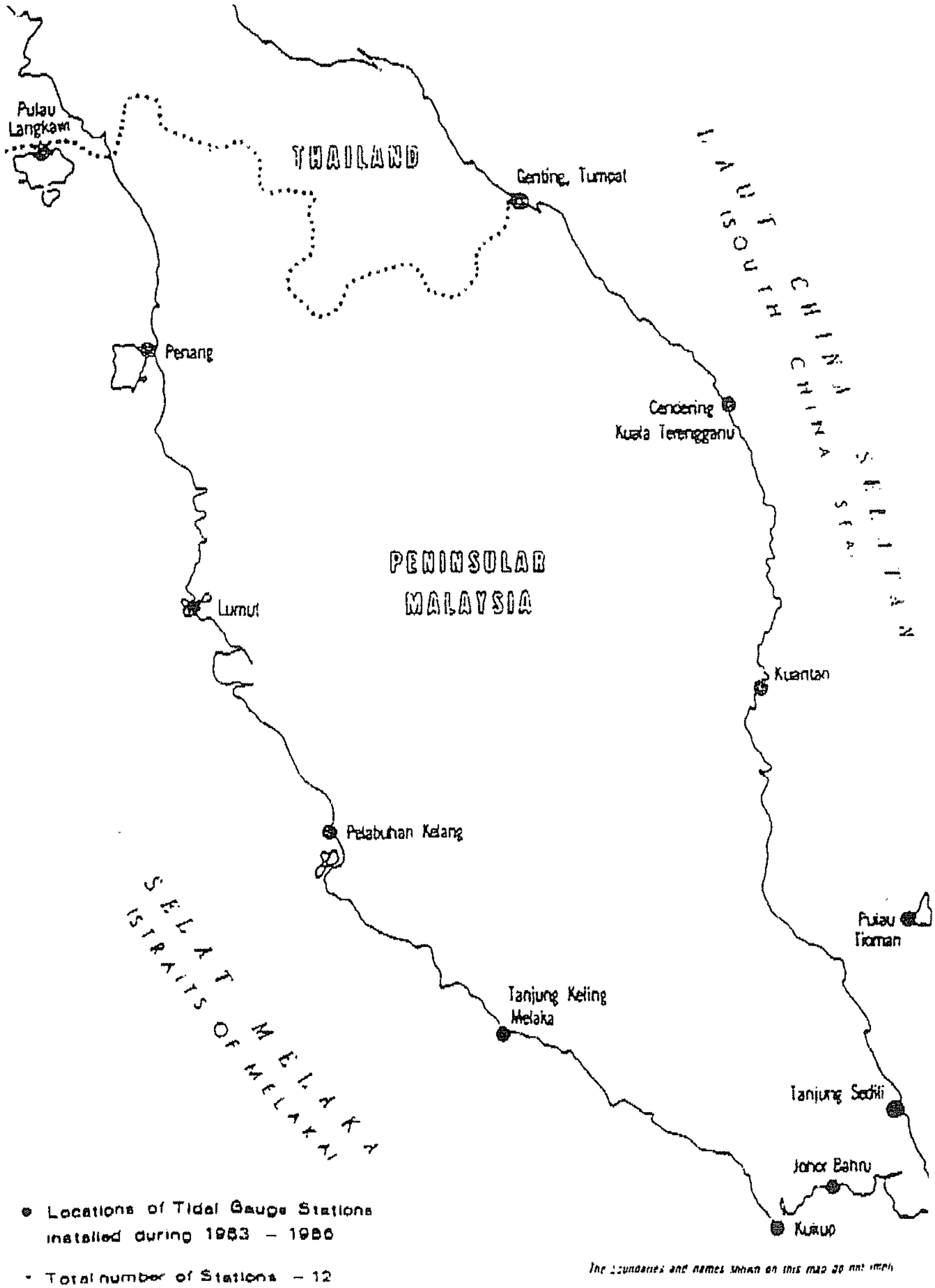

TABLE 1 PROGRESS OF STANDARD TOPOGRAPHICAL MAPPING. DECEMBER 1990

| No. | Series | Total sheets | Scales | Progress by December 1990 | Coverage |
|---|---|---|---|---|---|
| 1 | L7010 | 136 | 1:63 360 | 136 | Peninsular Malaysia |
| 2 | L7030 | 177 | 1:50 000 | 74 | Peninsular Malaysia |
| 3 | T738 | 278 | 1:50 000 | 1 | Sabah/Sarawak |
| 4 | T735 | 336 | 1:50 000 | 336 | Sabah/Sarawak |

TABLE 2 PROGRESS OF LARGE-SCALE TOPOGRAPHICAL MAPPING. DECEMBER 1990

| No. | Series | Total sheets | Scales | Progress by December 1990 | Coverage |
|---|---|---|---|---|---|
| 1. | L905 | 104 | 1:3 000-1:12 500 | 98 | Towns in Semenanjung, Malaysia |
| 2. | L808 | 45 | 1:10 000 | 45 | Kuala Lumpur and environment |
| 3 | T931 | 43 | 1:3 000-1:12 500 | 36 | Towns in Sabah and Sarawak |

*State maps*

State maps of all the states in Malaysia have been published at various dates during the last 20 years. These maps are unrestricted, and the specifications cover details such as; communications and drainage patterns, administrative boundaries, alienated land, forest and other reserves and such other details as are useful to the general map user.

*Miscellaneous maps*

Besides the national series maps and state maps, the Department also produces various other types of maps, such as geological, soil, tourist, meteorological, road maps, political and physical maps, unrestricted town maps and other miscellaneous maps and charts.

## EQUIPMENT

For the period under review, various survey instruments and cartographic equipment have been purchased to provide support to geodetic surveys and cartographic activities in the country. A list of the additional instruments/equipment acquired since 1987 is shown in the annex.

## FUTURE TRENDS AND ACTIVITIES

### *Computer implementation and future upgrading: a digital database for the whole country*

Recognizing that data are an important resource and expensive in acquisition, consideration must be given to maximizing their use and availability while protecting them from waste or loss. As a government agency responsible for providing topographical data for the country, future mapping activities will focus on the creation of the National Topographic and Cartographic data bank to serve the needs of the various land-related agencies for research, planning and national development purposes, and of the armed forces for security strategies and operational requirements. The CAMS facilities will be revised and upgraded to meet these requirements.

### *New geodetic network for the country*

The Department is planning to upgrade the present geodetic network to a scientific network for the country, at the same time maintaining the existing triangulation network. This exercise will incorporate establishment of a common geodetic datum for Peninsular Malaysia and Sabah/Sarawak. Densification of GPS control points will become a major feature in activities for geodesy, mapping and scientific purposes.

## ANNEX

**Additional equipment acquired for the period 1987-1990**

A. EQUIPMENT PURCHASED UNDER CAMS PROJECT

| | |
|---|---|
| 1. CPU VAX 8350 | 2 |
| 2. Vera 100 TM workstation | 3 |
| 3. Vera 360 workstation | 9 |
| 4. Vera 540 workstation | 3 |
| 5. Vera 544 workstation | 2 |
| 6. VT 330 alpha-numeric terminal with graphic | 4 |
| 7. VT 320 alpha-numeric terminal | 12 |
| 8. Epson dot matrix printer | 5 |
| 9. Seiko D-Scan colour hard copy | 1 |
| 10. Stereotrack | 15 |
| 11. Calcomp plotter | 2 |
| 12. Kongsberg drafting system | 1 |
| 13. Kartoscan | 1 |

B. COMPUTER

| | |
|---|---|
| 14. IBM computer PS-2 Model 30 | 2 |
| 15. IBM computer PS-2 Model 50 | 1 |
| 16. Monitor PS-2 (Mono) | 1 |
| 17. Monitor PS-2 (Colour) | 2 |
| 18. Personal computer (Francis Baker) | 3 |
| 19. Printer. Epson Ex 1000 | 1 |
| 20. IBM adaptor | 3 |
| 21. IBM support program | 1 |
| 22. NEC Powermate 386 | 3 |
| 23. Pin Writer | 1 |
| 24. Brother laser jet printer | 1 |
| 25. MUTOH plotter | 1 |

C. SURVEY EQUIPMENT

| | |
|---|---|
| 26. Precise level | 5 |
| 27. Carl Zeiss Model N 1002 motorized levelling | 1 |
| 28. Automatic precision level. Carl Zeiss Jena N 1002 | 1 |
| 29. Land gravity meter with electronic readout, Model G-888 | 1 |
| 30. Electronic distance measurement (EDM) | 8 |
| 31. ASHTECH Model LX II dual frequency GPS receiver | 4 |

D. PHOTOGRAMMETRIC AND CARTOGRAPHIC EQUIPMENT

| | |
|---|---|
| 32. Phototype setter | |
| CR Tronic 320 | 1 |
| CR Tronic 360 | 1 |
| CR Terminal 300 | 2 |
| Typeview | 1 |

## CARTOGRAPHIC ACTIVITIES IN NEPAL*

*Paper submitted by Nepal*


### RÉSUMÉ

Le Département de cartographie, qui relève du Ministère de la réforme agraire et de la gestion des terres, est l'organisme central du Gouvernement chargé de l'ensemble des activités cartographiques dans le pays. Créé en tant qu'unité de l'armée en 1924, il est devenu un bureau de cartographie en 1940 avant de prendre la forme de l'actuel département en 1958. Le premier projet de cartographie a commencé en 1924 avec des levés à la planchette. Les activités restèrent limitées au cadastre, même après la séparation d'avec l'armée. Le Département reçut un élan décisif en 1964 grâce au programme de réforme agraire.

Le Service géodésique a été créé en 1969 (sous le nom de Service de trigonométrie) afin d'améliorer les activités de levé cadastral en fournissant les points géodésiques de base. Actuellement, il produit également des données géodésiques pour le génie. Un service de levés topographiques a été créé en 1972 afin de répondre aux besoins de services topographiques ainsi qu'à la demande croissante de cartes pour les projets de développement. En 1968, un centre de formation à la topographie avait été mis en place afin de répondre au besoin de personnel qualifié de niveau inférieur et intermédiaire. Actuellement, 3 060 personnes travaillent pour le Département de cartographie. Parmi elles, on compte 2 754 techniciens, dont 70 ont suivi un enseignement et une formation à l'étranger.

Le Népal est un pays en développement. Il est régi par une monarchie constitutionnelle et un système multipartite depuis les manifestations du premier trimestre de 1990. Il réalise actuellement divers projets de développement, notamment dans le domaine des ressources en eau, de l'irrigation, de la construction de barrages, de l'alignement des routes, du développement rural, de la conservation des forêts et des sols, de l'aménagement des bassins hydrographiques, etc., afin de promouvoir un développement global. Pour planifier et exécuter ces projets, il faut des cartes et des données. Si les cartes nécessaires sont aisément disponibles, les projets de développement seront exécutés dans des délais beaucoup plus courts.

Pour répondre à la demande croissante de cartes destinées à divers projets, il faut que ces cartes soient fournies en temps voulu et soient précises, fiables et à jour. Le Népal doit développer ses activités cartographiques afin de réaliser une nouvelle série de fonds de cartes, en s'appuyant sur ses ressources propres ainsi que sur une assistance bilatérale et multilatérale.


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The Kingdom of Nepal is a constitutional monarchy with the multi-party system. Located in the lap of the Himalayas, it is bordered on three sides by India and by China to the north. There is a wide variety of terrain, which changes in quick succession from the peak of Mt. Everest to the low-lying valleys and plain area of the Terai region. The Nepalese Himalayas, which contain more than 200 peaks exceeding 7,000 m in elevation, are considered to be the youngest mountain system in the world, the result of several impulses from 35 million years ago. At present, the Himalayas show little tectonic activity. Upheaval has not completely ceased however, and small spasmodic rises still occur which, in turn, make the Nepalese Himalayas relatively unstable.

The country comprises five physiographic regions: Terai Plain, 14.2 per cent; Siwalik Low Hills, 12.8 per cent; Middle Mountains, 30.2 per cent; High Mountains, 20.1 per cent; and High Himalayas, 22.7 per cent.

Nepal is heavily dependent on agriculture, which provides the basic sustenance for over 90 per cent of the Nepalese people, who earn their livelihood mostly from the land. Most of the industries are based on agriculture. Mountain terrain is a main constraint for development of various sectors.

*The original text of this paper appeared as document E/CONF 83/INF 38.

The country is divided into five development regions, further divided into 14 zones, 75 districts and 4,250 village development committees with 33 municipalities. Some geographical information on Nepal follows:

| | | |
|---|---|---|
| *Location:* | Latitude 26° 22′– 30° 27′N | |
| | Longitude 80° 04′– 88° 12′E | |
| *Area:* | 147,181 sq km | |
| *Elevation:* | 60 to 8,848 metres (Mt. Everest) | |
| *Land use:* | Agriculture | 21.9% |
| | Forest | 37.5% |
| | Snow covered | 15.3% |
| | Grazing | 13.4% |
| | Other | 11.9% |
| *Population:* | 19 million (1990 projected) | |
| *Density:* | 120 persons per sq km (average) | |
| *GNP per capita:* | $US 160 | |
| *Literacy:* | 30.1% | |

### CARTOGRAPHIC INFORMATION

The Survey Department, under the Ministry of Land Reform and Management, is the central organization of His Majesty's Government, responsible for all national cartographic activities within the country. It was established as an Army unit in 1924, later, in 1940, separated to a survey office, and ultimately in 1958, developed into the Survey Department. The first map making was started in 1924 with place-table survey. The work was limited to cadastral survey even after it was separated from the Army. A real impetus was given to this organization by the Land Reform Programme launched in 1964.

The Geodetic (then called Trigonometrical) Survey Branch was established in 1969 with a view to upgrading the cadastral survey work and providing basic control points; it is now supplying geodetic data for engineering works as well. To provide the topographical services and to meet the increasing demand of maps for development projects of the country, the Topographical Survey Branch was initially established in 1972. The Survey Training Centre was set up in 1968 to fulfil the need for technical manpower of lower- and medium-level skills. At present there are 3,060 persons working under the Survey Department. Among them 2,754 are the technical personnel, of whom 70 were educated and trained abroad.

Following is a summary of progress in cartographic activities:

| *Activities* | *Progress up to 1990* |
|---|---|
| Cadastral survey | 60 districts (out of 75) |
| Trigonometrical survey | |
| (*a*) Laplace stations | 7 |
| (*b*) Azimuths | 14 |
| (*c*) Doppler stations | 17 |
| (*d*) First-order control points | 68 |
| (*e*) Lower-order control points | 121,723 |
| Precise levelling survey | |
| (*a*) Datums stations | 8 |
| (*b*) Trigonometrical levelling station | 2,346 |
| (*c*) Spirit levelling (km) | 4,693 |
| Gravity survey | |
| (*a*) Gravity stations (relative) | 53 |
| (*b*) Gravity station of Kathmandu International Airport connected to Bangkok and Sri Lanka | |
| Magnetic survey | |
| (*a*) Magnetic stations (observed) | 7 |
| Astronomical observations | |
| (*a*) Star observations (groups) | 2,106 |
| Topographical survey | |
| (*a*) 1 inch:mile topo-map sheets (updated at scale 1:50,000) | |
| (*b*) Small-scale maps (physiographic, administrative, relief) | |
| (*c*) Maps of development regions, zonal maps and district maps (updated and reprinted) | |
| (*d*) Map of Nepal (by screen printing) | |
| (*e*) Maps of municipalities and village development blocks | |
| Survey education (persons) | |
| (*a*) Basic Survey | 1,858 |
| (*b*) Junior Survey | 910 |
| (*c*) Senior Survey | 276 |
| (*d*) Survey Computation | 28 |
| (*e*) Special Courses | 199 |

## Geodetic survey

The main task of the geodetic survey is to establish the various orders of geodetic control points and to provide geodetic data for all kinds of survey including engineering, research and study purposes. Survey activities carried out under the Geodetic Survey Branch are trigonometrical, levelling, astronomical, gravity, and magnetic.

### *Trigonometrical survey*

During the period 1987-1990 much emphasis was given to triangulation network of lower-order densities (second-, third-, and fourth-order), specially to meet the need to establish control points for cadastral survey work. So far, 27 districts and 13 municipalities have been covered by fourth-order triangulation. This work is continuing in 12 more districts and four municipalities.

### *Levelling survey*

For the last four years, precise levelling traverse has been continued along the highways, district roads and feeder roads. Besides, repeated field observations, from the Indian border to connect Chinese border points via Kathmandu, have been completed recently; but the absolute calculations are not yet completed. After the completion of this work Indian datums can be compared with the Chinese. Furthermore six more datum stations have been established since the eleventh Cartographic Conference.

### *Gravity survey*

A considerable number of additional relative gravity stations have been established during the last four years. The gravity point at Tribhuvan International Airport in Kathmandu has already been connected with the gravity stations of Bangkok and Sri Lanka. There is a plan to connect it also with Delhi and/or Calcutta. Until now, there is no absolute gravity station. However, a plan will be implemented to observe three gravity points in the very near future in N-S direction (High Himalaya, Middle Mountain and Terai Plain).

### *Astronomical survey*

A geodetic observatory is situated at Nagarkot 35 km east of Kathmandu city, at an altitude of 2,163 m above mean sealevel. It is responsible for astro-geodetic works. Astronomical observations with star groupings have been carried out regularly. The fundamental benchmark of the levelling and the basic trigonometrical station of the national baseline have been established at Nagarkot observatory premises to tie up the trigonometrical network of the country. Just recently GPS observation is being done at Nagarkot base point.

### *Magnetic survey*

Magnetic survey observations were started two years ago. This work has to be geared to procuring more equipment and adding technical hands and expertise.

### *Crustal movement*

Studies of crustal movement have been carried out in some parts of the country. Data have been recorded and established by means of repeated geodetic levelling of the land-slide area of Swayambhu and Korkha region. A study has been performed of the main boundary fault zone of part of western Nepal.

### *Global Positioning System satellite survey*

Recently, for the first time, Global Positioning System (GPS) observations were carried out on three basic trig stations of the national baseline. A few GPS receivers have been procured. The work is continuing to expand the exist-

TABLE 1 PROGRESS ACHIEVED IN GEODETIC WORK: 1987-1990

| *Control Station* | *1986/87* | *1987/88* | *1988/89* | *1989/90* | *Overall from beginning* |
|---|---|---|---|---|---|
| Triangulations | | | | | |
| (second, third, fourth orders) | 7 677 | 7 480 | 8 197 | 5 437 | 1 21 723 |
| Precise levelling (km) | 260 | 400 | 271 | 158 | 4 693 |
| Datum stations | 1 | 1 | 2 | 2 | 8 |
| Gravity stations (relative) | — | 6 | 14 | 6 | 53 |
| Magnetic stations | — | — | 4 | 3 | 7 |
| Astronomical observation | | | | | |
| (star groups) | 197 | 201 | 163 | 124 | 2 106 |

Note: 7 Laplace stations, 14 azimuth, 17 Doppler and 68 first-order triangulation stations were established before the Eleventh Conference

ing triangulation network of one of the zones (Lumbini), adding 17 points with this GPS technique Besides, in 1991 there is a programme to establish some 20 GPS stations and 3 absolute gravity stations in different parts of the country with the help of a friendly country. The main objective of this GPS programme is to strengthen, supplement and expand the existing geodetic control network, to define rates of uplift and crustal shortening, to analyse horizontal and vertical motions and to interpret these in terms of seismic hazards in Nepal.

## CADASTRAL SURVEY

The main purpose of this survey is to prepare land-tax records. The function of the cadastral survey, as provided by the Land (Survey and Measurement) Act of 1964 is to measure every parcel of land outside forest, establish its area, classify it and identify the land-owner and tenant (cultivator). It is also responsible for the preparation of revised tax records and the certificates of land-ownership.

The Survey system adopted is graphical. Boundary demarcation of the parcels are featured by bends and furrows. Ground survey methods with the use of plane-table is preferred to the photogrammetric method for reasons such as availability of manpower, thick vegetation cover, mountain terrain and small size of parcels. The need for field visits for identification of land-owner and tenant, and the adjudication process, are other factors that make the ground method preferable. A cadastral map depicts only the ground floor. However, there is a provision in the Land (Survey and Measurement) Act to provide certificates of ownership to each floor-owner and even part of the floor by cross-reference to the parcel number of the map.

There is a felt need for a multipurpose cadastre system to be adopted in the near future, especially in the municipal area of the capital Kathmandu, where the revisional cadastral survey operation is going on at present. Owing to the high price and scarcity of land in the city area, people are experiencing a need for a multipurpose cadastre giving information about the physical, legal, economic and social aspects of land and showing drainage, water pipelines and such matters on the map.

The scale of the cadastral plan varies from 1:500 to 1:2,000, depending upon size of parcel and value of land. The scale of 1:500 is chosen for city and high built-up areas, 1:1,250 for less dense townships and 1:2,500 for open field areas.

### *Maintenance of cadastral plans*

Maintenance and updating of cadastral plans and records are done in connection with daily land transactions. The Maintenance Survey Section is attached to the district Revenue Office to update the parcel boundaries in the cadastral plans. Updating of internal details within the parcel boundaries (such as newly added buildings, roads etc.) is lacking. Old, cadastral plans, worn-out due to over-handling during transactions, will be replaced by new retracings in the course of time.

### *Microfilming*

The cadastral plans and field books (legal documents of ownership) remain in a bad state because of daily handling. Microfilming of these plans and documents was started a few years ago and this work has made some headway in preserving them. The Government of the Federal Republic of Germany had cooperated by providing instruments and equipment for microfilming of these valuable documents, but some of the equipment have gone out of order. These will be repaired or replaced, the necessary units provided by Germany.

### *Survey of village blocks*

In the course of cadastral survey in the area of the Terai Plain, 1964-1970, compact settlements (congested homestead areas) were postponed to be surveyed later on large-scale plans. These were demarcated on the then cadastral plans as village blocks and left vacant. Smallness in parcel size, high price of land, non-availability of scientific survey instruments, lack of trained manpower were the reasons they were left for work to follow. Survey of some of these village blocks was started two years ago on a large-scale plan of 1:500. This work is coordinated with the Department of Housing and Urban Development (HUD) under the Ministry of Housing and Physical Planning. The Survey Department prepares the cadastral plan (map), and this will be handed over to HUD. A physical improvement plan consisting of basic road, drainage and water pipeline network, open space, parking area, open market place, health centre, public toilet space, school area etc. will be prepared over the cadastral map by HUD with the primary objective of providing a physical expansion and improvement framework for village block development. This physically planned map will be returned to the Survey Department to prepare the final land record and ultimately to distribute land ownership certificates.

Cadastral Survey works of 60 out of 75 districts have so far been completed. The work is going on in 8 more districts. In the same way, 15 municipalities have been covered and 4 more are in progress. Besides, survey of village blocks (compact settlement areas) of three districts have been started.

TABLE 2 PROGRESS ACHIEVED IN CADASTRAL WORK: 1987-1990

| *Cadastral survey* | *1986/87* | *1987/88* | *1988/89* | *1989/90* | *Overall from beginning* |
|---|---|---|---|---|---|
| Survey (*hectares*) | 106 790 | 132 543 | 112 270 | 68 363 | 4 527 274 |
| District completed | 1 | 2 | 2 | 3 | 60 |
| Municipality completed | — | 1 | — | 1 | 15 |
| Plans retracted | 960 | 900 | 586 | 494 | |

TOPOGRAPHICAL SURVEY

The Topographical Survey Branch was established initially as a unit in 1972 and upgraded as a Branch in 1976. The main function of the Branch is to provide topographical survey services and land resources maps, data and information for all the agencies of government. The Branch has capabilities for production of aerial photographs, map compilation by field and photogrammetric survey methods, cartographic and map printing. Most of the capital equipment including stereoplotters, aerial camera, process camera, rectifier/enlarger and colour offset printing press were procured with the assistance of the United Nations Development Programme (UNDP) from 1976 to 1982.

*Bagmati area mapping*

Topographical mapping of the Bagmati River catchment area at scale 1:5,000 has been completed with the collaboration of Swiss Air Surveys. These maps are specially prepared for irrigation purposes and financed by UNDP.

*Lumbini zone mapping*

Topographical mapping of the Lumbini zone (9,000 sq km) at scale 1:25,000 was started with the help of the Government of Japan. Aerial photographs have been taken and the field survey is going on. The main purpose of this mapping is to prepare the basic topographical mapping series for various development projects.

*Screen printing*

Screen printing was started last year. For the first time, a map of Nepal at scale 1:1,500,000 was printed, as well as some topo-sheets at 1:50,000.

*Mapping of international boundary*

Revisional and up-to-date field survey and strip mapping of the international boundary between Nepal and China have been completed and the joint boundary protocol was signed by both countries in 1988. The Nepal-India boundary survey work is proceeding. Field survey and strip mapping of the riverine sector were prepared in the field by the joint survey teams of both countries. Some more years are needed to complete the joint boundary works.

LAND RESOURCES MAPPING

Various land resources maps, data and reports were prepared and published at the beginning of 1987 in order to provide basic information needed by planners to formulate policies on land use, determine priority areas for action and

TABLE 3 PROGRESS IN TOPOGRAPHICAL SURVEY SINCE 1987

| *Map* | *Scale* | *Sheets* | *Progress since 1987* | *Remarks* |
|---|---|---|---|---|
| 1 Nepal (English and Nepali) | 1:2 000 000 | 1 | Reprinted | 4 types |
| 2 Nepal (English) | 1:1 000 000 | 1 | Reprinted (3 times) | |
| 3 Regional Nepal (English and Nepali) | 1:500 000 | 8 | Reprinted (4 times) | 5 sheets |
| 4 Zonal Nepal (Nepali) | 1:250 000 | 15 | Reprinted (3 times) | |
| 5 Districts of Nepal (Nepali) | 1:125 000 | 75 | Printed<br>Reprinted | 40 sheets<br>35 sheets |
| 6 Topography | 1:50 000 | | Updated | |
| 7 Nepal (screen printing) | 1:500 000 | 1 | Sheet | 1st time |
| 8 Bagmati irrigation maps | 1:5 000 | 297 | 160 sheets | |
| 9 Census maps | 1:10 000<br>1:50 000 | 4 048 | 4 048 sheets<br>Sheets | Ammonia print |
| 10 City maps | 1:5 000<br>1:10 000 | 2 | Sheets | |
| 11 Topographical map Lumbini zone | 1:25 000 | 81 | Photography | Field survey started |
| 12 Aerial photography | 1:10 000-<br>1:50 000 | | 40 500 sq km | Reflow |
| 13 Large-scale (Town and project) | 1:2 500-<br>1:10 000 | | 1 060 sq km | Ammonia print |

TABLE 4 SALES OF MAPS AND AERIAL PHOTOGRAPHS, 1986-1990

| *Sheets* | *1986/87* | *1987/88* | *1988/89* | *1989/90* |
|---|---|---|---|---|
| Map sale (various scales) | 18 122 | 32 336 | 33 771 | 41 003 |
| Aerial photographs (various scales) | 6 581 | 6 708 | 3 864 | 2 237 |

TABLE 5 COURSES CONDUCTED AT THE TRAINING CENTRE AND PROGRESS ACHIEVED: 1986-1990

| *Training course* | *1986/87* | *1987/88* | *1988/89* | *1989/90* | *Overall from beginning* |
|---|---|---|---|---|---|
| 1. Basic Survey | 36 | 53 | 75 | — | 1 858 |
| 2. Junior Surveyor | 75 | 46 | 51 | 57 | 910 |
| 3. Senior Surveyor | 24 | 12 | — | 6 | 276 |
| 4. Special Courses | 19 | 23 | 17 | 10 | 199 |
| 5. Survey computation | 7 | 7 | 8 | — | 28 |

undertake physical planning in different economic regions and ecological zones. These maps and reports include land utilization (present land use), land system (soil) and land capability (potential) maps, each at scale 1:50,000, covering the whole country. Besides, geological, climatological and mineral maps are prepared at scales ranging from 1:125,000 to 1:1,000,000.

Updating, since the Eleventh Conference, of various land resources maps are as follows:

1987—28 sheets 1988—20 sheets
1989—11 sheets 1990—8 sheets

Advisory services have been offered to various agencies for resource map interpretation, data handling and map compilation. A project on soil fertility and erosion of the Jhiku Khola (river) watershed region has been started for monitoring surface erosion to study the overall impact of land-use changes in that region. Field data have been collected and preparation of draft final base maps are to be completed.

### GEOGRAPHICAL INFORMATION SYSTEMS

Establishment of GIS using Terr 8C program with digitizing tables, pen-plotters and UPS with computer 20 Mbyte hard disk has been started. Two persons have been trained abroad on GIS and six personnel have received in-house training. Resource evaluation data have been entered for the whole country, by district, for food, fuelwood and fodder balance, projected to the year 2000. GIS techniques have been used for the evaluation of a small watershed region on an experimental basis. There is a need to establish a land information system (LIS) with the data and information generated by large-scale cadastral plans and records.

### SURVEY EDUCATION AND TRAINING

The Survey Training Centre was established in 1968 with the objective of producing basic and medium-level technicians to fulfil the need for technical manpower of the various surveying and mapping organizations in and within the country. For the higher level technologists, it has to depend upon foreign academic institutions. The Training Centre imparts training and courses to departmental, extra-departmental and also fresh candidates. The basic entrance qualifications for various courses are S.L.C., I.Sc., B.Sc. in mathematics and M.A. in geography.

Special courses contain cartographic draughtsman, photogrammetric operators, geodetic observers and map reproduction technicians.

### REMOTE SENSING

The Nepal Remote Sensing Centre was established in 1981 under the Department of Soil and Watershed Management with the help of the United States Agency for International Development (USAID). It is now a branch of the Forest Resources Survey Division. The objective of the Centre is to bring multi-disciplinary scientists together for generating information necessary for national development and establishing data by interpretation of various satellite imageries.

The Centre has taken up a few study projects on watershed management, monitoring of deforestation, assessment of potential hazard and winter crop estimation. Collaboratively it has produced and published imagery maps of Nepal and some land-use maps of watershed river catchment areas.

### MAPPING SUBCOMMITTEE

A mapping subcommittee is established under the National Council for Science and Technology comprised of 13 members from concerned ministries, departments, organizations and the university. The main objectives of the subcommittee are to frame the mapping and surveying policy of the country, to produce necessary suggestions to the Government on cartographic activities, to coordinate map-making agencies and to instigate preparation of maps and surveys that are more scientific, reliable and accurate, conform to standard and permit aerial photography operations without duplication. It has published the *Economic Atlas of Nepal, Wall Map of Nepal, Map Inventory of Nepal* and *Index of Geographical Names of Nepal* (5 volumes, regional). A revised edition of the *Map Inventory* is under publication. It has permitted quite a number of aerial photography missions for development projects, including those operated by foreign teams.

### CONCLUSION

Nepal is a developing country. It has a multi-party system within a constitutional monarchy following the people's movement in the first quarter of 1990. Various development projects are under way in such areas as water resources, irrigation, dam construction, road alignment, rural development, forest and soil conservation, watershed management etc. All these need maps and data for planning and execution of the projects. If the necessary maps are readily available, development projects can be completed within the planned period of time.

To satisfy the increasing demands for maps for various projects, they must be supplied promptly on the one hand and on the other be accurate, reliable and up-to-date. Therefore, to fulfil the need for a national series of new basic maps, cartographic activities must be increased with internal resources as well as with bilateral and multilateral assistance.

# CARTOGRAPHIC ACTIVITIES IN NEW ZEALAND, 1987-1990*

*Paper submitted by New Zealand*

## RÉSUMÉ

Le présent rapport décrit les progrès réalisés en Nouvelle-Zélande dans le domaine cartographique entre 1987 et 1990, sous l'égide du nouveau Department of Survey and Land Information (DOSLI).

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### CARTOGRAPHIC ACTIVITIES OF THE NEW ZEALAND DEPARTMENT OF SURVEY AND LAND INFORMATION

The Department of Survey and Land Information (DOSLI) was formed in 1987 when the Department of Lands and Survey was disestablished. This occurred as part of a widespread government restructuring programme designed primarily to separate statutory and regulatory functions from potential and existing revenue-earning operations. Central government departments involved in the management of natural resources were also integrated through the restructuring programme to consolidate environmental management, policy development and monitoring. These reforms effectively removed conflicts of interest, allowed operational departments to resemble some aspects of private companies, and introduced a requirement to function according to cost recovery or user-pays principles. Several State-owned enterprises were created, some of which were subsequently sold in the Government's State Asset Sales programme, while essential service delivery agencies remained within the State sector.

The new Department is the principal government civil and military agency for surveys, mapping and land information. The current State sector environment demands the provision of quality products and services by the Department. Consequently, DOSLI has focused on anticipating and responding to government, local authority and private clients' needs, technological developments, and the changing requirements of New Zealand society.

These functions provide the basis for:

(*a*) Secure land tenure and property rights, the use and management of land-related resources;

(*b*) Support for the management and monitoring of the environment, communications, security, social, economic, commercial, administrative and government systems in New Zealand and extended as appropriate to the South Pacific and Antarctic regions;

(*c*) Assistance in the implementation of the Government's policies on indigenous peoples' land rights issues, as guaranteed by the Treaty of Waitangi, the devolution of service delivery functions to Iwi Authorities, and the transfer of land assets.

There is a responsibility to maintain several major national land record systems that are central to the maintenance of secure land tenure, security and safety, and for general national and public benefit from the carefully planned and sustainable use of land resources. These systems include the survey control and cadastral system; cadastral survey records and mapping; and basic topographic mapping

The Department is also required to administer or dispose of Crown land not allocated to a government or State-owned enterprise, and provide policy advice to the Government on land-related issues.

DOSLI is strongly decentralized, with 12 district offices and 4 sub-offices spread throughout the country. The organization is structured into four broad groups, encompassing data capture, database applications and statutory functions. Five specialist operational directorates provide cartographic, photogrammetric, geodetic computing, cadastral database services and statutory services within this framework. There are a number of supporting activities, such as computer support, map distribution, research and development etc.

In addition to DOSLI, two other government agencies carry out mapping and charting activities. These are the Science Mapping Unit of the Department of Scientific and Industrial Research and the Hydrographic Branch of the Royal New Zealand Navy.

The Science Mapping Unit (SMU) is responsible for the preparation and publication of geological, geophysical, oceanographic and soil survey maps. Hydrographic survey and charting activities are described in the last section of this report.

Mention was made in the last report of the mapping activities of the New Zealand Forest Service. That department ceased to exist in 1987 and its functions were taken up by other organizations, including DOSLI. Some forest mapping is still carried out in a limited form but the majority was discontinued. Records of all of the New Zealand Forest Service 1:10,000 orthophotography are held in DOSLI.

### THE LAND SURVEY SYSTEM

New Zealand enjoys the benefits of an integrated survey system that was introduced in 1876. This is achieved by:

(*a*) Relating every survey to one control system which provides the positional framework for all measurements;

(*b*) Standardizing procedures, accuracies and records;

(*c*) Providing a single source of administration through DOSLI and servicing of the survey industry by a professional body.

Cadastral surveys are defined and governed by the Survey Regulations, which are regularly reviewed to meet the changing needs of the land survey system and new technology. The two-plan system (survey and title) is being maintained, and retrieval of data is readily available through a microfilm system. With the ever-increasing use of sophisticated technology in computers and measuring equipment, survey methods and standards are constantly under investigation. All new survey data approved is recorded. This forms the basis for the publication of cadastral maps. Approximately 20,000 plans are added each year to the land

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survey records of the department. These surveys are predominantly undertaken by registered surveyors in private practice.

### *Triangulation and control surveys*

During the period covered by this report there has been a reduction in control survey activities. Nevertheless a number of important surveys have been completed in various parts of the country, notably Southland, Wairarapa, Taranaki and Waikato–Bay of Plenty. The triangulation surveys completed in this time have been largely confined to third-order densification and generally smaller in extent than in the past. Equipment such as the Wild DI-20, DI-3000, Rangemaster II and III, plus the Wild T2 theodolite supplemented with the T3 have been used.

A major triangulation survey involving 35 stations over the Ross Island–McMurdo Sound–Dry Valleys region in Antarctica was completed. This was undertaken as a cooperative project with the United States Geological Survey (USGS) and included horizontal and vertical observations, electronic distance measurement (EDM), transit satellite observations, astronomical observations and tide-gauge data. The resulting adjustment has defined the McMurdo Sound Geodetic Datum (1990), based on the WGS 84 spheroid.

The design of a geodetic records database and the transfer of all existing trig station and benchmark records from a manual system to a computerized database has been completed, involving 31,500 stations.

A small amount of precise levelling has been carried out in the 1987-1990 period. The connection between Canterbury and Westland via Arthurs' Pass and the Atiamuri-Putaruru section were completed. Work is proceeding between the Upper Wairau Valley and Hamner Springs. This job crosses several major alpine faults.

DOSLI purchased 6 dual-frequency Global Positioning System (GPS) receivings (ASHTECH XII) from 1989. These have been used with considerable success for photo control, cadastral control points, earth deformation studies and upgrading triangulation. The receivings have been deployed in the Antarctic where they were used for 1:50,000 mapping photo control.

Software has been developed and tested for kinematic GPS using helicopters and land vehicles. This enabled a 30 kilometre mean high-watermark line to be measured in a single day.

Assistance has been provided for several international GPS campaigns. These were:

Orbit determination pilot project: National Mapping, Australia, 1987

Central and South American GPS collaboration (CASA/UNO): NASA/JP (Jet Propulsion Laboratory) 1988

Global tracking experiment: JPL/United States National Geodetic Survey 1988.

(APEX) Asia Pacific Experiment (APEX): NASA/JPL, 1989

A Cooperative International GPS Network (CIGNET) station was established in Wellington in 1990, and is operated by the Department.

An analysis of historical records dating back to the turn of the century has shown a mean sea-level rise of 1.8mm ± 0.1 per year. This is now being confirmed elsewhere in the world. These gauges continue to be used for sea level monitoring.

The tide gauges have been established in the Ross Dependency, Antarctica. Comparisons with a gauge at Scott Base, established in 1958, indicated a mean sea-level rise of 0.11mm ± 0.08.

Negotiations are in progress with the U.S. National Oceanic and Atmospheric Administration (NOAA) over a proposal to establish two high accuracy tide recording stations in New Zealand as part of the Global Level of Sea Surface (GLOSS) programme. There is particular interest with respect to the southern ocean current.

### *Topographic mapping*

New Zealand has complete national coverage of basic topographic mapping. The published metric Infomap 260 series (1:50,000 with 20-metre contours) is available over the whole of the North Island and 66 per cent of the South. Some of the older 1:63,360 imperial mapping is still being used until the 1:50,000 is complete in 1994. Of the 320 sheets covering New Zealand, 260 have been printed and published and the balance are in various stages of production.

Photogrammetric production of the Infomap 260 series is nearing completion. The mapping has been captured by both digital (6 per cent) and graphical (94 per cent) means at a scale of 1:25,000. Four sheets are combined and reduced to make one 1:50,000. These provide the base material for all derived topographic mapping and are available as another series in their own right. They are supplied in plan print form as either separate contour or detail sheets or as a composite.

Owing to budgetary constraints revision of the 260 series has proceeded at a slower pace with six sheets being completed since 1975. More are planned for the next three years. Photogrammetry and field verification will be used in urban areas where large changes have occurred. Field methods alone will be employed in rural and undeveloped localities.

Other Infomap series, which fully cover New Zealand, are the Infomap 262 (1:250,000) and 242 (1:500,000). Full coverage of the imperial NZMS 1 (1:63,360) is available, but sheets are being withdrawn as they are superseded by the 1:50,000.

DOSLI undertakes a number of other major mapping activities. These include 12 sheets of 1:50,000 Antarctic mapping for the United States Geological Survey, the production of a large number of cross sections and profiles as well as the measurement of lower accuracy Crown forest cadastral boundaries by photogrammetric means.

A topographic database of the 1:250,000 series has been completed since the last United Nations Conference in 1987. Line drawings were scanned and converted into vector formats. The information has been structured into layers, networks and features. Attributes have been added to all features. Extra information, such as local authority boundaries, power distribution transmission lines etc. have been included. Further resource information may be added in the future. Full querying facilities are available.

Other small-scale topographic databases with different accuracies are under consideration. Some of the Pacific islands within New Zealand's administrative responsibility have been databased in the last three years. These include Tokelau, Cook, Campbell and Chathams Islands.

In 1988 GeoVision capture and edit stations were interfaced with analog stereoplotters. Their task is to create a topographic database, at a nominal scale of 1:500, of the physical locations of all ground features in Wellington City. The data is to be used for utility management purposes and town planning activities. Edit stations were purchased to enhance the quality of data, add attribute information and form a seamless database.

In the last three years 10 per cent of the country has been covered by a 100-metre digital terrain model (DTM). These are predominantly located over the main communication routes through the North Island and the east coast of the South Island. Coverage is being extended as demand requires.

A number of applications have been developed for DTMs and digital topography. These range from perspective simulations to slope analysis. Digital mapping techniques have been applied to the measurement of historic buildings, as built, plans of railway locomotives and the location of cracks in the beds of water storage reservoirs.

### *Orthophotography*

Orthophotography is produced on a demand basis for government, local authorities and private sector clients. It is used for a number of purposes, such as mining activities, flood control, city management, forestry and farming operations. Orthophotography is normally produced from DTMs, as are any overlaid contours. A major new orthophoto product has been developed and will be produced as clients require. This will enable orthophoto images to be used as an information layer in a geographic information system.

### *Aerial photography*

The Department's ability to sequentially cover New Zealand with 1:25,000 aerial photography has been reduced in recent years through financial limitations. However some key areas where only outdated photography was available have been reflown in conjunction with the map revision programme. The Department maintains a National Photo Library which holds most Crown and some private copyright photography. This is becoming an increasingly valuable resource for historic comparisons of land use. A computerized aerial photo index system has been developed.

### *Remote sensing*

Software was purchased in 1989 to enable photogrammetric restitution from stereoscopic SPOT imagery. Promising results were obtained but there was a degree of uncertainty about the cost-effectiveness in comparison with standard aerial photography. A number of tests have been carried out which include comparing a 100m DTM measured from SPOT with a corresponding one from aerial photos. Auto-matching techniques have also been tested.

Stereo SPOT has been obtained over the Dry Valley region in Antarctica to extend the 1:50,000 50 m contour mapping being undertaken for the United States Geological Survey. Some technical difficulties are presently being encountered with the convergence of the orbits and the limitations of the analytical stereoplotter to compensate for them.

### *Aeronautical charts*

Separate publications are produced and maintained on a monthly basis according to civilian and military requirements for instrument, visual and military (Royal New Zealand Air Force) chart supplements, also a South Pacific Flight Guide. The thrust towards integration and economical joint civil/military charting has continued.

Visual terminal and en-route charts at 1:250,000, 1:500,000 and 1:1,000,000 have been revised at 18-month intervals. En-route and area charts have been revised at 6-month intervals. Plotting charts at scales of 1:1,000,000 and 1:2,000,000 (New Zealand) and 1:3,000,000 and 1:6,000,000 (Pacific) are revised when required.

A special designed series of 18 charts at 1:250,000 has been produced, based on the topographic map series of the same scale, for both civilian and military use.

The digital data bank of aeronautical information is being maintained and is now an essential part of the totally automated production of aeronautical charts. Digital maps are generated and updated for radar control centres.

### *Tourist and recreational maps*

Currently produced are 37 maps showing national parks, forest parks and tourist areas at scales of between 1:40,000 and 1:250,000. The forest park maps were previously produced by the now disbanded New Zealand Forest Service. The maps vary in format to suit the area of interest and to highlight recreational information.

### *Resource mapping*

This mapping was described in the 1984-1987 report. Since then 170 land inventory maps at a scale of 1:100,000 have been printed. No further production is contemplated for the foreseeable future.

### *General purpose and special maps*

1:25,000 mapping of the South West Pacific and New Zealand's Sub-Antarctic Islands is continuing and will be completed as the preparatory work becomes available.

A series of climatic maps has been produced for the NZ Meteorological Service. The Robinson Projection is being used to produce a new map of the world. Nomenclature will be based on the donor principle.

### *Cadastral mapping*

New Zealand has complete national coverage at a scale of 1:50,000 as a complementary map to its topographical series at the same scale.

There is also complete large-scale map coverage. These are known as Cadastral Record Maps and are produced at scales suited to the density of boundaries, appellation, area, subdivisional plan references and other relevant information. They are updated on a daily basis on approval of subdivisional plans required by statute to be submitted to the department for custody and guarantee of title definition. The record maps are drawn to a format which is a subdivision of the published 1:50,000 cadastral map series and are used in the production of that series as well as other cadastral themes on various published maps or products. Approximately 18,000 record maps are in use nationwide graphically representing 2,500,000 land parcels and associated descriptive information. Over 30,000 new land parcels are created each year, which have also to be depicted.

In 1986 the Department commenced the conversion of its cadastral record map series to digital form. Known as the DCDB (Digital Cadastral Data Base) its objectives are:

(*a*) To provide a spatial framework for LINZ (Land Information New Zealand) core developments;

(*b*) To provide an information system for use within the Department with efficiencies in access, distribution and maintenance over existing manual systems;

(*c*) To provide integration with other related datasets and outputs for the LIS/GIS community.

To date (December 1990) 1,066,000 parcel polygons or 42 per cent of the estimated 2.5 million parcel polygons have been captured. Complete national coverage is planned for December 1992. The computer system is based on software by GeoVision of Canada residential Digital Equipment Corporation hardware.

### *Electoral mapping*

New Zealand also has complete national coverage of urban and rural Electoral Record Maps showing meshblock statutory and administrative boundaries. Meshblocks are the smallest geographic collection areas used for the Census of Population and Dwellings and other surveys. Meshblock boundaries usually follow cadastral boundaries or physical features and form the basic building blocks of other statutory or administrative district boundaries such as those used for local and national elections.

These maps are also at present being converted to digital form and will be marketed jointly by DOSLI and the Department of Statistics as a product called SMA (Socio-economic Area Mapping). By digitizing the meshblocks and integrating a wide range of statistical information held about each area, detailed socio-economic, demographic and market analysis can be derived.

To date 50 per cent of the estimated 35,000 meshblock polygons have been converted. Completed national coverage is planned for November 1991.

A computerized textual Authoritative Streets and Places Index has been developed and is updated on a daily basis to support the above mapping and other electoral activities.

### *Overseas aid*

New Zealand has a close and long-standing involvement with its neighbour countries of the South Pacific and South East Asia. It has been active in many areas in providing survey and mapping aid to these countries through short- and long-term secondment of New Zealand personnel, training overseas staff within New Zealand and providing expertise for aid investigations. This support has continued at a high level for the last three years.

A pilot land information system has been demonstrated to the Government of Fiji. Further developments are likely in 1991. Discussions have been held with a Government agency in the Solomon Islands to determine ways to improve their survey and mapping capabilities. A land titling surveyor is currently working in Niue for a period of two years. The Government of Western Samoa has been provided with an integration surveyor and a survey draughting officer since 1988. An extensive aerial survey of hurricane-damaged areas was carried out in mid-1990.

Numerous international delegations have travelled to New Zealand in the last three years to gain a first-hand look at the Department's activities. These have included representatives from Thailand, the Philippines, Indonesia, the Soviet Union, Samoa, Fiji, Niue, Vanuatu, China and many others.

## Department of Scientific and Industrial Research

Considerable organizational change has taken place within the Department of Scientific and Industrial Research (DSIR) since the last report to this Conference in early 1987. The first with a major impact was the Government's requirements for departments such as DSIR to become more cost recoverable. To this end, the Science Mapping Unit was required to be 100 per cent cost recoverable from 1 April 1987, contracting for work both within DSIR and on the commercial market. There was no obligation on other DSIR divisions to use the Unit's services. This requirement caused a halt in R & D work and a swing towards competition on the open market for scientific graphics, cartographic and photolithographic work.

Cost recovery has also had considerable impact on the number of maps being published by DSIR divisions. During the period, staff numbers have been allowed to decline by natural attrition from 22 to 10, to reflect the downturn in workflow. Geological, geophysical and oceanographic maps are still being published, although in fewer numbers than previously. However most geological maps are now drawn and printed in Australia, as the Science Mapping Unit's level of overhead means it cannot bid successfully for this type of work. Soil maps are no longer being published. Instead the information is being used to build a GIS of land resource data. The information will be sold to individual clients.

Many of the conventionally published maps during the period have been produced by computer generating the linework, marginal text and layout, and using conventional masking and photolithographic screening to prepare colour area infills. This method has saved the expense of off-site computer processing and has assisted in keeping staff fully employed.

In April 1990, DSIR underwent a department-wide restructuring which resulted in the previous 23 divisions and 7 stand-alone units, (such as the Science Mapping Unit), being amalgamated into 10 major divisions. The Unit became part of DSIR Land Resources (along with the former Soils, Ecology and Botany divisions). The Unit was shifted from Wellington to the DSIR Taita campus (some 20 km north of Wellington) in June 1990.

The mapping thrust of DSIR Land Resources is the building of a GIS to service client requirements in the wider land resource area. A considerable amount of expertise is available, and the cartographers from the Unit will be fully involved. Recently more use has been made of digital scanning for bulk data capture. When compared to hand digitizing, it has been found expedient to produce "clean" linework with technical pens on draughting foil and have this copy scanned to produce computer files.

With the recent change of Government in New Zealand, there has been another major change in science policy. DSIR and other public-sector science organizations will cease to be departments of State. Instead, research and development will be carried out by a yet undetermined number of Crown-owned institutions which will come into being on 1 July 1992. These will concentrate on special government-funded priorities rather than on commercial, revenue-earning tasks.

## Hydrographic Activities

The area of operations for the Hydrographic Service of the Royal New Zealand Navy encompasses New Zealand's harbour and coastal waters, its offshore islands and the surrounding coastal area. The latter includes that area of the South Pacific in which New Zealand has a responsibility under bilateral charting arrangements with the United Kingdom/Australia and the International Hydrographic Organization (IHO). Within this area it fulfils the following:

(*a*) Conduct and quality control of hydrographic surveys for defence and charting purposes and the maintenance of the national hydrographic archives;

(*b*) Production, quality assurance, correction, distribution and maintenance of stocks of navigational charts and publications;

(*c*) Provision of weekly and annual editions of Notices to Mariners and promulgation of long-range Navigation

Warnings (for an internationally agreed area of the South Pacific (NAVAREA XIV);

(*d*) Provision of tidal data and maintenance of national tidal archives;

(*e*) Collection and publication of random sounding data from international sources as part of the International Hydrographic Organization's General Bathymetric Chart of the Oceans;

(*f*) Recording and preparation of definitive charts showing base-lines, territorial waters, fishing zones and exclusive economic zones.

The major survey unit is HMNZS Monowai (3,900 tons displacement). This vessel has the full range of coastal and ocean surveying equipment, with automated data logging and plotting facilities, the capacity for the collection of selected geophysical data, coring current and temperature measurements and underwater photography.

Since the last Conference, the *Monowai* has surveyed approximately half of a large area on the east coast of New Zealand, the last area on this coast not yet surveyed by the Navy, and completed large-scale surveys of Poverty Ban and Port Taranaki. A large-scale survey of the Bay of Islands, expected to take several years, had been commenced in 1989 and was to conduct a large-scale survey at Aliepata on the south-east coast of Western Samoa. However, persistent strong winds prevented work from progressing within the allotted time. A large-scale survey of the northern shore of Rarotonga, including Avatiu and Avarua harbours, was carried out in July 1990.

The two Inshore Survey Craft HMNZ *Tarapunga* and *Takapu* (24 tons displacement) have completed some small surveys in the Haukaki Gulf and several surveys in the Marlborough Sounds. The *Tarapunga* carried out a sketch survey of the Kerikeri inlet and river and assisted in the survey of Port Taranaki. The *Tarapunga*'s Officer in Command and leading hydrographic assistant carried out clearance surveys of two harbours and hydrographic assessment of a third in Western Samoa in the wake of cyclone "Ofa".

A new Hydrographic Automated Data Logging and Processing System (HADLAPS) is being developed to replace the old HYDROPLOT system and will be fitted in the ship's boats as well as in the ships themselves.

Chart production has centred around the reschemed 1:200,000 coastal series. A new chart of Cook Strait necessitated changes to limits of seven charts in the area from East Cape and Cape Egmont to Banks Peninsula. Improved coverage of the approaches to Otago Harbour has been achieved with the publication of 1:100,000-scale chart. New charts of New Zealand's sub-Antarctic islands are being compiled and new charts of the Cook Islands are planned. A New Zealand edition of *INT 1 Symbols, Abbreviations, and Terms Used on Charts*, originally produced by the Deutsches Hydrographisches Institut for the IHO has been published.

Two officers of the Royal Malaysian Navy have been given a six-month course in basic cartography, another will receive training in early 1991.

The Notices to Mariners service has been maintained, expert advice has been provided to the Crown, government departments and the general public with respect to nautical charting, maritime boundary delimitation and other related professional matters.

New Zealand input to the Sea-Level Pilot Project of the Integrated Global Ocean Station System (IGOSS) has been maintained in addition to routine analysis predictions.

## SURVEYING AND MAPPING IN THE PHILIPPINES, 1986-1990*

*Paper submitted by the Philippines*

### RÉSUMÉ

Jusqu'à ces derniers temps, les activités hydrographiques du pays étaient à la charge de l'ex-Bureau d'hydrographie et de géodésie relevant du Ministère de la défense. En 1987, dans le cadre de la réorganisation générale de l'administration, cet organisme a été fusionné avec trois autres bureaux de cartographie pour former le Service national de cartographie et d'information sur les ressources, rattaché au Ministère de l'environnement et des ressources nationales. Ce service gère quatre départements d'exécution, dont le Département d'hydrographie et de géodésie qui est actuellement chargé de tous les projets hydrographiques dans le pays. Ce département, qui a à sa tête un directeur assisté de deux directeurs adjoints, se compose de quatre divisions d'exécution: la Division de géodésie, la Division d'hydrographie, la Division d'océanographie et la Division des opérations de levé. Il compte au total 357 personnes réparties en un corps d'officiers et d'appelés chargé des levés sur le terrain et un groupe civil chargé de traiter les données dans les bureaux.

Les principales fonctions du Département d'hydrographie et de géodésie sont les suivantes : formuler, planifier et exécuter des travaux concernant la topographie, l'océanographie, le magnétisme et la gravité; et rédiger des cartes marines, des ouvrages à l'intention des pilotes côtiers, des avis pour les navigateurs, des tableaux de prévision des marées et des courants, des catalogues concernant les opérations planimétriques et de nivellement, ainsi que d'autres publications analogues.

Dans le cadre de sa mission, le Département gère les équipements suivants : une petite flotte de trois navires hydrographiques comprenant l'*Atyimba* (686 tonnes), l'*Arlunya* (250 tonnes) et l'*Arinya* (250 tonnes); 10 observatoires principaux de la marée, y compris les 4 créés récemment dans le cadre du projet régional ANASE/Australie d'étude des marées et

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des phénomènes de marée; un observatoire magnétique; un centre national de données océanographiques; et une banque de données géodésiques.

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Until recently hydrographic activities in the Philippines were a function of the former Bureau of Coast and Geodetic Survey (BGGS), a line Bureau under the Defense Department. Starting in 1987, with the implementation of massive government reorganization, this agency was merged with three other government mapping offices to form the National Mapping and Resource Information Authority (NAMRIA), an attached agency of the Department of Environment and National Resources. NAMRIA has four line departments under it, one of which is the Coast and Geodetic Survey Department, which is currently charged with the handling of all hydrographic projects in the country. This Department is headed by a director aided by two assistant directors, and consists of four line divisions: Geodetic Division, Hydrographic Division, Oceanographic Division and the Survey Operation Division. It has a total manpower of 357 composed of a commissioned and enlisted corps who attend to field survey operations and a civilian group that takes care of office data processing.

The basic functions of the Coast and Geodetic Survey Department are as follows:

(*a*) Formulation/planning and execution of geodetic, topographic, oceanographic, magnetic and gravity surveys;

(*b*) Production of nautical charts, coast pilot books, Notices to Mariners, Tide and Current Prediction Table;

(*c*) Horizontal and vertical control catalog and related publications.

As the country's hydrographic entity, NAMRIA operates and maintains the following assets and installations in connection with its mandate:

(*a*) A small fleet of three hydrographic survey vessels consisting of Atyimba (686 tons), Arlunya (250 tons), and Arinya (250 tons);

(*b*) Ten (10) primary tide stations, including the four stations established recently in connection with the regional project "ASEAN-Australia Tides and Tidal Phenomena";

(*c*) A magnetic observatory;

(*d*) A national oceanographic data centre;

(*e*) A geodetic data bank.

### Hydrographic activities

During the last five years the former BCGS, now NAMRIA, continues to undertake the hydrographic surveys of the various Philippine waters, confining itself mostly to ports/harbours, rivers and lately congested sea-lanes in the aftermath of a series of maritime accidents. Inclusion of rivers were either for dredging, or for studies of pollution or other environmental concerns (see annex I).

Efforts to improve productivity by way of introducing new instruments and equipment have been made. This year, NAMRIA acquired the following: a Syledis positioning system; a side-scan sonar; a multibeam echo-sounder; trisponder, salinometer and some computers, courtesy of the Japanese International Cooperation Agency (JICA); and some minor equipment.

Relevant to hydrographic activities, another JICA expert is assisting the country in the drafting of new Hydrographic/Oceanographic Survey rules and regulations. It is expected that, with the subsequent enactment into law of these rules, involvement and utilization of surveys conducted by other agencies, both government and private will be enhanced.

As mentioned earlier, NAMRIA's attention will be focused in the coming years on hydrography of congested sea-lanes without affecting surveys of ports/harbours throughout the country. Areas most likely to be sacrificed with this development is the survey of coastal waters including the EEZ, which will have to wait if no outside assistance can be found. There are 63 identified sea-lanes in the country, the majority of which needed introduction of traffic separation schemes to safeguard marine travel.

#### *Nautical chart production*

Production and reproduction of nautical charts continue to be a major undertaking, giving special emphasis on the revision of existing charts. Metrication is being done particularly on old charts being revised, although at a slower pace. During the period under review, there were 17 revised/metricated charts and three new charts published (see annex II).

One significant feature in the construction of new charts in NAMRIA is the gradual shift to the use of International Hydrographic Organization (IHO) chart specifications away from the United States chart standards, which, until recently, was the only system being employed. IHO format and symbols are now making their initial appearances in newly published charts of NAMRIA. The use of buff (or yellow) for land, blue for waters, magenta for compass roses and restricted areas and black for other planimetric details are now standard practice. Later on, newly revised charts will be mostly in five-colour format, adding more important information such as source diagrams and reliability diagram, information on amount of coordinate shift for vessels using GPS, traffic separation schemes and others.

#### *Computer-assisted charting*

The use of personal computers in the processing of hydrographic data was introduced by a JICA expert several years back. The system made use of a NEC PC9801 VM computers, a graphic digitizer (KD 4300) and a IWATSU personal plotter (SR 660Z). Since then, moderate improvements have been made by the succeeding JICA experts with the addition of new computers and a larger format flat-bed plotter. Writing of new software to reflect the various positioning systems being used by NAMRIA field parties was also introduced.

Overall, the application of computer in hydrographic data processing has made remarkable strides and contributes immensely to the reduction of backlog in unprocessed field sheets piling up in archives.

#### *Notices to Mariners/Radio Navigational Warnings*

The flaws in the publication and dissemination of the Notices to Mariners and the promulgation of Radio Navigational Warnings were noticed in the aftermath of the series of sea disasters that the Philippines experienced in recent years. Prior to these, there have been reports of ships grounding or ships damaged by sunken wrecks especially in busy harbours like Cebu several days after the visit of strong typhoons which caused the sinking of some ships in the area. Obviously, the fault lies partly in the passiveness and indifference of local shipping companies or ship masters of local vessels who do not bother to report promptly to the proper authorities incidents of such sinking. In fact, the "I don't care attitude" as regards acquiring the fortnightly publication of Notices to Mariners seems to be prevalent among the local maritime communities.

The assignment of a JICA expert on Notice to Mariners aims to identify causes and correct those situations. While the long-term solution would be tied up to the result of the March 1990 Maritime International Cooperation Center of Japan (or MICC) report, which were supported by an inter-agency committee on maritime affairs in the Philippines, a short-term programme would have to be devised and made operational in the interim to help prevent similar sea accidents in the immediate future.

Relevant to the above, a revised edition of the List of Lights, published by NAMRIA, will soon be issued. Moreover, revision work is proceeding in earnest for the two-volume Coast Pilot publication, which was last revised in 1967.

## Oceanographic activities

Because of the absence of a new or seaworthy vessel capable of venturing far offshore, the oceanographic activities of the country may be said to be in hiatus. Although oceanographic programmes have been drawn up, implementation will have to wait until a seaworthy oceanographic vessel becomes available, apart from occasional inter-agency cruises utilizing ships of other government entities, like for instance the one in the Kalayaan I group, where NAMRIA was able to establish a tide station on one of the offshore islets and conduct some BT observations along the ship's track.

### *Tidal observations*

Participation in the regional project "ASEAN-Australia Tides and Tidal Phenomena" enabled the country to increase the existing primary tide stations from the original 6 to 10. The additional stations are those in Port Irene, Cagayan; San José, Mindoro; Puerto Princesa, Palawan; and Surigao City, Surigao del Norte. Old stations are those in Jolo, Sulu; Cebu City, Cebu; Legaspi City, Albay; Davao City; San Fernando, La Union and Manila. Later, it is envisioned to add another two to be situated in Baler, Quezon, and another possibly along the east coast of Samar.

Processing of data obtained from the above stations for the purpose of publishing the annual Tide and Current Prediction Table continue to improve with the application of systems acquired from the regional project, as well as innovations introduced with the acquisition of new computers for the tasks. At present, NAMRIA is utilizing two sets of IBM computers with 640 K memory capacity, math co-processor, printers and video monitors for the processing of tidal data.

### *National Oceanographic Data Center*

Another significant undertaking started recently was the creation of the National Oceanographic Data Center. To this end, JICA experts have been contributing expertise and equipment for its operation. The Center makes use of two NEC computers with 640 K memory, 2″ × 5.25″ disk drivers, 40 MB hard disk, math co-processor and printer for its tasks of collating and disseminating oceanic information to interested users.

The country also maintains/updates the General Bathymetric Chart of the Ocean (GEBCO) as its contribution to IHO efforts to provide oceanic information to the maritime community.

## Geodetic and other activity

The provision of adequate geodetic control for the purpose of undertaking hydrography of any area is a well known fact. The existing old network of second order accuracy covering the Philippine archipelago is mostly located along or near the coastline and established primarily for hydrographic charting.

In 1980, an ambitious project was launched designed to establish a nationwide first-order geodetic control network with the use of the Global Positioning System (GPS). Executed through an Australian bilateral assistance programme for the Natural Resources Management Development Project (NRMDP), it seeks to establish 210 first-order geodetic control stations and 200 secondary and tertiary control points over a period of two and a half years. Moreover, short-term tidal observations on 25 pre-selected places all over the country are being made to upgrade the accuracy of tidal predictions. The completion of this project is expected to hasten topographic mapping as well as hydrographic charting and location of many outlying islands/islets, which are difficult to chart accurately using conventional systems.

## Personnel development

Training, particularly of technical personnel, has been a continuing concern. With the drying up of assistance in this field from traditional donor countries, the bulk of foreign training assistance is now provided by Japan. The natural consequence is the gradual introduction of Japanese systems and replacement of the heretofore survey methodology and standards borrowed from the United States. This has benefited the country owing to the much closer location and landscape of Japan and the Philippines.

In addition, local training is being conducted with the aim of keeping technical personnel in step with development in mapping and charting.

## Conclusion

The series of disasters and tragedies the Philippines experienced last year inadvertently became NAMRIA's allies in bringing to the attention of the national leadership the importance of its work. The M.T. Victor/Dona Paz tragedy that caused the death of over 3,000 passengers brought into focus the Government's lack of resources in the maritime sector, including hydrographic charting. There are now urgent efforts to improve sea travel, including hydrographic charting and designation of traffic separation schemes in congested sealanes. Sea communications and the installation of government-designated radio stations to cater to the promulgation of radio navigational warning, metrological broadcasts and other forms of information have become high on the agenda.

Even the 16 July earthquake in Luzon, which left a number of cities and towns in the area in shambles, necessitated the participation of NAMRIA in the reconstruction efforts. The sudden flooding of coastal towns, ground subsidence in many areas and the need to put up earthquake monitoring stations along identified fault lines became NAMRIA's concern.

To be fair, even prior to these tragedies, the Government through the former BCGS, and now NAMRIA, did its best not to be remiss in the conduct of its official mandates, as evidenced by the activities enumerated earlier. But the Government has been beset with other priority concerns that need immediate attention, and the country's financial resources can only go so far.

## ANNEX I

**Hydrographic surveys undertaken 1986-1990**

*Ports/Harbour surveys*(16)

Port of Ozamiz and Approaches, Misamis Occidental
Cebu Harbour
Port Bulan, Sorsogon
Manila International Container Port
Port of Baybay, Leyte
Port of Talibon, Bohol
Port of Jagna, Bohol
Phil-Sinter Corp Pier, N. Mindanao
San José Harbour, Mindoro Occidental
Manila Bay Reclamation Area
Port of Capiz
Port of Romblon
Port of Calapan, Oriental Mindoro
Ormoc Bay, Leyte
Portion of Manila Bay, from Cavite City to Ternate

*Rivers*(2)

Pasig River
Navotas-Malabon-Tenejeros-Tullahan Rivers

*Sea lane*(3)

Surigao Strain/Hinatuan Passage
Romblon Pass
Verde Island Passage

## ANNEX II

**Nautical chart production**

| | | |
|---|---|---|
| *Revised/Metricated charts* | | |
| Chart | 4203 | Philippine, Western Part, 1:515,000 |
| | 4208 | Vigan to San Fernando, 1:100,000 |
| | 4220 | San Bernardino Strait and Samar, 1:100,000 |
| | 4222 | Lagonoy Gulf to Lamit Bay, 1:100,000 |
| | 4227 | Digollorin Bay to Dingalan Bay, 1:200,000 |
| | 4309 | Baladao Strait, 1:200,000 |
| | 4323 | Maianao Island to Hariz, 1:100,000 |
| | 4415 | Southwestern Panay, 1:100,000 |
| | 4423 | Southern Part of Samar and San Pedro |
| | 4427 | East Coast of Cebu, 1:100,000 |
| | 4420 | Calbayog to Tacloban, 1:100,000 |
| | 4428 | Northern Part of Tanon Strait, 1:100,000 |
| | 4429 | Western Bohol, 1:100,000 |
| | 4430 | Tanon Strait, Southern Part, 1:100,000 |
| | 4457 | Biliran Strait, 1:10,000 |
| | 4466A | Refutio Pass, 1:5,000 |
| | 4463 | Escalante Harbor and Vicinity, 1:20,000 |
| *New Charts* | | |
| Chart | 4429A | Port of Tagbilaran, 1:7,500 |
| | 4320 | Table Port to Bahia Honda Port, 1:100,000 |
| | 4322 | Bahia Port to Maiahibay Bay, 1:100,000 |
| *In Process (Revision/Metrication)* | | |
| Chart | 4315 | Palawan to Culion Island including Linapacan Strait, 1:100,000 |
| | 4319 | Green Island Bay and Vicinity, 1:100,000 |
| | 4414 | Northwestern Panay, 1:100,000 |
| | 4495 | Visayas Sea, 1:200,000 |
| | 4415 | Jolo and Tapal Islands, 1:100,000 |

# MAPPING IN KOREA*

*Paper submitted by the Republic of Korea*

## RÉSUMÉ

Les activités cartographiques de la Corée se divisent en trois grandes catégories : établissement de fonds de cartes nationales, cartographie marine et cartographie commerciale.

Les fonds de cartes nationales sont élaborées par l'Institut géographique national (IGN) du Ministère de la construction, à des échelles diverses : 1/5 000, 1/10 000, 1/25 000, 1/50 000, 1/250 000, 1/500 000 et 1/1 000 000.

Les cartes marines sont réalisées par l'Office des affaires hydrographiques du Ministère des transports, à des échelles allant de 1/5 000 à 1/500 000. Elles servent aux administrations portuaires et à la navigation.

Sauf celles qui sont produites par l'IGN, les cartes destinées à des utilisations particulières, telles que les cartes touristiques, routières, etc., sont réalisées par des entreprises privées à partir des fonds de cartes de l'IGN.

L'IGN révise les cartes existantes tous les deux, quatre ou huit ans selon qu'elles portent sur des régions urbaines, rurales ou montagneuses. Il a publié la première édition de l'*Atlas national de la Corée*, comportant 78 rubriques, et il devrait achever en 1991 cet ouvrage qui comprendra alors 134 rubriques.

Pour la cartographie assistée par ordinateur et la création de systèmes d'information géographique, il a mis en place un système informatique en 1989 et réalisé quelques travaux expérimentaux en 1990.

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Il prévoit d'achever prochainement la production des cartes à 1/5 000 et 1/10 000, de renforcer en permanence le réseau géodésique national et de mettre en place un système efficace de cartographie assistée par ordinateur afin de créer et réviser des cartes et des bases de données topographiques.

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The entire Korean territory is a peninsula, located at 33° to 43° north latitude and 124° to 132° east longitude. It has a total area of 221,000 square kilometres. As the country is divided into northern and southern national entities, the Government of the Republic of Korea is concerned with maps covering about 100,000 sq km of the southern part of the peninsula.

Since 1960, the Government has developed industrial sites through reclamation of seashores, thus extending its land area in line with its industrialization policy. The increase of industrial plants has demanded such social and capital overhead as ports and railways, and, accordingly, there has been not only an increase in the annual demand for maps at various scales, but also in the need for current revision of old maps.

The National Geography Institute (NGI) has formulated a precise triangulation network as the framework for accurate national base mapping. Levelling, astronomical observations, and magnetic and satellite geodetic surveys are being carried out. The NGI is also establishing a database for topographical information on the national territory for the purpose of providing rapid information, and enhancing the accuracy of mapping and efficient revision.

### Mapping organizations

Mapping activities in Korea can be roughly divided into two parts, national base mapping and nautical charting. They are the responsibility of the following organizations:

(*a*) National base maps are produced by NGI at scales 1:5,000 to 1:1,000,000, and are used for public and civilian purposes. The present status of revision of the 1:25,000 scale map is shown in figure I.

(*b*) Nautical charts are compiled by the Office of Hydrographic Affairs of the Ministry of Transportation, at scale 1:5,000 to 1:500,000. They are used for harbour administration and navigation;

(*c*) Besides those produced by the NGI, maps are issued for specific purposes, such as the regional map, the tourist map and the road map which are made by commercial firms using the NGI's base map.

Table 1. Present status of territorial increase
(Square kilometres)

| *1987* | *1988* | *1989* | *1990* |
|---|---|---|---|
| 99 222 | 99 236 | 99 263 | Ongoing |

Table 2. Maps printed by the NGI
(1,000 sheets)

| *Scale* | *1987* | *1988* | *1989* | *1990* |
|---|---|---|---|---|
| 1:5,000 | 121 | 163 | 223 | 158 |
| 1:25,000 | 377 | 826 | 501 | 802 |
| 1:50,000 | 510 | 731 | 751 | 777 |
| 1:250,000 | 25 | 24 | – | 16 |

### Mapping activities

#### *National Geography Institute*

The NGI periodically revises maps already produced, such as the national base map at scale 1:25,000; the topographic map at scale 1:50,000; maps at scales 1:250,000, 1:500,000 and 1:1,000,000; and the land-use map at scale 1:25,000. Among these, the maps at scales 1:25,000 and 1:50,000 are being revised at 2-, 4- and 8-year intervals periodically, according to region, and whether they are urban, rural or other kind of area. Other maps are also being revised because of changes in topographic and planimetric features. Revision of the maps at scales 1:25,000 and 1:50,000 is shown in table 5.

Large-scale maps of 1:5,000 have been produced since 1975, and are mostly up to date except for parts of the mountainous regions for which maps are rarely used. The rest of the mapping is being expedited to be completed in the year 1992, and the already produced maps are being revised at the same time. In addition, on the basis of that, the map on scale 1:10,000 is now being made, and the present status of mapping at scale 1:5,000 and 1:10,000 is shown in table 6.

#### *Coastal sea area Map*

The Republic of Korea, being located on a peninsula, is surrounded by sea on three sides. Its eastern coastal area is mostly composed of rockwall owing to deep water and high waves, while its southern and western coastal area forms a

Table 3. Maps printed by the Office of Hydrographic Affairs, Ministry of Transportation
(*Number of sheets*)

| *Item* | *1987* | *1988* | *1989* | *1990* |
|---|---|---|---|---|
| Nautical chart | 68 400 | 15 400 | 48 350 | 50 150 |

Table 4. Specific maps printed by commerical firms
(*Number of sheets*)

| *Item* | *1987* | *1988* | *1989* | *1990* |
|---|---|---|---|---|
| Tourist map and others | 2 915 850 | 8 452 320 | 3 819 000 | 2 212 202 |

Table 5. Revision of maps of 1:25,000 and 1:50,000
(*Number of sheets*)

| *Item/Description* | *1987* | *1988* | *1989* | *1990* |
|---|---|---|---|---|
| 1:25 000 | | | | |
| Revision | 90 | 83 | 83 | 94 |
| Recompilation | 16 | 16 | 20 | 16 |
| 1:50 000 | | | | |
| Revision | 33 | 23 | 22 | 26 |
| Recompilation | 4 | 4 | 6 | 4 |

Figure I. 1:25,000 topographical map revision and recompilation since 1987

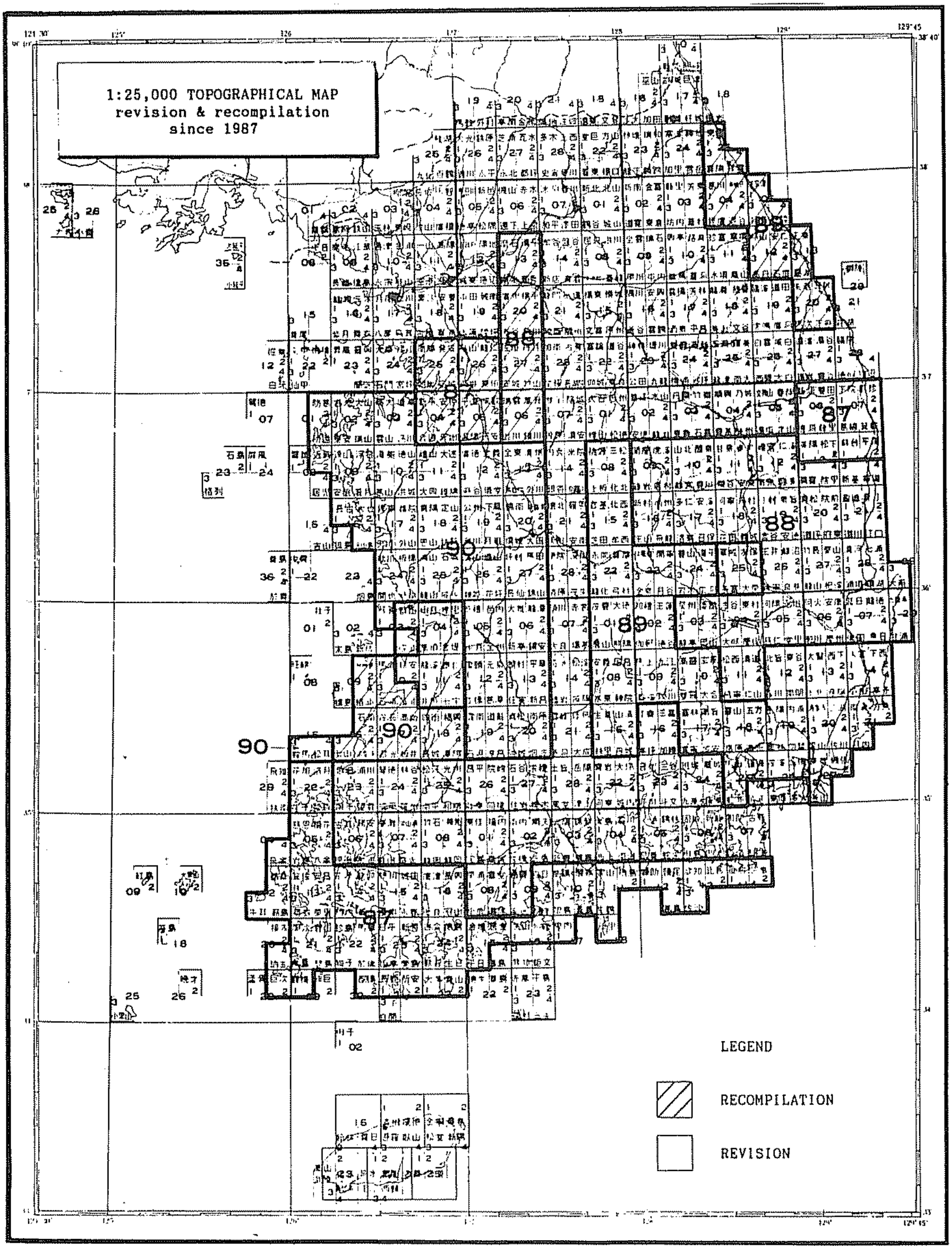

**Figure II. Index of industrial production**

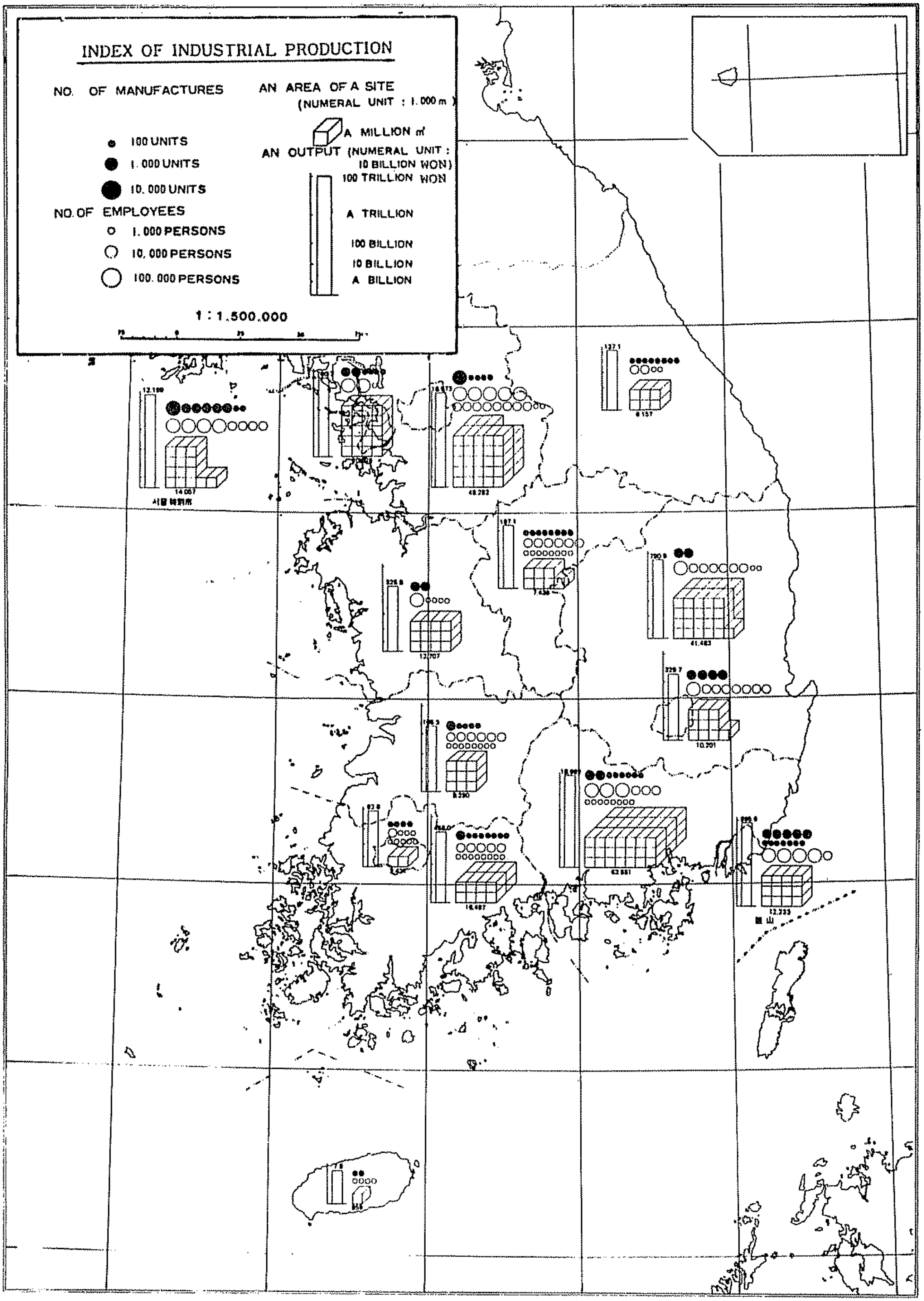

TABLE 6. COMPILATION AND REVISION OF 1:5,000 AND 1:10,000
*(Number of sheets)*

| Scale/Status | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| 1:5,000 | | | | |
| Compilation | 900 | 914 | 800 | 843 |
| Revision | 200 | 210 | 100 | 200 |
| 1:10,000 | | | | |
| Compilation | — | — | — | 13 |

TABLE 7. STATUS OF COASTAL SEA AREA MAP

| Item | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| Area (sq km) mapped | 682 | 620 | 600 | 544 |
| Map sheets | 9 | 9 | 6 | 8 |

rias coast with shallow waters of below 20 metres, possessing abundant fishery for a distance of three nautical miles. For the purpose of acquiring basic data for development of these coastal areas, NGI has conducted a hydrographical survey and since 1977, has been producing a coastal sea area map. The present status of compilation is shown in table 7.

### *National Atlas*

The *National Atlas of Korea* published by NGI, comprises 78 kinds of information on the national situation, such as population density by district and industrial productivity. The map is widely used. In 1991, the NGI will complete an edition containing 134 items in 56 categories and it plans to issue revisions every 10 years from now on. A sample sheet of the *National Atlas* is shown in figure II.

#### *Computer-aided mapping*

The NGI established a computer-aided mapping system for rapid support of topographical information needs for the efficient conservation and management of national land, upgrading the accuracy of the national base map and establishing an effective revision system.

The present status of the system is shown below.

| | *System establishment* | |
|---|---|---|
| Host computer | Sun 4/280 (32MB) | 1 |
| Graphic work station | Sun 4/150 (16MB) | 3 |
| A/N terminal | Fast 15 | 6 |
| EPP | Calcomp | 1 |
| Hard copy | Budde International | 2 |
| S/W | Mapping system<br>Image Processing System | |

### *Office of Hydrographic Affairs, Ministry of Transportation*

The Office of Hydrographic Affairs conducts hydrographical surveys, which can be classified as harbour, passage, coastal and ocean surveys according to coverage and scale, and a comprehensive survey to collect hydrographical information such as depths, submerged dangers, obstructions, underwater topography, and the character of the sea-bottom, for the purpose of acquiring information on conditions essential for safe navigation. On the basis of the results of these surveys, the Office edits and publishes nautical charts to be used by all mariners.

The Office makes and provides nautical charts in different series, such as the general chart and sailing chart, general charts of coast, coastal and harbour conditions at various scales, after reviewing scale and coverage according to the chart's purpose. The present status of nautical chart production is shown in table 8.

TABLE 8. STATUS OF NAUTICAL CHART PRODUCTION: 1991

| Area covered | Number | Purpose |
|---|---|---|
| Korean coast | 169 | Harbour and sailing charts |
| Japanese coast | 22 | Sailing charts |
| South-East Asia, Pacific Ocean | 34 | Sailing chart for coast and ocean |
| Fisheries chart | 21 | Fisheries chart on Korean coast |
| International chart | 3 | |
| Miscellaneous chart | 38 | Charts for special purposes |
| Reference chart | 5 | Charts for position fixing and harbour |
| TOTAL | 292 | |

TABLE 9. PRODUCTION OF MAPS BY OTHER ORGANIZATIONS FOR NON-MILITARY USE

| Year | Urban planning | Regional | Tourist | Road | Other | Total |
|---|---|---|---|---|---|---|
| 1987 | 83 | 295 | 1 776 | 40 | 558 | 2 752 |
| 1988 | 54 | 119 | 6 602 | 182 | 1 469 | 8 426 |
| 1989 | 21 | 269 | 1 371 | 171 | 1 505 | 3 337 |
| 1990 | 8 | 65 | 1 383 | 204 | 477 | 2 137 |
| TOTAL | 166 | 748 | 11 132 | 597 | 4 009 | 16 652 |
| | (1%) | (4.5%) | (66.8%) | (3.6%) | (24.1%) | |

### *Other mapping organizations*

Among the other mapping organizations, the Ministry of Defence is the largest, producing various kinds of maps for military use. Local governments, public organizations and civilians can also publish maps for their own purposes, such maps being compiled by sheet or book, or contained in publications. These add their ideas to the base map of NGI, with supervision by NGI for the sake of accuracy and precision. These maps play an important role in dissemination of map use. Annual map production is as shown in table 9.

## FUTURE PLANS

NGI will complete production of maps at scales 1:5,000 and 1:10,000 in the near future; upgrade the accuracy of various kinds of national control points through completion of the second-order triangulation network, succeeding the first order; and establish an efficient computer-aided mapping system for revision and production of maps and the geographical information system (GIS).

## MAPPING AND SURVEYING ACTIVITIES, 1987-1990*

*Paper submitted by Singapore*

### RÉSUMÉ

A Singapour, les activités courantes de cartographie nationale sont exécutées par trois grands organismes :

*a*) Le Service de topographie, chargé de la photographie aérienne et de la réalisation des cartes topographiques;

*b*) Le Département des levés, chargé de la triangulation géodésique, du nivellement et du cadastre;

*c*) L'Administration portuaire de Singapour, chargée de la publication des cartes marines.

En outre, plusieurs services gouvernementaux et organismes officiels effectuent des travaux de cartographie entrant dans le cadre de leurs activités principales. Le plus souvent, ils utilisent comme base de référence les cartes cadastrales indexées du Survey Department (feuilles normalisées). Ces services et organismes sont notamment les suivants : Singapore Telecom (câbles des réseaux de télécommunication); Building Control Division (croquis des bâtiments); Drainage and Sewerage Department (réseaux d'évacuation des eaux usées et d'assainissement).

Le Gouvernement étant à la pointe du progrès informatique, la tendance dans le domaine cartographique est à la création, à la tenue à jour et au partage de données informatisées. Les utilisateurs de cartes peuvent compter sur un nombre croissant d'informations sous forme numérique. Cette tendance élargira également l'objet et l'emploi des cartes numériques et accélérera l'application des systèmes informatiques qui incorporent des données cartographiques.

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### NATIONAL MAPPING ORGANIZATIONS

Three major mapping authorities are concerned with routine national mapping of Singapore. These are:

(*a*) The Mapping Unit, which is responsible for aerial photography and production of topographic maps;

(*b*) The Survey Department, which is responsible for geodetic triangulation, levelling and cadastral mapping;

(*c*) The Port of Singapore Authority, which is responsible for the publication of nautical charts.

There are also several government departments and statutory boards which carry out mapping work relevant to their main lines of activity. In most cases, these authorities use the Survey Department's cadastral index maps (Standard Sheets) as their reference base. The authorities include the Singapore Telecom (telecommunication network pipelines); Public Utilities Board (gas, power and water networks); Building Control Division (building outlines); Drainage and Sewerage departments (drainage and sewerage lines respectively).

#### *Topographic mapping*

The Mapping Unit continues to maintain the five standard national map series. Within the period under review, the 1:50,000-scale (L7022) and the 1:25,000-scale (L802) topographic maps were revised in 1987, and the 1:25,000 and 1:10,000-scale road maps in 1988 and 1990 respectively. The revision of the 1:5,000 topographic maps is currently in progress, using 1988 aerial photography.

The Mapping Unit has also launched map production from aerial photographs by digital process. In 1990, a computer-aided mapping system was installed to capture and process topographic data through existing stereo-plotters. The digital topographic data are supplied to the Land Data Hub, which coordinates sharing of computerized map information with other authorized users.

#### *Survey control*

The primary triangulation network was further densified: 24 new stations were added in 1989, bringing the total to some 50 usable stations. The precise levelling network currently consists of some 380 benchmarks, which are tied to tidal gauges established by the Port of Singapore Authority at various parts of the island. The Survey Department and the Mapping Unit continue to take observations to revise the values or to replace benchmarks lost or disturbed by land development activities.

#### *Cadastral surveys*

Prior to September 1972 all cadastral surveys were undertaken by the Survey Department. With the operation of the Land Surveyors Act on 1 September 1972, a surveyor registered with the Land Surveyors Board under the Act is entitled to undertake cadastral surveys. To date there are some 45 surveyors registered with the Board, which also regulates the practices of cadastral survey through the Land Surveyors Rules.

On completion of a cadastral survey, the registered surveyor is required to submit the relevant records, such as the certified plans, field books and calculation sheets, to the Department. When the certified plan is approved by the Chief Surveyor, all such documents will be filed in the Department as permanent survey records. Certified plans are increasingly being produced by surveyors in private practice and statutory boards.

*The original text of this paper appeared as document E/CONF.83/INF.33.

At present, the Department also maintains some 1,500 standard sheets drawn at 1:1,000 scale. These maps provide full cadastral map coverage of the whole island and are an index of latest land mutations. They show the parcel identifier, land parcel boundaries, area, certified plan reference and land tenure. The maps are widely used by the various government departments and statutory boards for planning and land administration functions and also by the public sector for various applications.

With the launching of the Civil Service Computerization Programme in 1982, government departments and statutory boards have resorted to information technology, particularly computer-aided mapping systems, to provide a more efficient means to maintain their land records. In line with this, the Survey Department also installed a computer system (SurMap) in 1987 to produce and maintain the standard sheets in digital form. To date about 15 per cent of cadastral data have been captured and the whole digital cadastral base is scheduled to be completed at the end of 1992. SurMap comprises 7 graphic workstations, 2 penplotters and other peripherals driven by a Dec-Vax mainframe computer.

In 1989, the Survey Department installed a micrographic system. Plans and other relevant survey records are now available for access through aperture cards or microfilm, from which hard copies can be produced within minutes.

In 1990, the Government set up a Land Data Hub to spearhead the sharing of digital map data among the agencies in the public sector. A computerized Geographic/Land Information System (GIS/LIS) was acquired to facilitate map data exchange among some 12 agencies employing four different computer-aided mapping vendor systems.

*Hydrographic surveys*

The Hydrographic Department of the Port of Singapore Authority produces the nautical charts of Singapore's port waters, which cover about 560 sq km. Prior to 1965, hydrographic surveys were undertaken by the British Navy. To date, the Hydrographic Department publishes and maintains some 30 nautical charts covering the stretch of Malacca Straits from One Fathom Bank to the Horsburgh Lighthouse, which marks the approaches to the Singapore Straits. The Department also maintains 5 lighthouses, 93 beacons and 90 buoys. With the installation of 2 acoustic Doppler current profilers on the seabed and telemetric links to a computer, harbour pilots are provided with real-time tidal current information. Recently, an Integrated Survey and Hydrographic Information System (INSHIS) was added to automate the field survey and charting operations. The system software has GIS capabilities for data analysis and modelling. The hardware comprises four graphic workstations and an AO-size electrostatic plotter networked with a minicomputer. Singapore has been a member of the IHO since 1972.

### Conclusion

With the Government spearheading and emphasizing information technology, the trend for the mapping field is towards creating, maintaining and sharing of computerized map data. Map users can look forward to the availability of more digital map information. This will also expand the scope and use of digital maps, and accelerate the application of information technology systems incorporating map data.

## PROGRESS REPORT ON CARTOGRAPHIC ACTIVITIES IN THAILAND*

*Paper submitted by Thailand*

### RÉSUMÉ

Les activités cartographiques de la Thaïlande sont confiées à divers organismes gouvernementaux. La responsabilité de chacun d'eux dépend des impératifs de sa mission. Le rapport présente les progrès réalisés dans le domaine de la cartographie et dans les activités connexes au cours de la période examinée (octobre 1986-septembre 1990).

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### Royal Irrigation Department

The Topographic Survey Division is responsible for surveying and mapping for the planning (including pre-feasibility and feasibility studies), design, and construction of water resources development projects of the Royal Irrigation Department. Two types of maps are produced:

(*a*) *Topographic line maps*. These maps are produced by the photogrammetric method as well as by conventional ground survey. Photogrammetry is generally employed to produce maps for project planning and preliminary design, whereas ground survey is utilized for detailed design. During the reporting period, the Division produced topographic line maps covering approximately 12,000 sq km at scales ranging from 1:500 for irrigation structure design to 1:10,000 for project planning and preliminary design of irrigation systems.

(*b*) *Photomaps*. Photomaps (rectified photo and orthophoto) are usually produced at 1:4,000 scale for the design and construction of onfarm development projects, which require very high altimetric accuracy. Photomaps are used as base maps for property boundary survey and spot height survey in the field. Coverage area of photomaps within the reporting period is approximately 4,900 sq km.

### Royal Thai Survey Department

*The National Board on Surveying and Mapping*

The National Board on Surveying and Mapping was established on 9 August 1989 as a special committee under the direct control of the Prime Minister. Members of the Board, 29 in all, are representatives from military and civilian governmental agencies as well as public enterprises. The Chief of Staff of the Royal Thai Armed Forces is the president, and the deputy director (technical) of the Royal Thai Survey Department (RTSD) is assigned as secretary of the Board. The meeting takes place once every two months.

*The original text of this report appeared in two documents, E/CONF 83/INF 21 and E/CONF 83/INF 21/Add. 1

The special tasks of this Board are determination of surveying and mapping policies in accordance with the National Social and Economic Development Plan and construction of common standards and methodology, so that all governmental agencies and public enterprises can cooperate smoothly for the national benefit without unnecessary repetition resulting in loss of time and budget.

The Board has since begun cooperation in:

(*a*) Production and correction of maps by means of aerial photographs and satellite imagery;

(*b*) Surveying and observation to establish geodetic and geophysical ground controls;

(*c*) Establishment of a geographic information system and land information system (GIS/LIS);

(*d*) Checking and appraisal of results from surveying and mapping operations;

(*e*) Establishment of a map data centre.

### *Geodetic and geophysical survey*

During the reporting period, the Royal Thai Survey Department (RTSD) has conducted the following geodetic and geophysical surveys:

*First-order traverse*

The Electronic Distance Measurement (EDM) Traverse was carried out on an extensive scale for establishing first-order horizontal controls. First-order traverse was chosen in order to ease the difficulty in laying out chains of triangulation. The traverse lines were run and connected to the existing first-order triangulation network in the central, north-eastern and southern parts of the country. The aforementioned traverse has established 151 additional controls (figure I).

*Geodetic astronomy*

In order to strengthen the existing geodetic network and to determine the geoid profile, 15 Laplace stations have been established at the existing first-order traverse and triangulation stations located in the central, north-eastern and southern parts of the country.

*Satellite geodesy*

The Doppler Geodetic Point Positioning Programme was initiated in Thailand in 1971. The signals received from transit satellites at various locations have been sent to the Defense Mapping Agency Hydrographic/Topographic Center in Washington, D.C., for computation of coordinates in geocentric datum and local geodetic datum. The total number of + 1 Doppler stations has been established during the reporting period.

The Point Positioning Programme in the Global Positioning System (GPS) was started in Thailand in 1990. The signals received are from GPS satellites. RTSD has been provided with 5 dual-frequency receivers. The results of testing, comparing to the previous baselines, are quite favourable (first-order). At present, RTSD uses these receivers to densify the existing national network (figure II).

*Geodetic levelling*

Five lines of first-order levelling were run in order to densify the existing national network. During the reporting period, 186 BMP and 879 BMS have been established at a distance of 1,710 km (figure III).

*Levelling for investigation of land subsidence in Bangkok*

The RTSD had conducted first-order levelling to assist the office of the National Environment Board in the investigation of land subsidence assumed to be caused by deep well pumping in the Bangkok area and vicinity. The project was commenced in 1978, and up to 1990, 13 runs of first-order levelling were repeatedly conducted in the same area in which 211 BMP and 1,195 BMS were located (figure IV).

*Land gravity survey*

During the reporting period, the gravimetric observation was carried out in the southern, central, and north-eastern parts of the country. A total of 520 stations were established at an approximate distance of 10 km apart (figure V).

*Geomagnetic survey*

Geomagnetic survey was carried out in order to re-observe the geomagnetic elements at the existing stations located in the central, northern, north-eastern and southern parts of the country. The objective is to provide data for geomagnetic variation. A total of 69 stations were re-observed during the reporting period (figure VI).

### *Aerial photography and remote sensing activities*

During the reporting period, aerial photography missions were transferred to the Royal Thai Air Force. The responsibility of the RTSD is to produce aerial photo products.

RTSD has established a new section, the Remotely Sensed Data Section, whose main task is to update the basic maps by means of satellite imagery data.

*Aerial photography*

Aerial photographs were produced for various mapping projects of the RTSD and other governmental agencies on different format.

558,873 photos on 9″ × 9″ bromide paper

1,745 photos on 20″ × 24″ bromide paper

2,522 photos on 30″ × 30″ bromide paper

971 photos on 36″ × 36″ bromide paper

119,356 diapositives (9″ × 9″)

*Aerial photograph rectification*

RTSD processed aerial photograph rectification for:

(*a*) One RTSD project for mapping purposes; the total number of 36″ × 36″ film is 4;

(*b*) Two projects at the request of other governmental agencies; the total number of 36″ × 36″ film is 180.

*Photomosaic production*

The RTSD accomplished aerial mosaics for various projects which can be classified as follows:

(*a*) Four RTSD projects for mapping purposes;

(*b*) 23 projects at the request of other governmental agencies.

The total number of photographs used for mosaicking is 2,243.

*Remote sensing activities*

The RTSD conducted a pilot project using high-resolution satellite imagery for updating of base maps. The updated area is located in the central plain of Thailand where map details have been so much changed. It corresponds to sheet No. ND 47-7 at 1:250,000 scale and covers a total of 24 map sheets at 1:50,000 scale.

### *Mapping*

*Standard topographic maps*

The RTSD conducted recompilation and revision of the bilingual topographic maps series L 7017 at scale 1:50,000 in order to improve accuracy. During the reporting period,

**Figure I. Thailand: First-order triangulation and traverse**

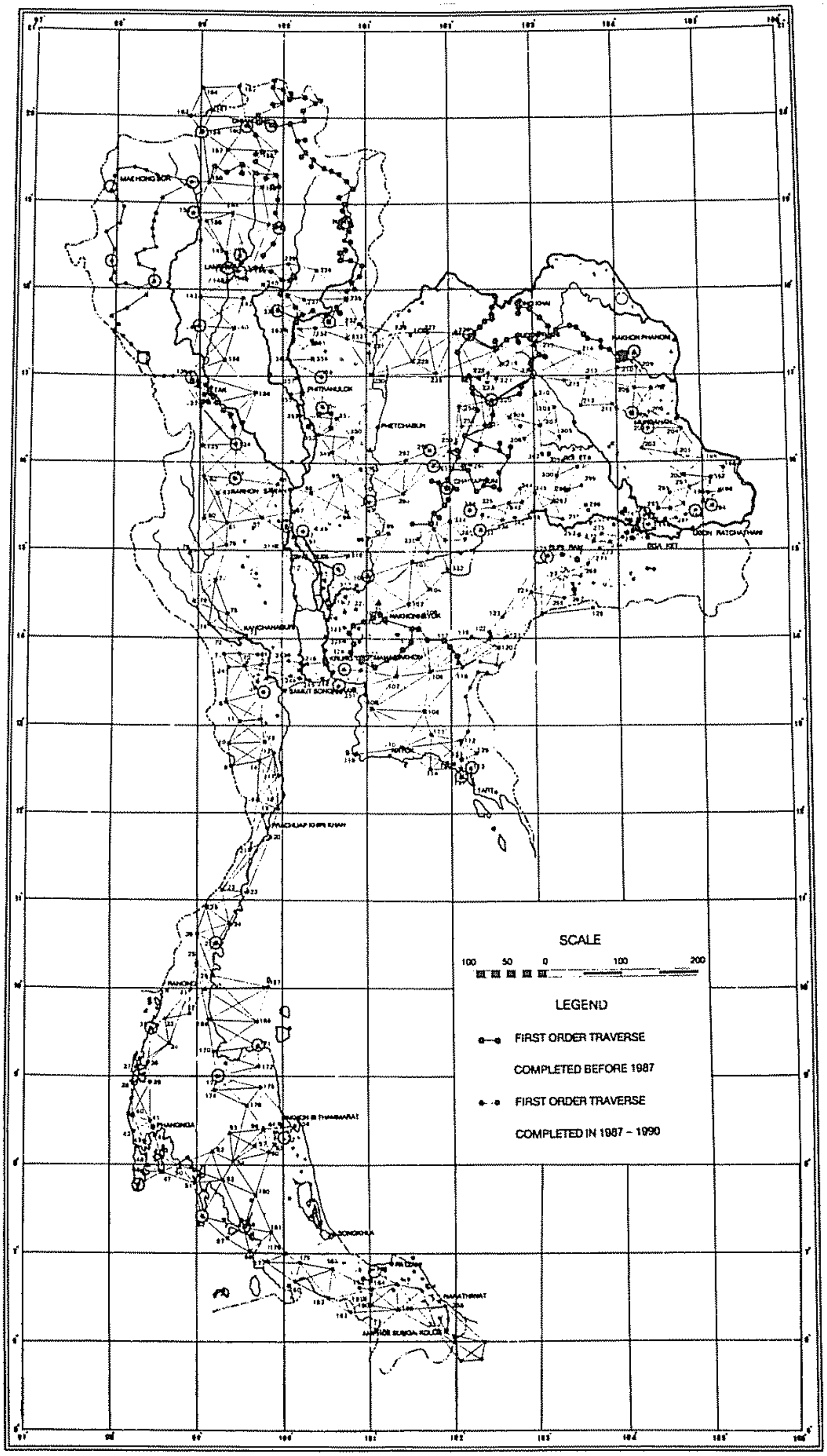


**Figure II. Thailand: Doppler stations established**

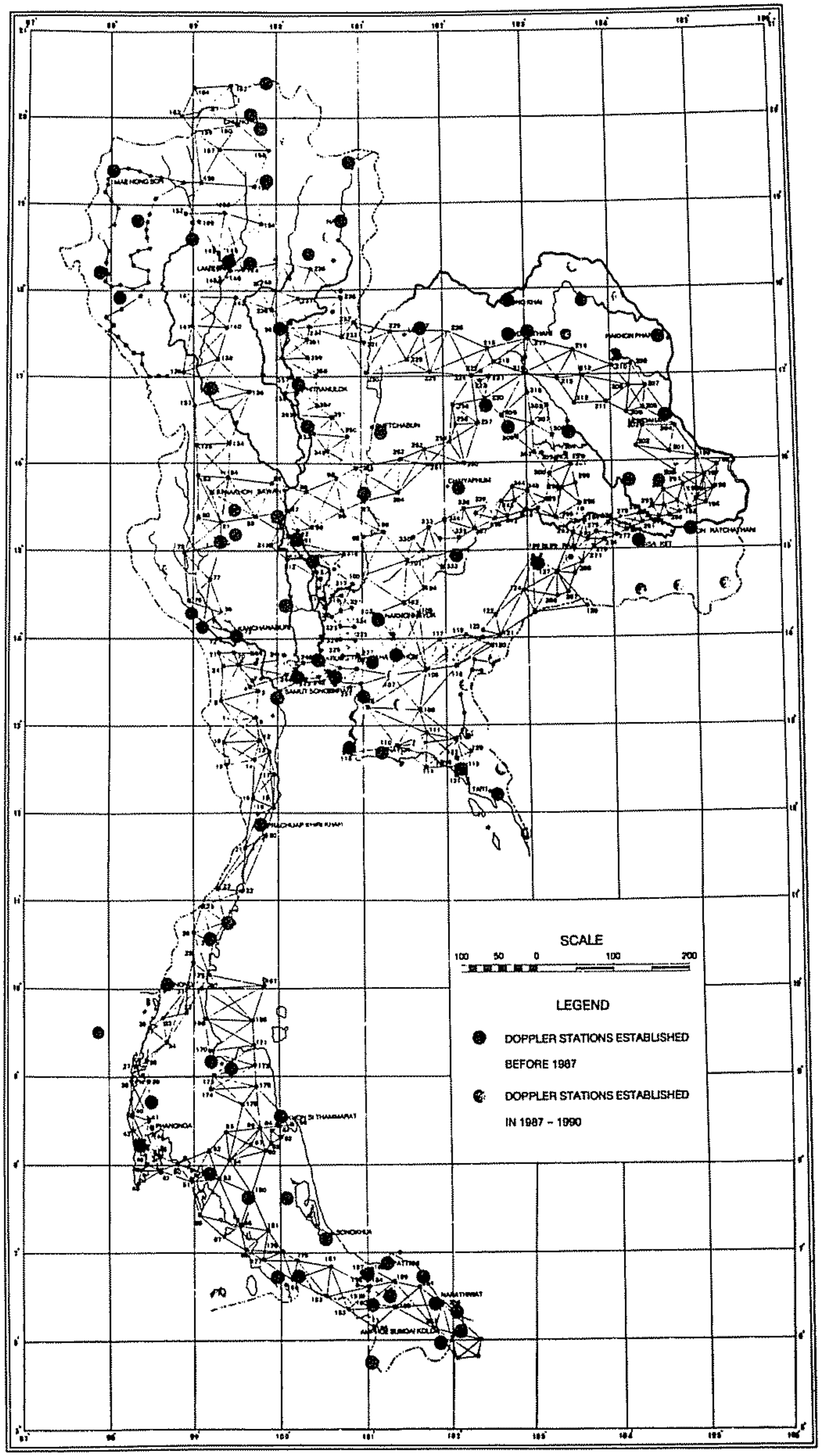


**Figure III. Thailand: First-order levelling**

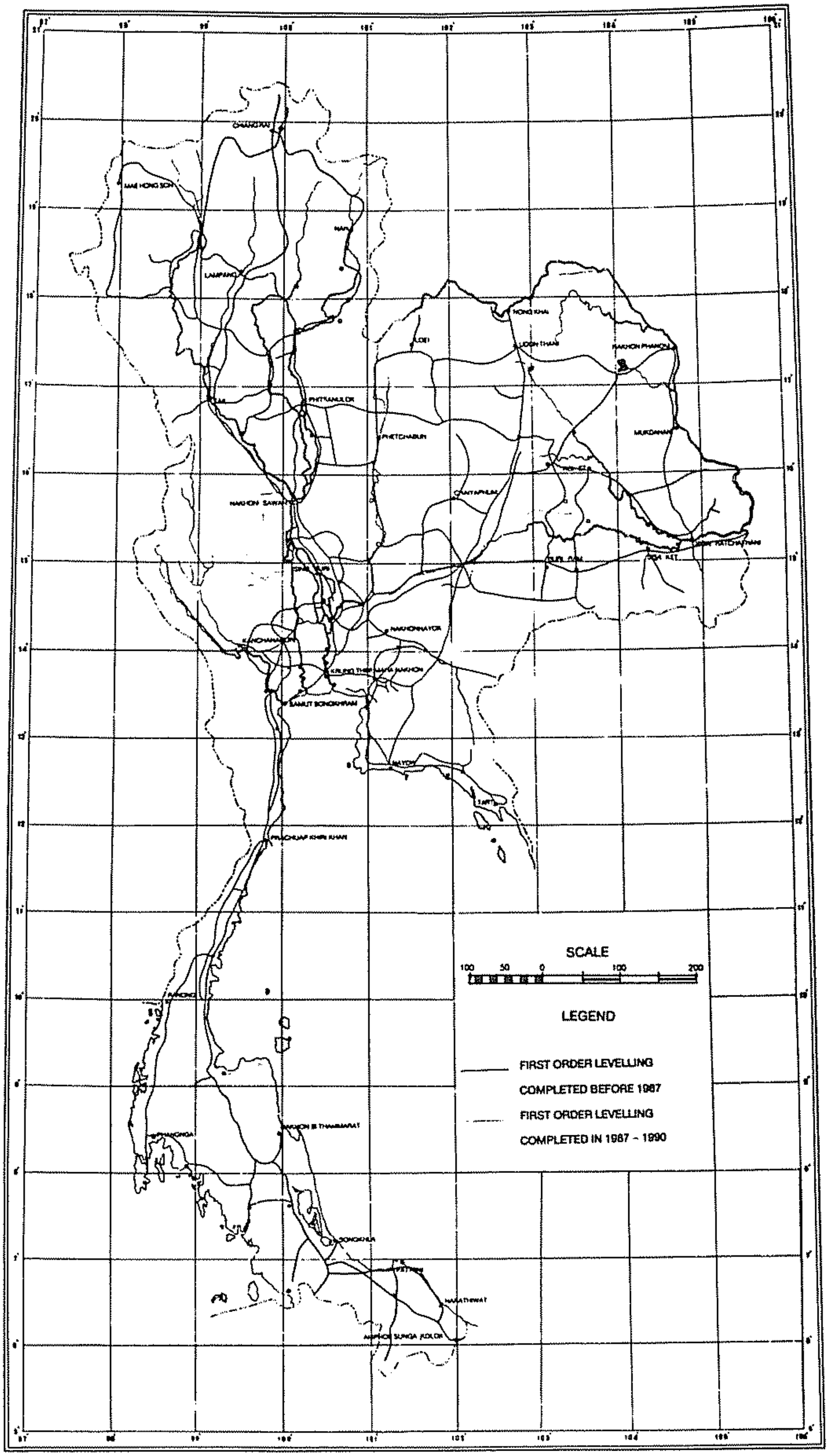


Figure IV. Thailand: Index map to first-order levelling for investigation of land subsidence in Bangkok

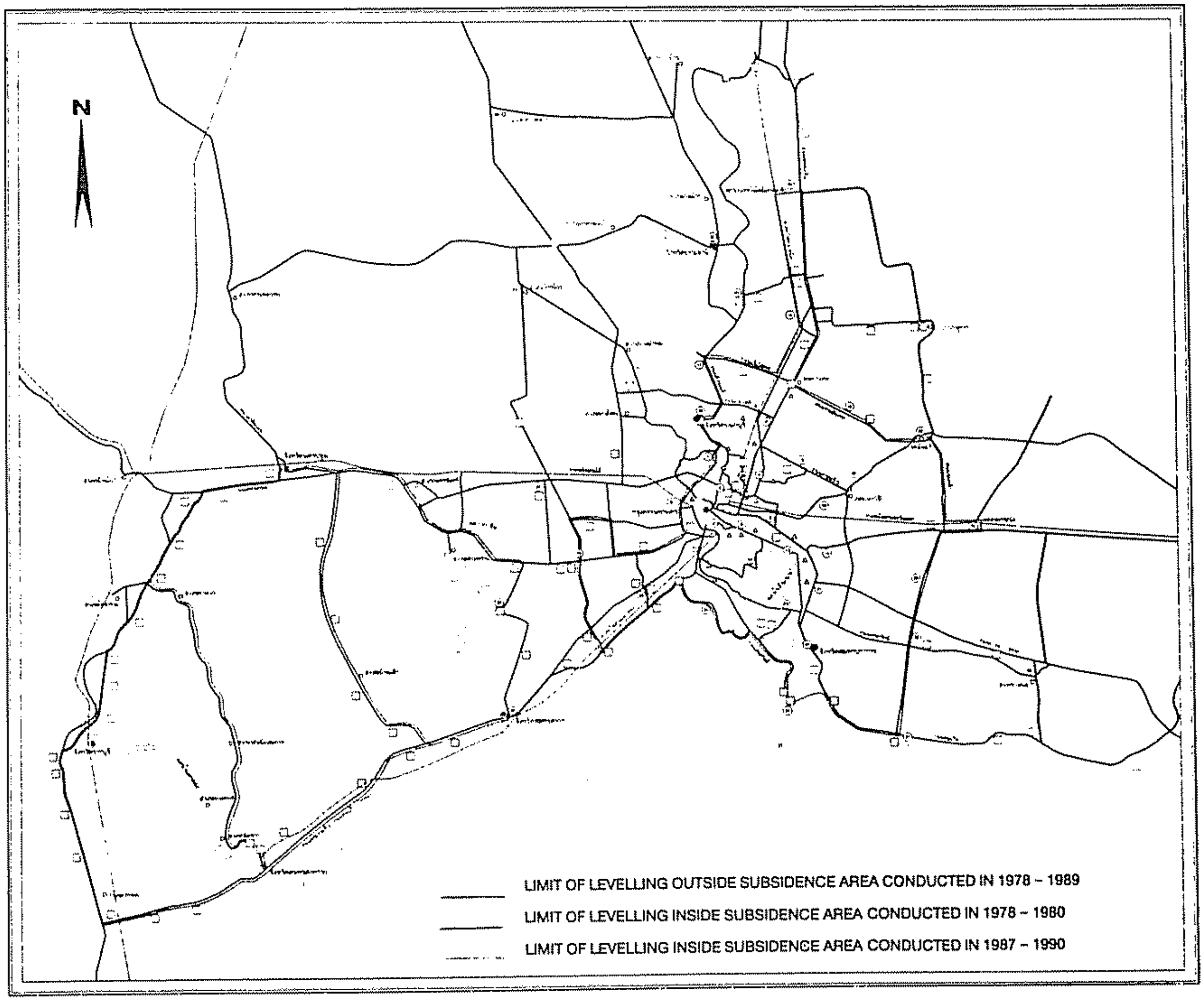


Figure V. Thailand: Progress in gravimetry

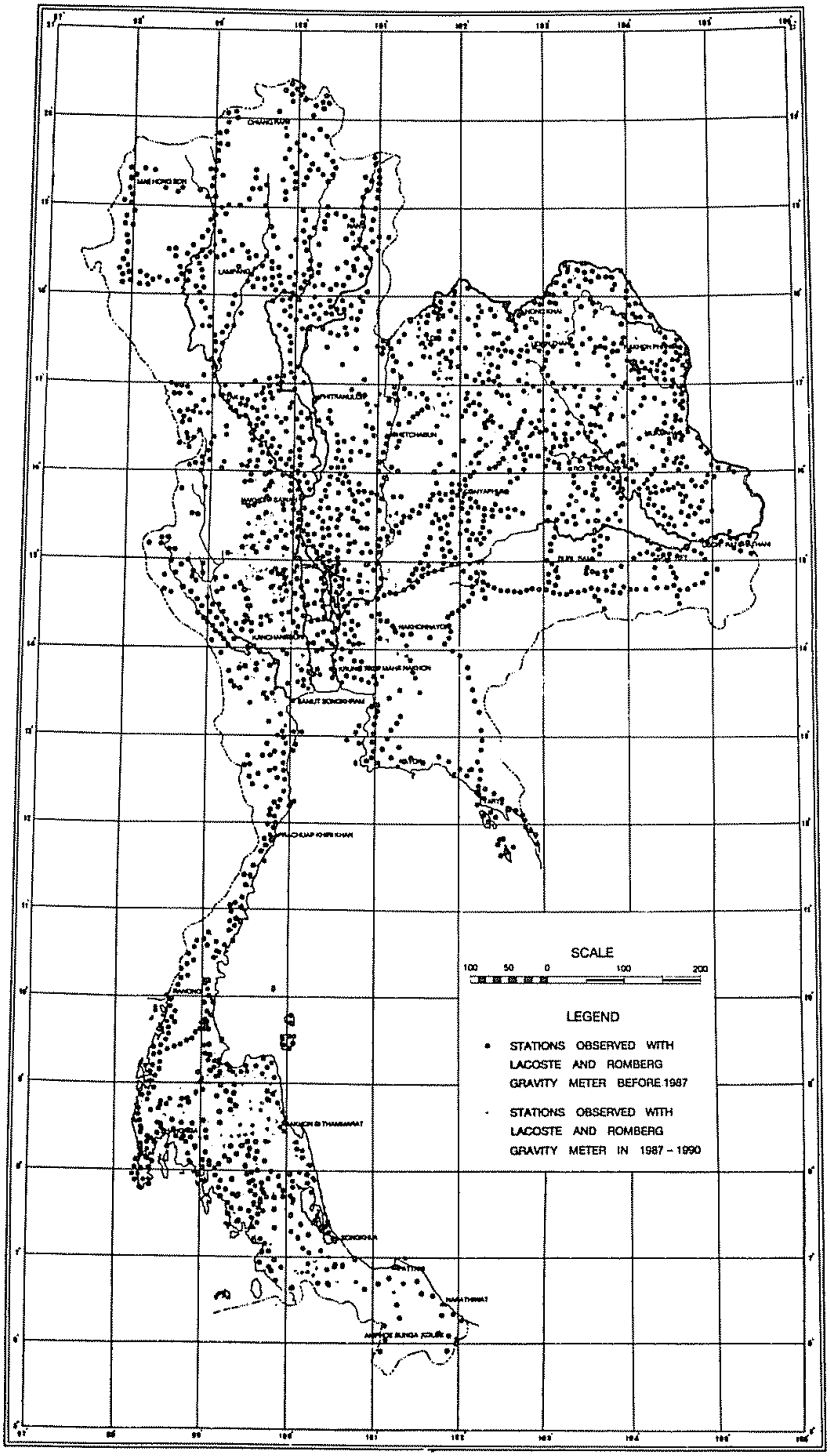
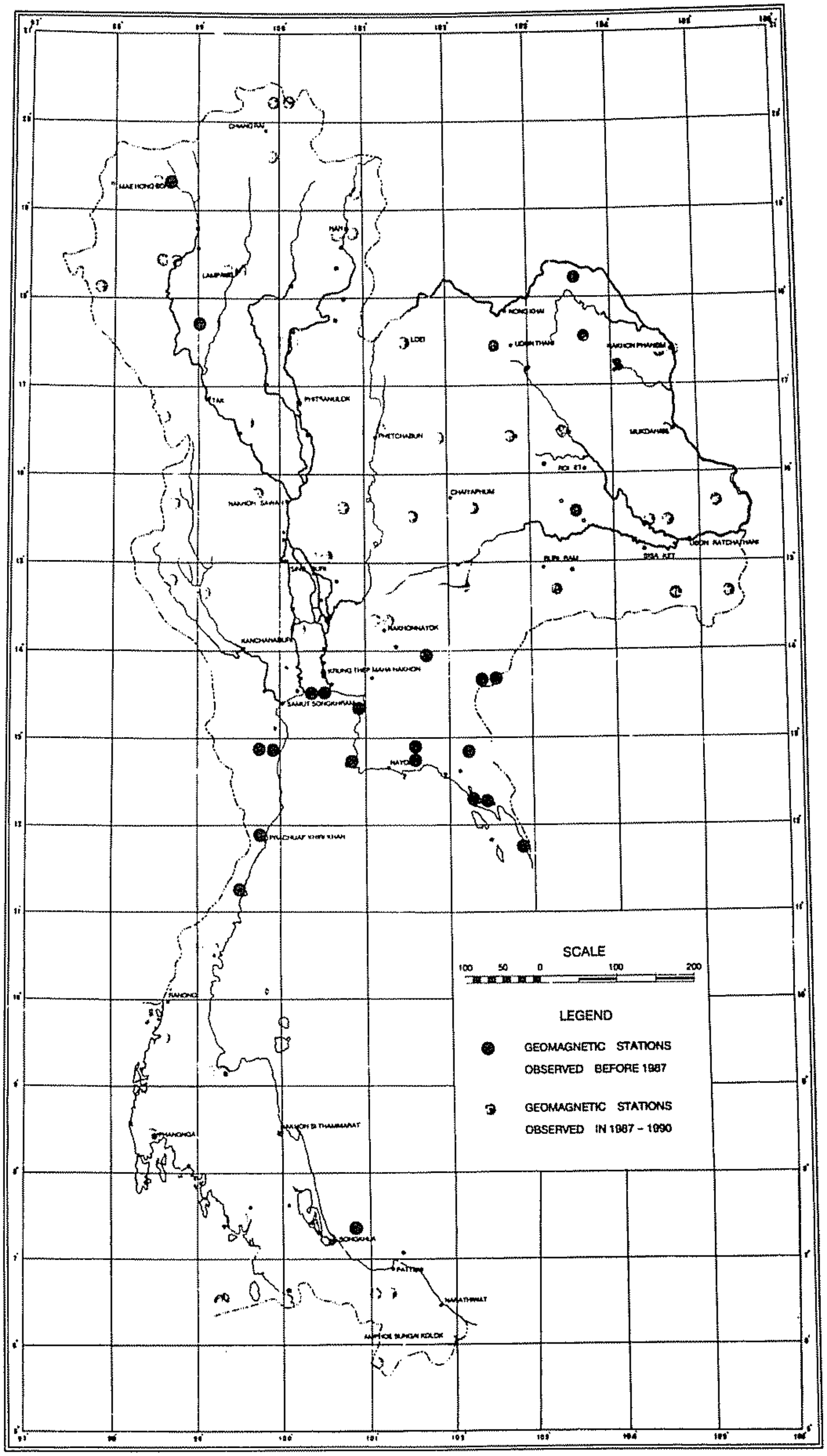


Figure VI. Thailand: Progress in geomagnetic observations



80 sheets covering certain areas in the northeastern, eastern, northern and southern parts of the country were recompiled and revised but only 51 sheets were published.

*Other topographic maps*

During the reporting period the following work was done:

(*a*) 37 sheets at 1:25,000 scale of bilingual topographic maps covering some southern parts of the country were published. Up to the present 344 sheets are available for military use;

(*b*) Two sets of bilingual city maps, one consisting of 130 sheets at scale 1:12,500, and the other of 20 sheets at scale 1:20,000 covering the urban areas had been published. These maps are updated from time to time. During the reporting period, 6 revised sheets of the Bangkok area at scale 1:20,000 were published;

(*c*) 53 sheets of bilingual topographic map at scale 1:250,000, series 1501, 1501 A and 1501 S (for public use), covering the entire area of the country, were revised from time to time;

(*d*) A set of bilingual maps of the Thailand-Myanmar boundary (Mae Sai–Nam Ruak Rivers sector), consisting of 1 sheet at scale 1:50,000 and 26 sheets at scale 1:5,000, have already been published during the reporting period;

(*e*) Special purpose black-and-white maps of 136 sheets at scale 1:5,000 and 81 sheets at scale 1:10,000 were compiled during the reporting period for the land development area.

*Thematic maps and atlases*

These were:

(*a*) The *National Resources Atlas of Thailand*. This set of the *Atlas* has 52 topics, which were completely published in 1984; 6 topics were revised, as reported at the Eleventh Conference. During 1987-1990 4 additional topics were revised:

Agriculture II, 1980-1981

Tourist map of Thailand

Tourist centre

Administrative Divisions, 1990

(*b*) The *Topographic Atlas of Thailand*. Three volumes of *Topographic Atlas*, i.e., volumes II, III, and IV, were published during the reporting period. At present, this *Atlas* is being rearranged and revised to consist of only two volumes, instead of four as initially planned.

*General purpose map and road maps*

(*a*) The *World Map* at scale 1:40,000,000, with geographical names in Thai, was revised and published in 1989;

(*b*) The *Road Map* at scale 1:2,000,000, showing the road network throughout the country, was revised and published in 1990.

### *Map reproduction*

During the reporting period, 5.2 million map copies at large, medium and small scales were produced in 6-colour offset on 100-120 gm paper. Of these maps, classified into topographic maps, thematic maps and atlas, 81 per cent were printed from RTSD's repromats, while the other 19 per cent were printed by RTSD from repromats supplied by other governmental agencies.

### *Geographical names*

The list of names obtained from 814 out of 830 sheets of 1:50,000-scale topographic map of Thailand, series L 7017, has already been compiled. It is at the manuscript stage and will be stored as database in the computer system in the near future.

### *Map Information Centre*

During the reporting period, the Information Centre has received 363 sheets of various maps from 33 countries.

### *Education and training*

Courses offered in the Royal Survey School, RTSD, during the reporting period, were as follows:

5-year survey engineering course for military cadets

26-week advanced survey engineering course for senior commissioned officers

26-week associated surveying course for junior commissioned officers who did not attend the 5-year survey engineering course

2-year basic surveying course for non-commissioned officer students

26-week advanced surveying course for master sergeants

24-week associated surveying course for non-commissioned officers who did not attend the basic surveying course for non-commissioned officers

*Personnel training*

During the reporting period, qualified personnel of the RTSD were awarded scholarships for study at universities and institutes abroad. One commissioned officer received a master's degree in photogrammetry from Ohio State University in the United States; 14 commissioned officers and 7 non-commissioned officers received diplomas and certificates from universities and institutes in Australia, Canada, France, Japan, the United Kingdom and the United States in the fields of surveying, geodesy, cartography, photogrammetry, geography, remote sensing and printing, while 3 commissioned officers are studying for master's degrees in the fields of computer, remote sensing and cartography at universities in the United States.

## AGRICULTURAL LAND REFORM OFFICE

The Agricultural Land Reform Office (ALRO) was established in 1975 under the Ministry of Agriculture and Cooperatives. It is responsible for public and private land reform and has objectives as follows:

(*a*) To convert tenants and landless farmers into owner-operators;

(*b*) To increase agricultural production and improve credit and marketing facilities to ensure better economic and social conditions of the farmers;

(*c*) To promote farmers' organizations in order to foster growth of the agricultural economy;

(*d*) To promote education, public health, public utilities, and public facilities for rural betterment;

(*e*) To reduce the gap in economic and social status between the rural and urban areas.

The land reform activities undertaken up to October 1990 cover 160 *amphoe* and 43 *changwat*. In the planning phase of the land reform project, ALRO used topographic maps at scales 1:50,000 and 1:250,000 provided by RTSD. In the operation phase, ALRO produced its own maps. Topographic maps, at scales 1:10,000 and 1:5,000 with 1-metre contour intervals, were produced by ground survey and photogrammetry: These maps were used for feasibility studies. The 1:1,000- and 1:500-scale topographic maps were used for construction design, and the 1:4,000-scale cadastral

TABLE 1 SURVEY AND MAPPING COMPLETED BY ALRO, 1986-1990

| *Catalog* | *1986* | *1987* | *1988* | *1989* | *1990* | *Total* |
|---|---|---|---|---|---|---|
| *Maps for planning* | | | | | | |
| Topographic ($km^2$) | 997.6 | 540.4 | 716.0 | 511.8 | 910.1 | 3 675.9 |
| Cadastral($km^2$) | 749.0 | 758.3 | 1 522.0 | 2 552.6 | 3 154.8 | 8 736.7 |
| *Maps for implementation* | | | | | | |
| Road(km) | 132.3 | 176.3 | 276.2 | 227.7 | 436.9 | 1 154.4 |
| Canal(km) | 25.9 | 42.9 | 53.9 | 16.2 | 40.3 | 139.2 |
| Site plan($km^2$) | 1.9 | 2.4 | 2.4 | 3.4 | 4.8 | 14.9 |
| Village($km^2$) | 10.0 | 14.0 | 8.0 | 10.0 | — | 42.0 |
| Land and water conservation($km^2$) | 40.0 | 68.8 | 96.0 | 68.8 | 20.0 | 294.4 |

maps for certificate of utilization (ALRO 401 k). Horizontal and vertical controls from RTSD were used as reference in producing these maps.

Total mapping of ALRO during 1986-1990 is shown in table 1.

## DEPARTMENT OF SURVEY ENGINEERING, FACULTY OF ENGINEERING, CHULALONGKORN UNIVERSITY

The Department of Survey Engineering offers a bachelor's degree and a master's degree in survey engineering: a four-year undergraduate programme for the degree of Bachelor of Engineering and a minimum two-year graduate programme for the degree of Master of Engineering. The range of courses offered in the Department covers the broad fields of surveying, geodesy, photogrammetry, cartography, and remote sensing. Other new survey-related disciplines such as GIS/LIS, GPS, and digital photogrammetry are also covered. For the conventional undergraduate programme, students are furnished with sound basic knowledge in civil engineering as well as surveying consciousness; this programme is called "Engineering Surveying". A new option, a "Surveying and mapping" programme, has been set up since 1990 to concentrate on the surveying and mapping disciplines only. Total credits needed for graduation with the degree of Bachelor of Engineering are 144 semester credits, with a minimum average grade point of 2.00 from a 4.00 scale. The curriculum is a blend of theory and laboratory work. Undergraduate students gain their confidence in practical work through field exercises in the University's surveying camp, as well as through on-the-job training.

The Department's graduate programme is regularly revised to reflect the trends in modern surveying and mapping technology. It is also devised to encompass GIS and other new survey-related disciplines. Total credits needed for graduation with Master of Engineering degree are 48, of which 30 credits are for course work and 18 for a research thesis. The minimum average grade point for graduation is 3.00 in this case.

In addition to the academic activities of teaching and researching in the field of surveying and mapping, the Department's role is the provision of several academic services, in the form of organizing conferences, seminars and special lectures, consulting, advising and conducting surveying projects. Between October 1986 and September 1990, a number of projects were undertaken, some of them complete, and some in progress. Following are some of the Department's important projects:

1. *Detailed surveys of 5 Bangkok existing roads for engineering design purposes*: a project completed in 1987 for the Bangkok Metropolitan Authority (BMA);

2. *Establishment of vertical control points in Greater Bangkok areas (1985-1986)*: a second-order vertical control project undertaken for BMA;

3. *Photogrammetric mapping of Khao Ngou areas for Rachaburi Province administration purposes (1988-1989)*;

4. *Topographic mapping of archaeological sites in Kanchanaburi for the Department of Fine Arts (1990)*;

5. *Digital mapping and creation of GIS base maps for the Bangkok Land Information System (BLIS) project (1990)*: photogrammetric mapping at scale 1:1,000 over an area of 25 sq km is being undertaken. Certain geographic details and related attributes were created in the form of GIS data-base for the use of the BLIS project;

6. *Pilot project on geographic information system for land reform area development planning*: an ongoing project to study the possibility and feasibility of establishing a GIS for land area development planning purposes. This GIS pilot project is undertaken for ALRO. It is expected to be completed in May 1991.

### *Cooperation with the Department of Lands in the Land Titling Project (Phase II)*

The "Thailand Land Titling Project" is a 20-year programme being organized by the Department of Lands (DOL) with the World Bank's financial assistance. Part of the project, especially technical assistance, is sponsored by the Australian Development Assistance Bureau (ADAB). Based on the Royal Thai Government's policy to issue title deeds to all lands in the shortest time possible, the project's objective has been set to complete the issuance of 8 million title deeds all over the country in twenty years.

In the first phase of the project, which covers a six-year period (1984-1990), the Department has played a significant role in the cooperation with DOL by recruiting 20 additional students each year. After graduation, these students must work for the DOL for at least eight years. In return, three Australian academic advisers had stayed at the University, each for one year, for teaching and working as counterparts. Further, an amount of funds was provided by the project to the Department for the purchase of new equipment for training.

Owing to the Department's cooperation and the urgent needs of surveying and mapping personnel, the DOL has contracted another four-year programme as the second phase of the project (1990-1994) with the Department. The programme is to produce 80 survey engineers in the next four years, 20 each year.

### *Current status of the Department*

At present there are 13 faculty members, three of which are studying abroad. There are 150 undergraduate and 7 graduate students enrolled. The Department is now very active in digital mapping and LIS/GIS. Equipment available for teaching and training purposes covers all the basic surveying equipment and a few modern instruments, namely, electronic theodolite, analytical stereoplotter, and LIS/GIS workstations. GPS satellite receivers and image processing system are under acquisition.

### Department of Mineral Resources

Cartographic work in geology during 1986-1990 was to prepare and publish the series of basic geologic maps of Thailand at scale 1:50,000, about 40 sheets each year. All of them are the preliminary maps and texts. Two sheets at 1:250,000 scale were prepared as the provincial maps, which are revised map series.

Many types of the geological and the geophysical maps have been published in this reporting period by the Department of Mineral Resources, as follows:

(*a*) Hydrogeological maps at scale 1:50,000 in the north-eastern region of the country;

(*b*) Airborne geophysical maps prepared and published under the Mineral Resources Development Project at various scales. Most of them are available.

### Hydrographic Department, Royal Thai Navy

#### *Hydrographic survey*

During the reporting period, the main objective of the work was focused on passage survey for out-of-date nautical charts revision; thereinafter the harbour survey has predominated. This is due to the increasing demand for coastal development projects. Major drawbacks hampering the progress of this aim are the lack of a hydrographic specialist and budgetary limitation. Activities of the Department are as follows:

| *Type of survey* | *1986* | *1987* | *1988* | *1989* | *1990* |
|---|---|---|---|---|---|
| Harbour | 3 | 2 | 5 | 8 | 4 |
| Updating | 4 | — | 6 | 2 | 4 |
| Passage | 6 | 6 | 4 | 4 | 5 |
| Coastal | — | — | — | — | 1 |

#### *Nautical and aeronautical charts*

*Aeronautical charts*

*New print*. No. 2617 WAC 1,000,000, August 1990, 3rd edition.

*Nautical charts*

Table 2 lists new charts published between 1986 and 1990.

### National Energy Administration

Mapping of reservoir damsite and appurtenant structures of the hydropower and electrical pumping projects since 1 October 1986 is as follows:

(*a*) Topographic mapping of reservoir damsite and appurtenant structure of the hydropower project at scale 1:2,000 and 2-metre contour intervals: mapping for 31 projects was carried out with a total area coverage of 60 sq km;

(*b*) Topographic mapping by photogrammetry for the electrical pumping project at scale 1:5,000 and 2.5 metre contour intervals: mapping for 178 projects has been carried out with the total area coverage of 1,780 sq km;

(*c*) Topographic mapping by photogrammetry for reservoir area at scale 1:10,000 and 5-metre contour intervals:

- (i) Mae Suai project (Changwat Chiang Rai); mapped area is about 50 sq km;
- (ii) Nam Songkhram project (Changwat Sakon Nakhon); mapped area is about 500 sq km;
- (iii) Khong-Chi-Mun project (north-eastern region of Thailand); mapped area is about 300,000 sq km

### Department of Land Development

Cartographic activities in the Department of Land Development, which had been conducted by the Soil Survey and Land Classification Division after its inception in 1963, led to an intensification in field-work and consequently a greater demand for efficient, high quality cartographic services for the production of maps and reports. To fulfil these needs on an integral part of project operations, a Surveying and Cartographic Division was set up. The Division installed several items of cartographic equipment and established a complete section for survey, photogrammetry, cartography and printing to produce maps, reports and other materials. At present, the Department of Land Development is able to handle modern cartographic work, classified as follows:

#### *Topographic survey and mapping*

*Satellite geodesy*

A Doppler geodetic translocation programme has been used for survey and mapping in the Department since 1984. There are, currently, 185 established Doppler stations.

*Traverse and levelling*

Electronic Distance Measurement (EDM) Traverse has been used on an extensive scale in establishing horizontal controls. Levelling has been operated for vertical controls. Traverse and levelling lines were run and connected to the existing first-order triangulation network of the RTSD and/or other Doppler stations.

*Topographic maps*

The Land Development Department has improved mapping activities in photogrammetry. There are 2 analog stereo-plotters (Wild AG I, Kern PG 2) and 1 analytical stereo-plotter (Wild BC 1).

The scale of topographic maps varies, according to the need of users, from 1:2,000 to 1:5,000 and contour interval are 1-2.5 metres. Each year the Department has produced topographic maps covering areas of about 800,000 rai (625 rai = 1 sq km) from aerial photos at scale 1:15,000.

#### *Thematic mapping*

*Detailed reconnaissance soil maps*

Detailed reconnaissance surveys were made of the *changwat*, with a publishing scale of 1:100,000, except in the south of Thailand where the scale was 1:50,000. Soil boundaries were printed in red on topographic maps of the Royal Thai Survey Department, which were printed in black and used as the base. Until now, all of detailed reconnaissance soil maps of the *changwat* were produced, and four *changwat* in the north-east of Thailand have been revised. Illustrated soil mapping units are soil series, soil variant, soil association of soil series or variant, with some phase of each, and some land types. These soil maps are mainly used in provincial and regional development planning and for the evaluation of large drainage irrigation or drainage projects.

*Distribution of soil organic matter map of Thailand*

Results of the study on the amounts and distribution of soil organic matter were illustrated on a map at 1:2,000,000 scale. Evaluation had been made from all data available in the Department, consisting of 631 profiles from 187 soil series collected from different parts of the country. The data

TABLE 2 THAILAND: NAUTICAL CHARTS, 1986-1990

| Chart No. | Title | Scale | Date | Edition |
|---|---|---|---|---|
| | *New charts* | | | |
| 354 | Ko Rang Nok to Kantang | 1:80 000 | December 1986 | |
| | *New publications* | | | |
| 116 | Ko Samet | 1:20 000 | October 1986 | 6th |
| 118 | Ko Saba to Ko Chik Nok | 1:60 000 | December 1986 | 5th |
| 331 | Entrance to Ranong | 1:40 000 | October 1986 | 3rd |
| 335A | Ao Man and approaches | 1:8 000 | June 1986 | 3rd |
| 350 | Ko Tarutao to Satun | 1:8 000 | August 1986 | 2nd |
| 309 | Ko Rawi to Satun | 1:200 000 | March 1987 | 2nd |
| 117 | Laem Thoraphim to Ko Saba | 1:40 000 | August 1987 | 3rd |
| 335 | Phuket Harbour | 1:20 000 | May 1987 | 9th |
| 115A | Sattahip Commercial Port (Chuk Samet Harbour) | 1:8 000 | October 1987 | 2nd |
| 243 | Chong Samui to Ko Phangan | 1:70 000 | June 1988 | 4th |
| 333 | Ao Phangnga | 1:40 000 | August 1988 | 4th |
| 141 | Laem Thoraphim to Ko Khram | 1:120 000 | August 1988 | 9th |
| 045 | Krung Thep to Singapore | 1:1 550 000 | May 1989 | 3rd |
| 226 | Lang Suan and approaches | 1:30 000 | August 1989 | 7th |
| 335A | Ao Man and approaches | 1:8 000 | December 1989 | 4th |
| | *New printing* | | | |
| 203 | Lang Suan to Prachuap Khiri Khan | 1:240 000 | March 1986 | 10th |
| 114 | Ko Sichang Harbour | 1:15 000 | February 1987 | 14th |
| 141 | Laem Thoraphim to Ko Khram | 1:120 000 | March 1987 | 8th |
| 206 | Songkhla to Kelantan | 1:240 000 | July 1987 | 10th |
| 111 | Krung Thep Port Zone II (Bangkok Port Zone II) | 1:10 000 | August 1987 | 3rd |
| 332 | Ko Phra Thong | 1:60 000 | December 1987 | 2nd |
| 230 | Ao Pattani | 1:40 000 | January 1988 | 5th |
| 147 | Ko Lan to Laem Phatthaya | 1:25 000 | January 1988 | 4th |
| 203 | Lang Suan to Prachuap Khiri Khan | 1:240 000 | February 1988 | 11th |
| 120 | Chong Ko Chang | 1:50 000 | March 1988 | 7th |
| 336 | Entrance to Kantang | 1:35 000 | March 1988 | 7th |
| 045 | Krung Thep to Singapore | 1:1 550 000 | July 1988 | 2nd |
| 001 | Prachuap Khiri Khan to Ko Chuang | 1:240 000 | July 1988 | 14th |
| 137A | Ao Udom (Krasu) | 1:6 000 | October 1988 | 2nd |
| 223 | Entrance to Mae Nam Mae Klong | 1:25 000 | December 1988 | 5th |
| 227 | Ao Ban Don | 1:50 000 | May 1989 | 5th |
| 244 | Pak Phanang to Laem Kho Kwang | 1:80 000 | May 1989 | 4th |
| 248 | Hat Chao Samran to Samut Sakhon | 1:80 000 | May 1989 | 2nd |
| 115 | Ao Sattahip and approaches | 1:40 000 | June 1989 | 9th |
| 350 | Ko Tarutao to Satun | 1:80 000 | March 1990 | 3rd |
| 203 | Lang Suan to Prachuap Khiri Khan | 1:240 000 | March 1990 | 12th |
| 205 | Songkhla to Laem Kho Kwang | 1:240 000 | June 1990 | 5th |
| 116 | Ko Samet | 1:20 000 | June 1990 | 7th |

include analytical and environmental aspects related to the differences in soil organic matter content.

*General soil map of Thailand*

This map was also published at scale 1:1,000,000 and each soil sub-order is shown on the map in different colours. Different colours can be obtained for each area by using a different map colour-separation process, and tint-screens, with the four primary colours. There are 89 group levels of USDA Soil Taxonomy, and the broad geographic relations among soils indicating contrast between regions are represented.

*Suitability map of coconut plantation*

These maps represent the area for coconut plantation and other crops, such as para-rubber, cocoa, rambutan, cashew (intercrop) and other fruit trees.

The multicoloured maps covered the area of Changwat Phuket, Pattani, Songkhla, Surat Thani, Nakhorn Si Thammarat, and Chumporn at scale 1:50,000.

*Distribution of saline soil maps*

These maps are in processing stage at the cartographic subdivision and will be finally printed as multicoloured maps at scale 1:250,000 covering 11 *changwat* in the north-east region and in some other parts of Thailand.

The data were compiled from the provincial soil maps, hydrological and geological maps and LANDSAT imagery. Field check was accomplished by staff of the Soil Surveyor and one of the specialists of the Department.

*Semi-detailed soil maps*

Most are those of the *amphoe* areas at scale 1:250,000. The data were compiled from detailed reconnaissance surveys of *changwat* with results from field check and photo-interpretation for more details suitable to the scale. These identified land suitability areas for paddy, upland crop, fruit trees, permanent pasture crops or rangeland livestock farming, engineering use, and water storage.

*Provincial land-use planning maps*

The land-use planning maps show suitable uses of land with recommendations for soil improvement. Most are multicoloured, at scale 1:250,000. Currently, the mapping of 41 *changwat* has already been finished and others are in the processing stage. However, maps and reports of land-use planning will be produced for 10 *changwat* a year.

*Potential land-use maps for fruit tree plantation in the north-eastern region of Thailand*

There are 17 multicoloured maps of 17 *changwat* in the north-eastern region, reproduced at scale 1:1,000,000 for the North-east Regional Office of Agriculture, Thaphra, Khon Kaen. The data were compiled from the provincial soil maps and LANDSAT imagery and were also field checked.

*Land holdings map*

This map shows the condition of land holdings, both legal and illegal, to fulfil the need for land-use planning and land development information.

### NATIONAL RESEARCH COUNCIL OF THAILAND

#### *Remote sensing activities*

Satellite remote sensing has been applied by various government agencies since the technology was introduced. The fields of application have been concentrated on forestry, land use/land cover and crop-mapping. The Remote Sensing Division, internationally known as the Thailand Remote Sensing Centre (TRSC), acts as the secretariat of the National Remote Sensing Coordinating Committee and therefore interacts with national and international agencies involved in remote sensing, besides being a regional satellite data distribution centre.

Cooperation with regional and international organizations has been in the fields of research, conduct of projects and technological development.

#### *National Remote Sensing Centre*

The Thailand Remote Sensing Centre is the principal national remote sensing body. It is composed of six branches, namely General Administration; Research Coordination and Follow-up; Data Analysis; Technical and Maintenance; User Service; and Ground Receiving Station.

The Centre has about 80 staff members, half of whom are remote sensing specialists. Major current activities of the Centre can be highlighted as the following:

(*a*) *Data reception:* The Thailand Ground Receiving Station, which is operated by the Thailand Remote Sensing Centre, is presently receiving and processing LANDSAT-TM and SPOT data. LANDSAT-MSS is received on request only because of lower sales volume since the availability of LANDSAT-TM data.

(*b*) *Data distribution:* At present, the Centre has a large archive of satellite data which could serve all users' needs. In the calendar year 1989, the value of data distributed was $US 800,000. The trend of data usage in the country and in the region is increasing because of the high potential of the present satellite data.

(*c*) *Research grant allocation:* Each year TRSC offers a grant of one to two million baht to remote sensing application projects proposed by national researchers as a means to promote the application of this technology in the country. In FY 1989 there were 13 projects funded under this grant.

(*d*) *Technical support:* The Centre has two digital image analysis systems—DIPIX and Meridian—and an optical-mechanical projector called PROCOM-II for remote sensing projects. TRSC staff also give technical advice to users and help to train them in the operation of the systems. In addition, TRSC provides the services of two digital plotters to produce hard-copy results of their analysis.

(*e*) *Remote sensing projects:* The Centre, in cooperation with other agencies or with direction of the Government, conducts studies with the use of satellite data.

(*f*) *International cooperation:* The Centre has cooperated with countries/organizations in the region as well as outside the region for the development of remote sensing technology. Cooperating countries/organizations have been the Association of South-East Asian Nations (ASEAN), Australia, Canada, China, France, Japan, the United States, the Economic and Social Commission for Asia and the Pacific (ESCAP) and other United Nations organs. Areas of cooperation are in joint research and technical development as well as human resources development.

#### *Remote sensing activities in other organizations*

The various government agencies that deal with the management of natural resources have applied satellite remote sensing in their respective fields. To mention some of the active users, they are: Land Development Department, Royal Forest Department, Office of Agricultural Economics, Royal Thai Survey Department, and Department of Agriculture.

#### *Education and training facilities*

Most of the universities in Thailand have one or two courses on remote sensing in their curricula. As for TRSC, in order to promote the application of this technology, training courses on the principles of remote sensing and on digital image analysis are organized almost as an annual event for training of national scientists. To further enhance their expertise in specific fields of application, these scientists attended regional information exchange events held either in the country or abroad. In the past two years, the Centre, in cooperation with other agencies, organized several forums, which were attended by over 450 Thai scientists and some 200 non-Thais.

#### *Publications*

The Centre publishes two versions of a newsletter annually for dissemination of information to users. One version is in Thai and the other in English. Their frequency is quarterly. The Centre also publishes its annual report, which summarizes its activities in the past year; however, it is published only in the Thai language. Most research works are published in Thai as well, except those conducted in cooperation with international organizations.

#### *Future of remote sensing in Thailand*

The development of remote sensing in Thailand has been growing steadily in data acquisition, distribution and applications, since Thailand Ground Station has the capabilities to provide high resolution satellite data of LANDSAT TM, SPOT and MOS-1. In the near future, Thailand station facilities have been planned to be upgraded to receive and process ERS-1 data of ESA. This plan would assist Thailand and neighbouring countries to obtain multi-level satellite data for natural resources management. Cooperation among all countries concerned would also be a key factor in bringing full benefits of remote sensing to the region. So far a total of 108 projects, from 70 principal investigators, are in the areas of agriculture, forestry, land use, computer science, geography, geology, hydrology, oceanography, earth science and multi-disciplinary environmental monitoring.

These research projects are from various agencies; in economic analysis of the projects it is very hard to estimate the direct and indirect benefit/cost ratio, which varies from 1:1 to more than 1:10. Remote sensing applications are cost-effective in that they are more accurate, save time, save labour and also save budget to implement the project.

ROYAL FOREST DEPARTMENT

The progress of forest thematic mapping (during October 1986-September 1990) is as follows:

*Mapping using LANDSAT-MSS and TM data*

Existing forest maps of 1989 covering the whole country (forest and non-forest areas) surveyed and interpreted by visual technique have been produced at the scale of 1:250,000.

Forest land-cover and environment maps, analysed by digital image processing technique, have been completed for 12 *changwat*, i.e., Prae, Phanga, Udon Thani, Sakon Nakhon, Nakhon Phanom, Mukdahan, Kalasin, Ubon Ratchathani, Surin, Roi Et, Loei and Phayao. These maps are produced by Tektronix inkjet printer at scale 1:250,000.

*Mapping using large-scale aerial photographs*

The 1:15,000 scale aerial photographs were used for classification of the forest type maps and transferred to the base map at scales 1:50,000 and 1:250,000. This work has been continued in the amount of 20,000-40,000 sq km per year.

## CARTOGRAPHIC ACTIVITY IN THE USSR*

*Paper submitted by the Union of Soviet Socialist Republics*

### RÉSUMÉ

Les travaux cartographiques, en Union soviétique, sont confiés à l'Administration centrale de la géodésie et de la cartographie, qui relève du Conseil des ministres de l'URSS. Cet organisme se charge également d'opérations de géodésie et de gravimétrie fondamentales et appliquées. Les travaux cartographiques exécutés sont notamment l'établissement et la mise à jour de cartes topographiques et thématiques, ainsi que de cartes des fonds marins de la plate-forme continentale. Tout le territorire de l'URSS est désormais couvert par des cartes topographiques au 1/1 000 000, au 17/500 000 au 1/100 000 et au 1/25 000. Il existe des plans au 1/2 000 et au 1/5 000 des villes et des agglomérations. On poursuit l'établissement de cartes topographiques des plates-formes continentales. Les levés aérospatiaux sont désormais largement utilisés en URSS pour l'établissement de cartes topographiques et thématiques, non seulement de la Terre, mais également d'autres planètes. En URSS, on attache aussi une grande importance à l'établissement de cartes pédagogiques et de cartes touristiques.

In the Soviet Union, national mapping is entrusted to the National Geodetic Service, the Main Administration of Geodesy and Cartography (GUGK), which, under the Council of Ministers of the USSR, carries out fundamental and applied geodetic, gravimetric, and cartographic operations, including compilation and updating of topographic, thematic and shelf-bottom maps, as well as aerial and space surveys and special engineering and mining geodetic operations.

Responsibilities of the Service embrace several research institutions and specialized instrument-building factories, and over 30 regional agencies engaged in geodetic and cartographic operations and map editing, as well as a number of technical schools responsible for training specialists at secondary level.

The highest-level specialists are trained in two specialized schools and about 30 polytechnical high schools.

Geodetic and cartographic production agencies generally use domestic technologies, instruments and equipment.

HORIZONTAL AND VERTICAL DATUMS

The territory of the USSR is provided with sufficiently dense horizontal and vertical geodetic networks. The national horizontal datum consists of about 600,000 stations of first-, second-, third- and fourth-order triangulation; the national vertical datum comprises over 800,000 benchmarks of first-, second-, third- and fourth-order levelling; and the fundamental first-order gravity network consists of about 240 stations.

The astrogeodetic network of the USSR formed by the first- and second-order networks has an accuracy of 1:370,000 for the baselines, 1.2″ for Laplace azimuths, and 3-4 m for coordinates over a distance of several thousand kilometres.

The general adjustment of the astrogeodetic network and computer-based compilation of coordinate catalogues are now being completed. The total number of normal equations to be solved is about 350,000.

The levelling network, in its homogeneity and rigour of treatment, is a unique geodetic construction satisfying all the requirements and recommendations of the International Association of Geodesy. The Geodetic Service carries out systematic updating and densification of the network because of the inevitable loss of a certain portion of benchmarks and vertical crustal movement. All first-order lines and some second-order lines are relevelled at least once in 25 years and, in seismically active areas, once in 15 years. From these relevelling data the map of recent vertical crustal movements for all the territory of the USSR has been compiled.

A new adjustment of the levelling network of the first and

*The original text of this paper, prepared by V. K. Jashenko, Main Administration of Geodesy and Cartography, appeared as document E/CONF.83/L.17

second order should have been completed by 1995 and the national levelling database created.

The Geodetic Service conducts a complex of research and practical operations for the study of geodynamic processes in geodynamic and technogenetic test areas established in seismically active regions and in areas of mines and hydro-electric power stations. In the latter case the effect of human activity on behaviour of the Earth's crust is investigated. Crustal deformation monitoring data are used for reliable forerunner studies and temporal spatial earthquake prediction.

The national gravity net of the USSR is used for precise determination of the parameters of the Earth's gravitational field from terrestrial and satellite data, as well as for metrological standardization of gravity surveys of different accuracy and application. It is also used with horizontal and vertical nets for determination of the shape and size of the Earth.

The national horizontal and vertical geodetic datums as well as the national gravity network hence provide not only horizontal and vertical control for mapping at every scale but also data for resolving a number of scientific problems.

## AEROSPACE SURVEYS

Aerial survey in the USSR is carried out for solution of economic problems both from special air survey aircraft and from specially equipped aircraft, helicopters, and microlight carriers. Aircraft TU-134 XC and AN-30 are specially equipped aircraft. AN-2 aircraft, MI-8 and KA-26 helicopters and microlight carriers are used for large-scale surveys.

Depending on the problems to be solved, air survey carriers are provided with cameras of focal length from 50 to 500 mm, gyrostabilization and precision-navigation systems.

For further improvement of information content the aerial survey equipment is constantly improved through modification of geometric and energetic parameters of lenses, forward motion compensation etc. The problem of high-precision autonomous determination of external orientation parameters is now resolved. The improvement of air survey techniques and instrumentation is carried on both in GUGK and in other departments of the USSR.

Remote sensing of the Earth from space, which is now widely used for topographic and thematic mapping, is accomplished from permanently manned orbital stations "Saljut", and in recent years the station "Mir"; and from automated space apparatuses "Resource-F1" and "Resource-F2". Space survey data are distributed to more than 900 agencies of various ministries and departments. Some survey data are sold abroad according to contracts and individual requests.

The automated space station "Resource-F1" is equipped with photographic twin camera KFA-1000 with lens focal length of 1000 mm, image-size, 30 × 30 cm, longitudinal overlap, 60 per cent, lateral overlay, 20 per cent, relative lens opening, 1:10, width of coverage strip (2 apparatus fan-like), 180 km, film supply for one apparatus, 1,700 exposures, and forward motion compensation.

Space apparatus "Resource-F2" is equipped with a 4-channel multispectral camera MK-4. The camera is provided with special high-precision lens securing a resolution of 150 lines/mm as to absolute contrast target. The focal length is 300 mm and the size of the window is 180 × 180 mm. The compensation of image motion due to angular satellite movement is achieved by linear displacements of the flattening table. The ground resolution of the image is from 5 to 8 m depending on the flying height and the spectral range of the survey.

The main application sphere of remote sensing from space is compilation and updating of topographic and thematic maps.

## TOPOGRAPHIC AND SHELF SURVEYS

The territory of the USSR despite its rather hard geographical and climatic conditions is now completely covered by topographic maps at the scales of 1:1,000,000, 1:100,000 and 1:25,000. The cities and towns of the country are mapped at the scales of 1:2,000 and 1:5,000. Considering the tremendous areas mapped, it is an impressive achievement.

Topographic map-making is carried out mainly by the photogrammetric technique, but the surveys at large scales (1:1,000 and 1:500) are performed by terrestrial methods, such as tachometer (studia surveying).

Digital methods, with development of digital terrain models and cartographic data banks having influence upon all technological phases from map compilation and updating to map delivery to users, are systematically introduced, but the progress is relatively slow.

Topographic surveys of sea and ocean shelf areas, as well as of bottoms of internal reservoirs, connected with increased economic activities in equatorial areas, such as prospecting and extraction of minerals, construction of special engineering structures, and environmental studies, are actively pursued. The scale of the surveys extends from 1:2,000 to 1:50,000, but in some distant shelf areas it is 1:100,000. Production agencies of GUGK carrying out these surveys use modern technology such as small-sized echolots, sonars for measurements of sound-propagated velocity in water and side-looking and topographic hydrolocators. Horizontal positioning of survey carriers is performed by radiogeodetic and satellite navigation systems.

## SMALL-SCALE AND THEMATIC MAPPING

GUGK systematically produces maps for different branches of the economy, education, science and tourism as well as for individual needs. About 800 different maps and atlases are produced yearly.

The maps fall into two principal groups: general geographical maps showing geographical physical characteristics of the Earth and its regions; and thematic maps showing natural components and complexes as well as territorial branch structure of the economy.

General geographic (folded) maps for territories of the Soviet Union republics, autonomous republics, *krai* and *oblast* (smaller administrative units) at various scales as well as a series of atlases and maps of almost all States and territories of the world are produced in a great number of copies and are very much in demand.

Thematic mapping of individual regions of the country is often carried out by GUGK and other interested departments in the framework of special joint-study projects with wide utilization of remote sensing data. Thematic maps produced as a result of these projects are badly needed for detailed study of variations of the environment (relief, vegetation, landscape, hydrography etc.) and resolving of ecological problems, and, therefore, for optimal land management. For example, complex studies revealed a great supply of fresh water suitable for pasture watering in the semi-desert area of the Aral Sea, which was later confirmed by boring data; and a number of mineral deposit indications in other regions of

Central Asia. More precise estimations of mountain snow and ice cover, water and hydroelectric resources were also made possible.

Thematic mapping dedicated to studies of other planets, particularly the Moon and Venus, is actively pursued in the Soviet Union. Space survey data enabled mapping of the reverse side of the Moon, detailed representation of the relief of Mars and Mercury and photo-interpretation of surface structures of Venus, Jupiter and Saturn. Of special interest is the space survey of the Moon's surface. Soviet automatic stations "Zond-6", "Zond-7" and "Zond-8" have been successfully used for this purpose. Optico-mechanical scanning of images from automatic interplanetary stations "Luna-3", "Luna-12", "Mars-3", "Mars-4", and "Mars-5" is applied for map compilation. In the reporting period, the atlas *Surface of Venus* (1989) and 27 sheets of the photomap of Venus at scale 1:5,000,000 (1987-88) were published.

In the USSR, great attention is paid to education in cartography. There are different maps and atlases for courses in geography, astronomy, history and natural science, supplemented by such cartographic products as *Educational World Atlas*, *Geographical World Atlas* (for teachers) and a number of atlases of smaller administrative units of the USSR. The atlas *World and Man* for children of pre-school age and school children of lower grades has acquired a special popularity. Unique new thematic map series for higher schools, intended as helps in training and research in geography, geology, soil study, economics and other spheres, are produced by GUGK. Annual production of educational works amounts to 80 million copies.

Cartography for tourism has been actively developed in recent years. Maps containing touristic itineraries of all kinds and based on large- and middle-scale topographic maps are of great informative value and may be used by hikers, hunters and anglers.

Many maps, atlases and city plans are edited both in Russian and in foreign languages.

Nowadays, the global problem of vivid interest for humanity is the state of the environment, and it is the task of the world cartographic community to create a world-wide system for cartographic representation of the environment from terrestrial and remote sensing data. The National Geodetic Service of the USSR would gladly take part in corresponding international projects and share its rich experience in this field.

## CARTOGRAPHIC ACTIVITIES IN ASIA AND THE PACIFIC, 1986-1990*

*Paper submitted by the United Kingdom of Great Britain and Northern Ireland*

### RÉSUMÉ

Le présent rapport sur les activités de levé et de cartographie menées par les organismes gouvernementaux et les organes associés du Royaume-Uni qui opèrent en Asie et dans le Pacifique couvre la période écoulée depuis la onzième Conférence.

Les activités des organismes suivants y sont traitées : Overseas Surveys Directorate de l'Ordnance Survey, Natural Resources Institute (ancien Land Resources Development Centre), Directorate General of Military Survey, et Hydrographic Office.

Les sujets ci-après y sont examinés : géodésie, photographie aérienne et images satellite, photogrammétrie, établissement de cartes topograhiques, télédétection, établissement de cartes thématiques, levés hydrographiques, cartes de navigation, détachement de personnel, et formation.

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This report describes the survey and mapping activities of the United Kingdom of Great Britain and Northern Ireland and associated bodies working in the Asia and Pacific region. It deals with progress made since the national report was made to the Eleventh Conference in 1987.

The United Kingdom Overseas Development Administration (ODA) has funded various projects in the region, which have been undertaken by the Overseas Surveys Directorate (OSD) and the ODA specialist unit: the Natural Resources Institute (NRI), formerly the Land Resources Development Centre (LRDC). These include topographic mapping at scales 1:50,000 and 1:100,000 in the Republic of Yemen, and a major programme of land resource thematic maps of Indonesia.

The Directorate General of Military Survey has been active during the reporting period in providing geodetic survey control for Bangladesh, the Maldive Islands and the Chagos Archipelago. Aeronautical charts in the ONC and TPC series have continued to be maintained for parts of the Asia/Pacific region, with the Directorate General producing one Operational Navigation Chart (ONC) and six Tactical Pilotage Charts (TPC) over the review period.

The Hydrographic Office has been involved in charting in the region particularly in the Gulf waters around Oman, and in the Red Sea. New metric charts have been prepared for the approaches to Jeddah, for the Solomon Islands, for Vanuatu, for the coastal waters of Sarawak and Sabah, and for Hong Kong.

A programme of secondment of experts and of training continues between United Kingdom Government departments and survey and mapping organizations in many countries in the region.

The overseas unit of the British Geological Survey has also been involved in mapping projects in the Asia and Pacific region, notably in Jordan where it has provided assistance with a geological survey and mapping programme, and in the Lao the People's Democratic Republic.

#### GEODESY

As a continuation of OSD's survey and mapping programme for Yemen Arab Republic (Republic of Yemen), 36

*The original text of this paper appeared as document E/CONF 83/L 51

Doppler satellite translocation stations were established in the north-east of the country during 1987 using the Magnavox 1502.

Following the completion in 1986 of the OSD tellurometer traversing programme in Yemen a comprehensive plan adjustment of the whole survey control network was undertaken. Eight precise ephemeris Doppler satellite stations were used as controls and this "National Control Network" was computed on the WGS 72 spheroid and datum.

In this reporting period the Directorate General of Military Survey observed position fixing surveys in Bangladesh, the Chagos Archipelago and the Maldive Islands. All the work done was at the request of the host countries and provided training opportunities for staff from the local survey departments to gain experience of Doppler and GPS position fixing.

In collaboration with the Government of Bangladesh 57 Doppler station fixes were observed, mainly by translocation, to provide air-photo control points for the new mapping in the Sundarbans area.

A number of stations were fixed by Doppler and GPS in the Chagos Archipelago to support hydrographic charting, including a station on the Blenheim Reef.

In the Maldive Islands 16 Doppler fixes were observed to control hydrographic charting. A gravity base transfer was carried out between Colombo (Sri Lanka) and Hulule and 12 gravity detail points were observed throughout the Islands.

### Air photography and satellite imagery

Advice and information on air photography is available from OSD, which retains a large air-photo library. A service for the planning, letting and managing of air photography contracts can also be provided. In the reporting period one such project was assistance to Sri Lanka with management expertise for the contract for air photography at 1:15,000 scale of 5,000 sq km of the Upper Mahaweli Catchment Area, required for a land-use survey and a reforestation project.

After experiencing difficulties in obtaining air-photo coverage of the north-east of Yemen, OSD acquired in 1987 18 stereo-pairs of SPOT-1 panchromatic stereo-imagery of an area of 25,000 sq km. After a period of experimentation and development OSD produced topographical map coverage of the area at 1:100,000, with a contour vertical interval of 20 m in the desert areas and 40 m in the more mountainous terrain.

### Photogrammetry

During the period under report, OSD's main activity in the Asia/Pacific area has been the continuing mapping programme for Yemen. Using 1987 imagery obtained from the then newly launched SPOT-1 satellite, tests were carried out in conjunction with University College, London, to develop a method of achieving a graphical output at 1:100,000 with contours, together with a digital terrain model with 50-m grid spacing.

Photogrammetric plotting was undertaken initially using the Kern DSR-11 analytical plotters, but later using the DSR-15. Results proved comparable to similar mapping of Yemen produced from conventional air photography. By the end of 1990 all 11 sheets in the mapping block were at the final print stages, with the trial sheet published.

### Topographic mapping

In cooperation with the Survey Authority, Sana'a, OSD produced a further 77 sheets of Yemen, 1:50,000 series, in Roman script; Arabic versions, incorporating revision where necessary, were published for 69 sheets. As reported above, work was well in hand to achieve 1991 publication of the 11 sheets at 1:100,000 of the north-east mapping block derived from SPOT imagery (see table 1).

The Natural Resource Institute, and staff from the former LRDC, continued to provide assistance to Indonesia in the preparation of 1:250,000 base maps to "backdrop" land resources mapping.

### Remote sensing

For Yemen, OSD investigated the possibilities of using satellite imagery to source 1:100,000 topographic mapping. Initial experiments involved the use of LANDSAT-TM Band 5 imagery, from EOS. Subsequently, panchromatic stereo-imagery from SPOT-1 became available, and as reported above, after a series of development trials the production of 11 sheets at 1:100,000 was successfully completed in 1989/90.

OSD are currently involved with the National Survey Authority of Oman in the preparation of a 1:50,000 scale experimental SPOT image orthophotomap.

For the Land Resources mapping project with the Government of Indonesia extensive remote sensing coverage of that country was obtained. Most of the imagery was from SPOT or thematic mapper, but MSS and SLAR images were also used to source some of the thematic mapping.

### Thematic mapping

OSD undertakes the fair drawing and printing of thematic mapping, where the geological, land-use, or other specialist information is supplied by the appropriate organizations.

During the reporting period the only project involving Asia and Pacific countries has been to provide Vanuatu with assistance in printing 1:100,000 geological maps.

Following the work of the LRDC, the NRI have continued to provide assistance to Indonesia to support the Regional Physical Planning Programme for Transmigration. In addition to the land-use maps at scale 1:250,000 covering many of the outer islands, thematic maps on a wide range of subjects have been prepared (table 2).

### Hydrographic surveying

HMS *Herald* was deployed on surveys in the Gulf and the Red Sea during 1988 and 1989. Details are given in table 3.

In addition to the secondment of experts, the Hydrographic Office continues to provide assistance in the form of advice on surveying and training to a number of countries in the Asia and Pacific region (see table 4).

Secondments and attachments in the reporting period include those to Fiji, Australia, New Zealand and Oman.

### Navigational charts

The British Admiralty chart series constitutes a compact navigational outfit of about 3,300 sheets distributed through a worldwide agency system. Details of the publication of new charts and new editions are contained in the weekly Admiralty "Notices to Mariners" and included in the cata-

TABLE 1 TOPOGRAPHIC AND THEMATIC MAPS PRODUCED BY THE OVERSEAS SURVEYS DIRECTORATE, ORDNANCE SURVEY: ASIA/PACIFIC COUNTRIES, 1986-1990

| *Country* | *Scale* | *Description* | *Sheets* |
|---|---|---|---|
| Vanuatu | 1:100 000 | Geological (reprints) | 3 |
| Yemen | 1:50 000 | English versions | 77 |
| | | Arabic versions | 69 |

TABLE 2 THEMATIC MAPS PRODUCED BY THE LAND RESOURCES DEVELOPMENT CENTRE AND THE NATURAL RESOURCES INSTITUTE: ASIA/PACIFIC COUNTRIES, 1986-1990

| *Scale* | *Thematic map* | *Sheets* |
|---|---|---|
| 1:250 000 | Land systems | 237 |
| | Land use | 237 |
| | Land status | 216 |
| 1:500 000 | Mean annual rainfall | 10 |
| | Major river catchments | 10 |
| | Mean annual wet months | 10 |
| | Mean annual dry months | 10 |
| | Mean length growing period, arable | 10 |
| | Mean length growing period, trees | 10 |
| 1:2 500 000 | Geology | 1 |
| | Mineral and energy sources | 1 |
| | Mean annual rainfall | 1 |
| | Agro-climatic zones | 1 |
| | Groundwater potential | 1 |
| | Physiographic types | 1 |
| | Physiographic regions | 1 |
| | Soils | 1 |
| | Land cover and suggested revised forest zoning | 1 |
| | Land use and 1982 forest class | 1 |
| | Environmental hazards | 1 |
| | Transmigration sites | 1 |
| | Population distribution | 1 |
| | Regional development | 1 |

TABLE 3 HYDROGRAPHIC SURVEYS BY ROYAL NAVY SURVEY VESSELS: ASIAN/PACIFIC WATERS, 1986-1990

| *Vessel* | *Area surveyed* | *Scale* | *Year* |
|---|---|---|---|
| HMS Herald | UAE: Fujayrah Anchorage | 1:50 000 | 1988 |
| | Gulf Routes | 1:25 000 | 1989 |
| | UAE: Ajman Harbour | 1:5 000 | 1989 |
| | UAE: Port Rashid | 1:10 000 | 1989 |
| | Red Sea—July Oilfield | 1:25 000 | 1989 |
| | Bahrain: Approaches to Bahrain | 1:25 000 | 1989 |
| | UAE: Jabal Ali | 1:25 000 | 1989 |

logue of Admiralty charts, which is updated every year. Steady progress continues to be made in the modernization and metrication of the Admiralty series; 59 per cent of the series are now published in metric format.

Metrication of Oman will be completed with the publication of a new chart of the southern approaches to Masirah, which is scheduled for early 1991. Metrication of the Red Sea continues and now includes four charts of Jeddah and its approaches. A *Mariners' Routing Guide* to the Gulf of Suez was published in 1988, providing information on passage planning, hazards which may be encountered in the Gulf of Suez, radio reporting and local regulations.

The large- and medium-scale metrication of the Solomon Islands and Vanuatu is complete and the large-scale metrication of Fiji is due for completion in 1991. The 1:1,500,000-scale metric cover of Micronesia will be completed shortly.

The metrication of coastal charts of Sarawak and the west coast of Sabah has been completed; a similar programme for the east coast of Sabah is to be started shortly. Effort is also being made to metricate coastal and passage charts of western Indonesia.

Metrication of Hong Kong, incorporating modern surveys carried out by the Hong Kong Marine Department, has been completed. Hong Kong is currently in the process of setting up its own unit for the compilation and production of nautical charts.

Metrication of the west coast of Thailand is due to be completed in 1991. A programme for a new metric series of charts of Viet Nam and Cambodia is to be commenced shortly.

As mentioned before, the Directorate General of Military Survey has published one new ONC for South-East Asia and

TABLE 5 AERONAUTICAL CHARTS PRODUCED BY THE DIRECTORATE GENERAL OF MILITARY SURVEY: NOVEMBER 1986–DECEMBER 1990

| *Series* | *Scale* | *Published* | *In production* |
|---|---|---|---|
| Operational Navigation (ONC) | 1:1 000 000 | L-10 (1990) | |
| Tactical Pilotage (TPC) | 1:500 000 | G-4C (1986) | |
| | | H-7D | |
| | | H-5B (1988) | |
| | | J-6C | |
| | | L-10B (1989) | L-10A (1991) |
| | | L-11B* | |

*TPC L-11A has been superseded by an extension to the sheet lines of TPC L-11B

TABLE 4 TRAINING PROVIDED TO STUDENTS FROM ASIA/FAR EAST AND PACIFIC COUNTRIES AT THE ROYAL NAVY HYDROGRAPHIC SCHOOL

| *Course* | *1987* | *1988* | *1989* | *1990* |
|---|---|---|---|---|
| Officers' Basic | 1 Indonesia | | | 1 Fiji<br>1 Indonesia<br>1 Singapore |
| Officers' Long | 3 Australia<br>1 New Zealand<br>1 Indonesia<br>2 Malaysia | 1 Australia<br>2 Malaysia | 2 Australia<br>1 New Zealand<br>1 Pakistan | 1 Fiji<br>2 Malaysia |
| Senior Rating | | 2 New Zealand | 1 New Zealand | |
| Able Seaman | | | | 2 Oman |

TABLE 6 SECONDMENT OF STAFF FROM ORDNANCE SURVEY AND HYDROGRAPHIC OFFICE TO ASIA/PACIFIC COUNTRIES, 1986-1990

| *To* | *Expert* | *Duration of service* |
|---|---|---|
| Fiji | Hydrographic surveyor (Lt Cdr) | Oct 1986-Dec 1990 |
| Indonesia | Senior survey and mapping adviser | Feb 1989-Dec 1990 |
| | Survey and mapping adviser | Feb 1989-Dec 1990 |
| | Land survey adviser: Irrigation Directorate | Nov 1986-Dec 1987 |
| | Cartographer: physical planning and transmigration | Oct 1986-Dec 1989 |
| | Surveyor and photogrammetrist: Irrigation Directorate | Nov 1986-May 1987 |
| Kiribati | Lands and surveys adviser | Oct 1986-May 1987 |
| Mauritius | Surveyor | Oct 1986-Nov 1988 |
| | Adviser in digital mapping | Aug 1990-Dec 1990 |
| Sri Lanka | Cartographer 1: land-use mapping | Mar 1989-Dec 1990 |
| | Cartographer 2: forestry mapping | Sept 1990-Dec 1990 |
| Vanuatu | Senior survey adviser | Oct 1989-Dec 1990 |
| Yemen | Survey and mapping adviser 1 | Oct 1986-Sept 1989 |
| | Survey and mapping adviser 2 | Feb 1990-Dec 1990 |
| | Surveyor | Oct 1986-May 1989 |
| | Print technician | Mar 1988-Dec 1990 |
| | *Short-term attachments and consultancy visits* | |
| Bangladesh | Consultancy visit, computerized land records | 2 months 1988 |
| India | Training advisers 1 cartography | 2 months 1987/88 |
| | Training advisers 2 map reprographics | 2 months 1987/88 |
| Indonesia | Map records/archivist | 3 months 1986/87 |
| | Map records consultancy | 3 months 1990 |
| | Surveyor training × 3 | 9 months 1989/90 |
| | Digital mapping consultant | 3 months 1990 |
| Iraq | Consultancy visit, GIS for urban use | 2 months 1989/90 |
| Solomon Islands | Map revision training | 2 months 1990 |

six new TPCs for the Middle East and Malaysia. Currently, one other TPC is in production (table 5).

## SECONDMENTS

OSD staff have been seconded to a number of countries in the region to assist in surveying and mapping projects, to provide specialist expertise and to fill essential posts while the incumbents are released for further training. Staff are currently in post in Indonesia, Sri Lanka, Vanuatu and Mauritius and during the review period have also undertaken secondments to Yemen and to Kiribati. In addition, short consultancy and adviser visits have been made to India, Iraq, Bangladesh and the Solomon Islands (see table 6).

The Royal Navy continued to provide a surveying officer to fill the post of Chief Hydrographer, Fiji, until December 1990.

In conjunction with the NRI, OSD provided cartographic experts to assist with Land Resources and Forestry mapping in Indonesia and Sri Lanka.

## TRAINING

Information on training courses in the United Kingdom for overseas students in surveying and mapping is given in another paper being presented at this Conference under agenda item 9. OSD also produces a booklet which lists in summary form the wide range of courses in the United Kingdom.

The OSD continues to provide practical, technician-level training in cartography, photogrammetry, and reprographics for students from survey and mapping departments in developing countries. The reputation of the former DOS for the high quality of training has been maintained and there is a continuing demand for this form of skill development training. Over the past four years the Training School has provided courses for about 80 students, of whom over 30 per cent have come from the Asia and Pacific region (table 7).

In recent years there has been a demand for a greater range of training and for shorter and more specialist study attachments to provide an understanding of the newer developments in the surveying and mapping fields. Recent courses have included attachments to the Ordnance Survey for print management training, advanced photogrammetry, digital mapping, the Global Positioning System, map library and record keeping, as well as cartographic upgrading courses.

Most secondments to overseas government departments include an element of training and technological skill transfer. Worthy of particular mention are the secondments to the forestry mapping project in Sri Lanka and the print training attachment to the Survey Department of Yemen.

Training in hydrographic surveying was provided at the RN Hydrographic School at Devonport for a number of personnel, details of which were given in table 4.

Short training courses in nautical charting were provided at the Taunton office for cartographers from Brunei (in 1988) and from Fiji (in 1989).

TABLE 7 TRAINING PROVIDED FOR STUDENTS FROM ASIA/PACIFIC COUNTRIES AT THE ORDNANCE SURVEY

*(Number of students)*

| *Course* | *1986/87* | *1987/88* | *1988/89* | *1990* |
|---|---|---|---|---|
| Cartography | 5 Philippines<br>1 Burma | 5 Philippines<br>1 Kiribati | 3 Philippines<br>1 Sri Lanka<br>1 Jordan | 1 Jordan<br>1 Yemen<br>2 Sri Lanka |
| Reprographics | | 2 India | | |
| Carto/repro | | | 1 Burma | 2 Jordan |
| Map records | | 2 Indonesia | | |
| Photogrammetry | | | | 1 Indonesia |
| Production management | | | 1 Jordan | 1 Indonesia |

## STATUS OF CARTOGRAPHIC ACTIVITIES IN THE UNITED STATES*

*Paper submitted by the United States of America*


### RÉSUMÉ

Depuis la onzième Conférence cartographique régionale des Nations Unies pour l'Asie et le Pacifique, les activités cartographiques des Etats-Unis se sont développées et ont bénéficié des progrès récemment intervenus dans les domaines de l'informatique, de la télédétection, des systèmes d'information géographique et des systèmes de positionnement inerte et par satellite destinés à appuyer les programmes de levé et d'établissement des cartes.

Dans toutes les phases de l'établissement des cartes aux Etats-Unis, l'influence des techniques et équipements cartographiques automatisés s'est nettement fait sentir. On a recours à l'informatique pour la compilation, la révision, la mise à jour et la production des cartes topographiques, des orthophotocartes et des cartes sur fond d'image ainsi que des cartes aéronautiques et nautiques.

Les progrès réalisés en informatique au cours des cinq dernières années ont incité les organismes cartographiques fédéraux à redoubler d'efforts en vue de créer des bases de données numériques utiles à l'étude de la géologie, des sols, de l'hydrologie, de l'utilisation des sols et de la couverture végétale. Depuis 1984, des normes pour les données cartographiques numériques ont été mises au point et acceptées par l'ensemble de la communauté cartographique, ce qui représente un progrès considérable.

Le Geological Survey du Département de l'intérieur des Etats-Unis est responsable, sur le plan national, de l'établissement et de la diffusion de cartes à usages multiples ainsi que de données cartographiques de base sous diverses formes. Ces dernières années, le Geological Survey des Etats-Unis a axé ses efforts sur la numérisation des grandes catégories de données figurant sur les cartes topographiques (hypsographie, hydrographie, systèmes de transport, etc.) afin de créer une base de données cartographiques numériques nationale. D'autres organismes fédéraux sont chargés de collecter d'autres données cartographiques présentant un intérêt pour le public. Le National Ocean Service de la National Oceanic and Atmospheric Administration est responsable des levés géodésiques et de l'établissement des cartes aéronautiques et nautiques. La Defense Mapping Agency du Département de la défense est responsable de l'établissement de cartes et de produits géodésiques, sur une base mondiale, en vue de répondre aux besoins de la défense nationale, ainsi que de produits cartographiques nautiques et aéronautiques destinés à assurer la sécurité de la navigation.

Les activités des principaux organismes fédéraux de cartographie au cours de la période considérée sont examinées.


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Since the Eleventh United Nations Regional Cartographic Conference for Asia and the Pacific was held in 1987, cartographic activities in the United States have expanded to include recent advances in computer technology, remote sensing, geographic information systems, and inertial and satellite positioning systems in support of surveying and mapping programmes.

All phases of mapping and charting in the United States have been significantly influenced by the development and implementation of automated cartographic techniques and equipment. The application of computers to cartographic activities has included compilation, revision, maintenance and production of topographic, orthophoto and image maps, and aeronautical and nautical charts.

Advances in computer technology over the last five years have prompted federal mapping and charting agencies to increase their efforts in building digital databases of categories that are useful to the study of geology, soils, hydrology, land use, and land cover. A major achievement since 1984 has been the development and general acceptance of standards for digital cartographic data throughout the cartographic community.

The United States Geological Survey (USGS) of the Department of the Interior has the domestic responsibility of preparing and making available multi-purpose maps and base cartographic data in a variety of forms. In recent years, USGS has concentrated on digitizing base categories of data found on topographic maps, such as hypsography, hydrography, and transportation systems, to create a National Digital Cartographic Data Base. Other federal agencies are responsible for collecting additional map data of public value. The National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA) is responsible for geodetic surveys and for the preparation of aeronautical and nautical charts. The Defense Mapping Agency (DMA) of the Department of Defense is responsible for the preparation of maps, charts and goedetic products on a worldwide basis to meet national defence requirements and for the preparation of nautical and aeronautical products to support safety of navigation.

The activities of these primary mapping and charting federal agencies in the United States during the reporting

*The original text of this paper appeared as document E/CONF.83/L.24. Use of trade names and trademarks in this report is for identification purposes only and does not constitute endorsement by the United States Government.

period are discussed under the following headings:

| | |
|---|---|
| Geodesy | Aeronautical Charting |
| Image Mapping | Geographical Names |
| Topographic Mapping | Digital Cartography |
| Hydrography and Oceanography | Global Change |

## GEODESY

The primary mission of the National Geodetic Survey (NGS) is to establish and maintain the national geodetic horizontal, vertical, and gravity networks that make up the national geodetic reference system (NGRS). Progress in improving the NGRS during fiscal year 1990 is described below.

### *Global Positioning System*

NGS continued the application of the global positioning system (GPS) to geodetic surveying, including the development of software packages, transfer of technology to other government agencies and the private sector, and determination of precise GPS orbits for the surveying community.

The application of GPS technology, using signals from the satellites of the NAVSTAR system being established by the Department of Defense, continues to be an efficient, economical, and accurate survey system.

NGS completed GPS surveys with 5 Texas Instrument model TI4100, 11 Trimble Navigation model 4000 ST, and 5 MACROMETER model V1000 GPS satellite survey systems. The MACROMETER and TI4100 receivers were retired and replaced during the year with 10 Trimble Navigation model 4000 ST GPS satellite survey systems.

NGS observed GPS satellite surveys in the vicinities of the tangent point to the Colville River area, Alaska; the Loma Prieta earthquake and Salton Trough areas, California; York County, the South Edisto river basin, and the hurricane "Hugo" storm-damaged areas, South Carolina; and in Alaska, Oregon and Washington for the purpose of statewide network upgrades. GPS surveys were also observed for the Departments of Transportation in Alaska, Florida, Michigan and Minnesota; the Nuclear Regulatory Administration; the Central Intelligence Agency; the National Crustal Motion Network project in Alaska and California; and seven projects in support of the Airport Datum Monumentation (ADAM) programme of the Federal Aviation Administration (FAA).

In addition to the above NGS-observed GPS surveys, 32 GPS survey projects were received from other agencies, including: U.S. 431, Highway 55, Highway 278, Corridor X and the Montgomery Test, Alabama; Morgan Hill, Calexico to Thermal, Huntington Beach, Tulare County, Fresno/Monterey counties and Butte/Tehama counties, California; Delaware/Pennsylvania boundary; Tallahassee/Leon counties, Marion/Volusia counties, State Route 40, U.S. Route 17 and Hillsborough County, Florida; Harford County densification, Maryland; Muskingum County and densification, Rhode Island; Cherokee County, Georgetown; Greenville and Orangeburg County, South Carolina; Chatham County, Texas; York County and Westmarket/Prince William County, Virginia; and the city of Appleton, Wisconsin.

The projects completed were in support of varied requirements, including: extension and densification of NGRS; monitoring of vertical and horizontal displacements associated with tectonic movements; monitoring crustal motion network stations and connecting FAA airports to NGRS; Global Mean Sealevel studies; state and county geodetic network and control survey upgrades; and state highway surveys. NGS observed the following projects between October 1989 and September 1990 using GPS surveying techniques:

| | |
|---|---|
| Number of projects | 19 |
| Number of receivings per project | 5/6 |
| Total stations occupied | 2,244 |

NGS participated in tests and demonstrations of two GPS satellite surveying systems. These tests make a total of 14 tests conducted since 1983 by the Federal Geodetic Control Committee (FGCC) on the FGCC test network located near Washington, D.C.

Use and enhancement of in-house GPS orbit computation software continue. Tracking data for 14 GPS satellites are being routinely received from 12 Cooperative International GPS Networks (CIGNET) and 5 Defense Mapping Agency (DMA) tracking stations throughout the world. The CIGNET data are prepared for archiving storage and distribution and are used with the orbit software package PAGE to compute precise GPS orbits. The DMA data are being used to check the results. This computational effort began the transition from the distribution of precise GPS orbits computed formerly by the Naval Surface Warfare Center and now by DMA to NGS-computed orbits for the civilian GPS user community. A planned April 1990 start for release of the CIGNET orbits was delayed until November 1990 because of the start of selective availability on the GPS satellites by the Department of Defense and its effect on orbit computation techniques and software.

Other fiscal year 1990 GPS satellite survey developments were as follows:

(*a*) Operational kinematic GPS field units completed observations in support of the FAA ADAM programme in Arkansas, Florida, Michigan and Missouri. Plans are being developed to observe the FAA LORAN-C airport programme in a similar manner.

(*b*) The operational use of the GPS vector reduction package OMNI continued in the office and on two of the NGS/GPS field units. The software package has been used successfully with data from four different GPS receivers and progress has been made with vector computations using mixed receiver combinations within the same observing session.

(*c*) All NGS/GPS field units are now capable of doing least-squares adjustments of field-reduced vector data. Two of the four units carry out this analysis on a routine basis.

(*d*) All orbit-tracking data and computation results, office vector computations, field computations and raw GPS observations are routinely archived on optical WORM (Write Once, Read Many) disks. This significantly reduces the cost of storing the data and the space required, and extends the projected usable life-span of the storage media when compared with nine-track tapes.

*United States Geological Survey (USGS).* GPS surveying techniques have become the predominant means by which mapping control is established and are playing an increasing role for geophysical surveys. Point positioning techniques are used extensively in support of all National Mapping Division map control work and GPS is also being used in Antarctica to support a variety of scientific projects sponsored by the National Science Foundation. Kinematic collection methods have demonstrated significant gains in productivity. The most promising is the GPS-controlled aerial photogrammetric technique, which is being tested for use in the revision of standard quadrangle maps.

The Geologic Division is using advanced GPS data reduction techniques to measure crustal deformation in tectonically active areas in the western conterminous United States, Alaska and Hawaii GPS surveys will be used to establish new crustal monitoring networks and are being groomed to replace the geodolite for existing networks. Deformation networks in the Long Valley Caldera and the San Francisco Bay area are currently being remeasured. Future biannual measurements of a number of four- to six-station geodolite networks along the San Andreas fault will be made using GPS.

The Water Resources Division is using GPS surveys to establish control for Superfund sites and to determine the elevations of well-heads for hydrological studies. Projects include the Fork River EPA Superfund site in Butte, Montana, and the Ciba-Geigy site at Toms River, New Jersey. GPS survey systems were purchased in 1989 for use in the south-eastern United States and will be shared by five district offices. Work also continues measuring the Sacramento, California, subsidence network.

*Defense Mapping Agency (DMA).* DMA continues to exploit the GPS for geodetic purposes. DMA operates a worldwide GPS satellite tracking network and has established a computer facility for the generation of GPS precise orbits. Data from the DMA network and the Air Force GPS monitor stations are used for orbit generation. DMA has assumed full responsibility for generation of these orbits from the Naval Surface Warfare Centre (NSWC) which was funded by DMA to develop the orbit reduction capability. The state-of-the-art programme for orbit generation is called OMNIS, which uses Kalman filtering and smoothing techniques. DMA has developed a GPS absolute positioning capability, and has procured relative positioning software.

*Technology transfer*

The NGS headquarters office personnel again trained field personnel as well as employees of other federal agencies in the use of microcomputers and GPS vector computational procedures. Two three-week training sessions in GPS technology were conducted for employees of the Bureau of Land Management (BLM), the Forest Service, and the Bureau of Reclamation. Under provisions of a formal Memorandum of Understanding, NGS is assisting BLM offices in their implementation of GPS for cadastral survey applications.

GPS technology transfer was also supported by participation in panel discussions, technical papers, speeches and the training of scientists and surveyors visiting NGS, both national and international. NGS continues to be an international focal point for GPS field-work, development and information. NGS is committed to the continued development of GPS as the primary surveying system for both the public and private sectors.

NGS continued to coordinate development of *Multipurpose Land Information Systems: The Guidebook.* The first release (chapters 1 through 3) was published in February 1990, the second release (chapters 4 through 7), in October 1990.

The National Oceanic and Atmospheric Administration (NOAA) state geodetic advisory programme is a cooperative fifty-fifty cost-sharing programme between federal and state governments. NOAA assists the states with their charting, geodesy and surveying programmes; suggests maintenance functions; ensures that surveys performed by the states meet federal standards and specifications; and helps in the transfer of new surveying technologies.

*Horizontal geodetic network*

The final report of the North American Datum of 1983 (NAD 83) was printed. Horizontal geodetic adjustments are now computed in SUN workstations. Graphics are being developed to analyse the new observations against the existing network. All in-house computers retrieve data from the NGS Integrated Data Base. Results of the computations are stored in the database within one month of completion.

Processing of horizontal data into NAD 83 continued with new GPS projects and classically observed projects. The current backlog consists of 368 projects containing 20,150 stations. An additional 84 projects, consisting of 5,745 stations, are in progress. In the past year, 115 projects containing 13,350 stations were completed.

Cooperative efforts to provide horizontal control were conducted in Florida, Alaska, Oregon, Michigan, and York County, South Carolina. Special projects were conducted in the natural disaster areas of the Loma Prieta earthquake in California and hurricane "Hugo" in South Carolina.

The cooperative efforts in the states of Florida, Tennessee and Oregon involve high accuracy (one part in 1,000,000) global positioning surveys. The development of high accuracy vector reduction techniques and network adjustment analysis has led to a new policy on integrating these results with the existing NAD 83 network.

To aid users of geodetic data, development was completed on a datum transformation technique between NAD 27 and NAD 83. The Corps of Engineers adapted this new North American Datum Conversion program to use and produce State Plane coordinates and Universal Transverse Mercator coordinates.

NGS continued to provide the FAA with horizontal control at 1,400 airport facilities. These airports have instrument approach procedures but no obstruction control surveys. During the last year, datum tie observations were made at 269 airports. Final coordinates were computed for 191 airports. Since the beginning of the project, coordinates have been computed for 914 airports.

Transfer of technology to state, county, and private surveyors and engineers continues to be an increasingly important activity within NGS. Two 1-day Coordinate Transformation Workshops and three one-day Use of the State Plane Coordinate System Workshops were presented through co-sponsorship with the American Congress on Surveying and Mapping.

Another aspect of the vertical control effort, the definition of a new vertical datum, will define the new reference surface on which to base the improved geodetic heights. The datum definition effort requires consideration of all agencies that will be impacted, including the United States Army Corps of Engineers, Defense Mapping Agency, Department of Energy, Federal Emergency Management Administration, United States Geological Survey and state and local users. Meetings will be held with each interested agency, and their requirements will be considered in the datum definition decision.

*Post-NAD 83 regional adjustment*

Because of the excellence of results obtained from GPS-based interferometric geodetic surveys, as well as the lower costs involved in making GPS surveys, states are considering the upgrading of their horizontal geodetic control networks by means of statewide, high precision GPS surveys in support of mapping, civil engineering projects and land information systems.

Cooperative efforts in the states of California, Colorado, Florida, Maryland, Tennessee, Oregon, Wisconsin, Washington and New Mexico involve high accuracy (one part in 1,000,000) global positioning surveys. Organizations in Delaware, Idaho, Montana, Utah, Virginia and Wyoming are actively considering similar upgrades. The development of high-accuracy vector reduction techniques and network adjustment analysis has led to a new policy on integrating these results with the existing NAD 83 network.

*Vertical geodetic network*

The new adjustment of the North American Vertical Datum of 1988 (NAVD 88) continued with the NGS counterpart agencies in Canada, the Geodetic Survey Division (GSD) of the Canada Centre for Surveying, and Mexico, the Instituto Nacional de Estadística, Geografía e Informática (INEGI). During fiscal year 1990 international cooperation was enhanced by technical exchange meetings, exchange of levelling data, and continued joint investigation of several technical and research areas involving NAVD 88. Completion of the primary phase of the new adjustment is scheduled for December 1990, with publication of resulting heights during 1991-1992. Some accomplishments of the National Ocean Survey (NOS) in support of the new adjustment associated with NAVD 88 are highlighted in the table below.

| *Accomplishment* | *1990* | *Total to date* | *Total programme* |
|---|---|---|---|
| New NAVD levelling surveys performed (km) | 2 225 | 81 160 | 81 500 |
| New levelling surveys processed (km) | 11 200* | 137 700 | 138 500 |
| Helmert blocking (data cleansing) performed (number of blocks) | 68 | 68 | 101 |

*Includes both NGS and non-NGS surveys

The vertical control portion of NGRS was strengthened by field survey projects in support of the NAVD 88 readjustment programme, cooperative levelling projects and levelling by state and county organizations. These surveys were accomplished primarily by NGS field units, USGS, the Metropolitan Water District of Southern California, the New Jersey Geodetic Survey, the North Carolina Geodetic Survey, the Los Angeles municipal government, Imperial and Ventura counties, California, the Florida Department of Transportation, the Minnesota Department of Transportation and the Mississippi Highway Department.

Cooperative surveys involving NGS field and office personnel (cooperating organizations in parentheses) included:

(*a*) Densification of vertical control in Harford County, Maryland (Harford County);

(*b*) Establishment of heights above mean sealevel for benchmarks used to determine deflection of the vertical by combining levelling and GPS data, Colonial Beach, Virginia (Naval Surface Warfare Center);

(*c*) Vertical control for the interstate highway system in the vicinity of Omaha, Nebraska (Nebraska Department of Roads);

(*d*) Levelling to support GPS surveys in the Coeur D'Alene area, Idaho (Idaho Transportation Department);

(*e*) Vertical control densification in Wicomico County, Maryland (Maryland State Highway Administration, Federal Highway Administration, and Wicomico County Public Works);

(*f*) Levelling to determine vertical deformation caused by the Loma Prieta earthquake in California (USGS);

(*g*) Re-establishment of baselines along the South Carolina coast after hurricane "Hugo" (South Carolina Coastal Council);

(*h*) Re-establishment of vertical control for Santa Cruz County, California, following the Loma Prieta earthquake (Santa Cruz County).

Several research activities are under way in support of the New Adjustment of NAVD 88. These include crustal motion effects and models, and orthometric heights derived from GPS ellipsoidal heights and gravity data.

Research in support of the redefinition of the International Great Lakes Datum (IGLD) included: updating all water-level transfer data from both Canada and the United States into the NGS database; processing and loading a portion of the Canadian levelling network into the NGS database; performing and analysing special adjustments combining Canadian and United States water-level transfer data and levelling data; and performing check levelling to detect data outliers in the levelling data.

With the completion of the majority of the NAVD 88 relevelling programme, the Vertical Network Branch of NGS has undertaken a special study to compile a primary vertical control network using the latest data available. This network consists of 202 loops containing 903 junction benchmarks. The network connects to 58 primary tidal stations, which are part of the National Primary Tidal Network, and 26 water-level stations along the Great Lakes. In addition, 26 connections were made to the Canadian vertical control network and 14 to the Mexican vertical control network. All geopotential differences have been generated and validated, using actual gravity values. Loop closures were computed, a least-squares adjustment performed, and data outliers were detected and removed. Adjustments imposing various datum definition scenarios have been performed.

The results of the study have been documented. The report has been reviewed by NGS, Canadian GSD, and Mexican INEGI personnel. Meetings were held to discuss and analyse the results. In addition, a list of United States agencies' products and services affected by NAVD 88 and a preliminary NAVD 88 implementation plan have been drafted. An FGCC Vertical Subcommittee has been meeting periodically to determine and document the impact of NAVD 88 on users.

Several technology transfer activities were directed toward state, local, and private surveyors and engineers. A two-day Vertical Control Workshop was presented in Seattle, Washington. Several other workshops, including those covering geographic information systems, coordinate computation and coordinate transformations, were coordinated through the Vertical Network Branch of NGS.

*Gravimetric network*

The Space and Physical Geodesy Branch of NGS is responsible for the relative gravity programme and the Geodetic Research and Development Laboratory is responsible for the absolute gravity programme.

*Relative Gravity Program.* NGS maintains a gravity data bank containing approximately 1.8 million observed gravity records. This data bank was extended by the addition of 185,000 gravity point values in the Mexico region obtained from the University of Texas at Austin. These data will strengthen the geoid definition in the south-west conterminous United States (CONUS).

Observation records of the gravity data bank were transferred into the NGS Integrated Data Base, resulting in better use of this essential resource and improved data integrity and security. The gravity data holdings of NGS were recently furnished to the National Geophysical Data Center in Boulder, Colorado, where they have been included in a compact disk "read-only medium" (CD-ROM) for efficient dissemination to users.

A new NGS product in the form of interpolated gravity was made available to the public. These gravity values are derived from observations; they are frequently requested for the calibration of various instruments which are affected by the local variations of the gravity field.

Geoid height values were also derived from GPS-determined ellipsoid heights and measured orthometric heights (i.e. obtained from levelling). Systematic deviations of gravimetrically derived geoid heights from GPS-levelling determined values were estimated via least-squares techniques. The fitting of gravimetric geoid to the GPS framework by the removal of systematic differences facilitates the densification of orthometric heights. Orthometric heights derived by these techniques are being used for vertical control in aerial photogrammetry.

Numerical techniques were investigated for the estimation of accurate gravity values for the NAVD 88 network adjustment. A weighted least-squares technique provided acceptable accuracies in interpolated gravity where dense observed gravity values were available. However, the estimated accuracies were judged to be inadequate in sparsely covered areas. Another technique, employing the multi-quadratic model of Hardy, provided accurate and reliable values in all geographic areas in the CONUS and was adopted for interpolating gravity at the 900,000 benchmark stations of the NAVD 88 datum.

The cooperative project between the Geophysics Division of the Geological Survey of Canada and NGS was continued. The optimal application of the Fast Fourier Transform method to gravity field modelling was investigated. Results of these investigations were accepted for publication in the *Bulletin géodésique* journal.

*Absolute Gravity Program.* The JILAG #4 absolute gravity instrument has been used to monitor gravity changes associated with vertical crustal motion under the NOAA Climate and Global Change Program. During the year 12 stations were occupied, including observations taken during the Third International Comparisons of Absolute Gravimeters in Sèvres, France, and the establishment of reference gravity values in Wettzell, Germany, and Edinburgh, United Kingdom. Since the measurement programme started in April 1987, approximately 85 gravity determinations at about 50 sites have been accomplished.

The instrument underwent testing and modifications during the year, and new data collection and analysis procedures have been developed. Part of the modifications and new procedures served to largely eliminate the effect of systematic floor vibrations on the measurements. A floor-gravimeter system response correction of +16 microgal was computed and added to the data at Wettzell, strongly suggesting that some of the large differences noted among the observations of absolute gravity by different instruments at the same sites could have been due to their different response to systematic vibrations. Due to these improvements, the scatter about the mean of the absolute gravity values at repeated sites has been reduced to 2 microgals or less.

The superspring assembly modifications included the addition of restraints allowing transportation of that component as regular cargo without damage, and the installation of a temperature compensating circuitry eliminating data loss due to bottoming of the superspring mass. Designs for both of these modifications were obtained from the Canadian Geological Survey.

*Geodetic astronomy*

The Defense Mapping Agency (DMA) provides geodetic and geophysical support to the United States Department of Defense. DMA is involved in satellite geodesy, gravity collection and evaluation and determination of world geodetic systems.

*World Geodetic System 84 (WGS 84)*

The DMA produces numerous mapping, charting, geodetic, gravimetric and digital products in support of the Department of Defense. It is advantageous to refer these products to a single geocentric coordinate system for many reasons. Such a system is needed due to accuracy and user interface considerations, the need for a product to support the widest possible range of applications (local, worldwide), the need to relate information from one product to data obtained from another source and the need to ensure a smooth transition in product use from one part of the world to another. In accomplishing the above, such a geocentric system, termed a world geodetic system, provides the basic reference frame and geometric figure for the Earth, models the Earth gravimetrically and provides the means for relating positions on various local geodetic systems to an Earth-centred, Earth-fixed (ECEF) coordinate system. In brief, a world geodetic system serves as the framework for DMA products and worldwide defence operations.

*National Geodetic Information Center*

This branch of NGS distributed geodetic information products to satisfy current and anticipated user requirements. These products include the results of geodetic surveys, software programs to compute, verify and adjust original survey observations, and publications describing how to obtain and use geodetic data and application products. The Center also conducts a marketing programme to increase user awareness and understanding of these products and to improve NGS responsiveness to its users.

As part of its marketing programme, NGS accomplished the following:

(*a*) Conducted workshops on how to obtain, understand, and use NGS information products;

(*b*) Displayed and described NGS products, services, and programme activities at more than 20 symposia and professional society meetings throughout the United States;

(*c*) Distributed Lambert projection tables for the State Plane Coordinate System of 1983, allowing users with a minimum of computing resources to compute State Plane coordinates from NAD 83 geographic coordinates;

(*d*) Prepared for distribution a detailed report describing the redefinition and adjustment of NAD 83;

(*e*) Provided users with new publications and software products to help them understand and use coordinate systems based on NAD 83;

(*f*) Distributed new software called VICES (Visual Cartographic Enquiry System) that allows users to plan a survey by easily retrieving and displaying control point and map name information;

(*g*) Conducted cost studies to ensure that the prices for all NGS information products are consistent with agency pricing guidelines and reflect only the costs of duplicating and distributing these products;

(*h*) Implemented an automated sales tracking system that prints invoices, mailing labels, and a daily log of orders; verifies the prices for all information products distributed; and prepares sales statistics for periodic reports and management decisions;

(*i*) Provided numerous publications, historical records, and the results of research investigations in order to fulfil diverse requests from universities, individuals, government agencies and businesses throughout the United States and from other countries.

In addition, the Center undertook the following steps to improve the quality and availability of geodetic data:

(*a*) Began a contract with Management Technology, Inc., to update and automate the backlog of approximately 100,000 station recovery notes;

(*b*) Implemented improved station description processing procedures; also implemented the Description Integration System, a way to unify all description tables in the NGSD Integrated Data Base;

(*c*) Prepared to consolidate data distribution from two locations to one;

(*d*) Submitted a proposal for a unified data sheet to replace separate data sheets for horizontal and vertical control points.

*National Ocean Service GEOSAT altimeter programme*

Prior to its failure in October 1989, the GEOSAT altimeter produced approximately 750,000 global observations of sealevel over a 5-year period. Throughout this time, NOS played a critical role in three areas of the mission: production of data sets for public distribution, near-real-time monitoring of tropical sealevel and climate research.

Under agreement with the United States Navy, NOS produced the GEOSAT data sets (known as Geophysical Data Records or GDRs) in Rockville by combining the raw measurements with a precise orbit, a tide model, and radar path length corrections for delays due to troposphere and ionosphere. GDRs are distributed to the public through NOAA/NESDIS and reach the user within 2-3 months of acquisition during the mission, a remarkably fast turnaround for a global satellite data set. Nearly 40 institutions around the world purchased subscriptions to the GEOSAT data.

In addition to processing the data for public distribution, NOS has developed a programme of tropical sealevel monitoring. The GEOSAT data are processed to derive sealevel change as a function of time, much like island tide-gauge data. During the 1986-1987 El Niño, NOS was able to monitor sealevel changes throughout the tropical Pacific in near-real-time, the first time this had ever been accomplished. An operational sealevel bulletin for the tropical Pacific, Atlantic and Indian Oceans was produced on a monthly basis and distributed to nearly 2,000 users worldwide.

Research is performed not only to interpret tropical ocean changes seen by GEOSAT but also to improve accuracy. This involves incorporation of new satellite ephemerides and tropospheric correction fields and algorithm development. Accuracy can be assessed by comparison with island tide-gauges and with results of wind-driven numerical models. For large-scale sealevel changes, GEOSAT has been shown to be reliable at the sub-centimetre level. This has enabled construction of the first detailed descriptions of sealevel change in the three tropical oceans and the first complete altimetric observation of El Niño.

NOAA's altimeter programme will continue with the launch of European Space Agency remote sensing satellite ERS-1 in April 1991. ERS-1 is an operational satellite which will offer access to most of its global data within three hours of acquisition. Additional altimeter observations to support NOAA's tropical sealevel monitoring programme will be available from NASA's Topographic Experiment (TOPEX) in 1992. Each of these missions is expected to last 3-5 years, providing continuous altimetric coverage well into the 1990s

*Marine geodesy and geodynamics*

As in the previous year, altimeter data from the GEOSAT Exact Repeat Mission (ERM) are also being used to map the marine gravity field for geodetic and geophysical purposes. Starting with the GDRs which are produced by NGSD, multiple repeat cycles are averaged together to produce precise, high-resolution profiles of long-track geoid undulations and deflections of the vertical. Such profiles have been derived from the first two years (44 cycles) of ERM data, in cooperation with Dr. D.T. Sandwell of the Scripps Institution of Oceanography. Within the past six months, improved along-track profiles have been derived using the much more precise GEM-T2 orbits in place of the operational NAG orbits. Comparisons between these along-track profiles and Sea Beam (swath sonar) maps of seafloor along particular ERM groundtracks have been made. These comparisons indicate that the resolution of these along-track altimeter profiles is quite high.

The United States Navy has just declassified and released the previously classified GEOSAT Geodetic Mission (GM) data for the Antarctic (i.e. all latitudes between 60° and 72° south). Final preparation and verification of these GM GDRs are now being performed at NOS. These GM GDRs will be distributed to the public soon through NOAA/NESDIS. The GM groundtracks are much more tightly spaced than the ERM groundtracks; therefore, these GM data should yield a very-high-resolution mapping of the marine geoid and gravity field around the margin of Antarctica. If and when GM data are released for other regions, similar high-resolution mappings will be possible for these other regions. If these GM data do not become available for other regions, then the European Space Agency's Remote Sensing Satellite (ERS-1) altimeter data will be used to produce accomplished high-resolution mappings of the marine gravity field.

*National Ocean Service (NOS) Very Long Baseline Interferometry Programme*

The NOS Very Long Baseline Interferometry (VLBI) observatories continued to participate in the IAG/COSPAR jointly sponsored International Radio Interferometry Survey (IRIS) Earth orientation monitoring programme. The IRIS Earth orientation parameters (EOP) time series are currently the most accurate and stable available. Polar motion (X,Y) values accurate to 1-2 milliseconds of arc at 5-day intervals, UT1 values accurate to 0.05-0.10 milliseconds at 5-day intervals and 0.1 milliseconds at daily intervals are produced routinely. The 5-day observations are also used to estimate corrections to IAU 1980 nutation time series, and to study crustal deformations, develop celestial and terrestrial reference frames, and for other scientific research.

Four antennas operate once every five days for a 24-hour period. Three of these are located in the United States; Westford, Massachusetts; Richmond, Florida; and Mojave, California. The fourth antenna is located at Wettzell, Germany, operated by the Institut für Angewandte Geodäsie. A fifth antenna at Onsala, Sweden, joins the network once a month.

The Mojave and Richmond Observatories also participate in monthly IRIS-P. 300 copies are distributed to users in approximately 40 nations and are available in machine-readable format from NGS.

The geodetic astronomy programme includes daily monitoring of variations in UTI. This effort involves the Westford and Wettzell antennas operating for an hour a day.

In October 1989, NGS loaned a Mark III terminal to the University of Tasmania, Australia, for use at the Hobart Observatory. The observatory is participating in IRIS-S, IRIS-P, and NASA Crustal Dynamic Project (CDP) observing sessions, totalling thirty 24-hour sessions per year.

Beginning in November 1989, NGS loaned, on a long-term basis, a Mark III data acquisition terminal to the Hartebeesthoek Observatory, South Africa, for VLBI observing campaigns involving stations in North America, Europe, Africa and Australia. Observing sessions are scheduled twice per month. Joint observations with the new observatory in Hobart, Australia, have already allowed NGS to extend the celestial reference frame to global coverage.

An agreement was signed by NGS and a consortium of geodetic agencies in Brazil, headed by the University of São Paulo, to develop a new VLBI observatory at Fortaleza, Brazil. NGS obtained a 17-metre radio telescope from the National Science Foundation for redeployment at the new station, and a new data acquisition system, including a VLBI type terminal and H-Maser, is being purchased. Plans are to complete the observatory by the end of 1990.

The mobile VLBI unit, MV-3, was deployed to Europe from May to September 1989, to densify the geodetic control network. A total of six stations in Germany, Finland, Norway, the United Kingdom and France were visited. The observations achieved centimetre level accuracy, providing excellent fiducial sites for GPS surveys in Europe.

Work continued on the Cooperative International GPS Network (CIGNET). New NGS receivers were installed at the Hobart, Australia, VLBI observatory and in Wellington, New Zealand. Additional sites will be added in 1990 to complete the Australian-New Zealand Network referred to as the "Southern Cross".

## IMAGE MAPPING

Remotely sensed image products have been recognized as valuable mapping tools, map supplements and alternatives to standard maps by mapping agencies in the United States. Today, image maps are utilized as interim substitutes for the line maps and as final products that incorporate detail not easily coveyed by line map symbolization. To provide source materials, programmes have evolved in high-altitude photography, orthophotography, satellite imagery and side-looking airborne radar.

### *National Aerial Photography Program*

The National High-Altitude Photography Program, managed by USGS, began in 1980 to acquire 1:80,000-scale black-and-white and 1:58,000-scale colour-infrared photography from a flying height of 40,000 feet (12.2 km). This programme was complete in November 1988, and uniform coverage of the conterminous United States is available from the archives of the Department of Agriculture, the Aerial Photography Field Office, in Salt Lake City, Utah, and the Department of the Interior, United States Geological Survey, in Sioux Falls, South Dakota.

The National High-Altitude Photography Program is a recognized success. It revealed a growing national interest in high-level resolution, colour-infrared photography for a wide variety of applications, such as agriculture, forestry, soils, land and resource management, mapping, and numerous earth-science applications, that require higher resolution than the programme provided. As a result of this interest, federal and state agency users agreed to establish a new programme called the National Aerial Photography Program (NAPP). The new programme, also under USGS management, began in 1987. Photography under the programme is acquired from a flying height of 20,000 feet (6.1 km) with a single 6-inch (15.2 cm) focal length camera exposing colour-infrared film or black-and-white at scale 1:40,000. The resulting photographs are centred on quarter sections of standard USGS 1:24,000-scale 7.5-minute quadrangles. The ground resolution of photography is 1.0 to 1.5 metres, depending on contrast of the terrain.

The first five-year cycle for the programme will be complete after the fiscal year 1991 flying is accomplished. A second cycle called NAPP II will begin in 1992. To date, about 65 per cent of the lower 48 states have been contracted. The NAPP II promises to continue this vital national programme on behalf of the contributing states and federal agencies and the user public.

### *Orthophotography*

Orthophotoquads portray land features on photographic images that have been processed to show surface detail in true position. Orthophotoquads do not include contours and are printed in shades of gray without image enhancements or cartographic symbolization. The demand continues for orthophotoquads to support numerous planning and resource management activities as companion maps to published topographic maps. Approximately 38,000 orthophotoquads have been produced by USGS and are available either as diazo or photographic reproductions. During this reporting period, USGS prepared approximately 56,700 orthophotoquads at scales 1:24,000, 1:12,000 and 1:63,360.

Special purpose orthophotoquads have been produced with enhanced colour portrayal of the terrain and selected cartographic symbolization. The United States/Mexico Border Mapping Project, conducted by USGS in collaboration with the Customs Service, the International Boundary and Water Commission and the Dirección General de Geografía of Mexico, was completed during the reporting period. All 211 1:25,000-scale photo image maps of the border are now published.

### *Satellite image mapping*

USGS has developed routine production techniques for preparing satellite image maps from LANDSAT Multispectral Scanner (MSS) and Thematic Mapper (TM) data and data from the French Satellite pour l'observation de la terre (SPOT). These techniques include digital image enhancement, image mosaicking and methods for graphic image preparation and lithographic printing. Using these techniques, 16 image maps at 1:250,000 scale were printed from LANDSAT-MSS data; 4 image maps at 1:100,000 scale were printed from LANDSAT-TM data; and 2 image maps were printed from SPOT data for areas in the United States. Image maps were produced for a number of foreign areas, including portions of Saudi Arabia, Jordan, United Arab Emirates, Kenya, Argentina and Antarctica.

A significant improvement was made in image enhancement for image mapping through the development of digital image restoration (deconvolution) software. Images processed using the restoration software as part of geometric rectification are both visibly sharper and of higher radiometric fidelity than those rectified without the procedure. Restoration improves image quality by removing sensor-introduced degradations, such as optical blurring and electronic signal smearing. This technique, which was developed by the University of Arizona under contract to USGS, is now applied during the image map preparation process to data from the LANDSAT-MSS and TM, SPOT and Advanced Very High Resolution Radiometer sensors.

USGS also implemented new spatial filtering enhancement procedures during the reporting period. This procedure is considered an optional step, dependent on subject detail and the intended use of the final product. Sometimes referred to as a boxcar spatial filter, it may be used either to modify low-frequency spatial data to increase the effectiveness of the contrast enhancement process, or to modify high-frequency spatial data to provide enhancement. It can also be used for pre-processing and noise removal.

Techniques have been developed for combining satellite image data sets possessing different spatial and spectral characteristics. The majority of this work has centred on combining 30-metre resolution LANDSAT-TM multispectral data and 10-metre resolution single-channel SPOT panchromatic data. This process creates an image that has the spectral information from the TM multispectral data and the 10-metre spatial resolution of the SPOT data. To demonstrate this capability, a multi-image display of satellite images of the Phoenix, Arizona, area has been printed to show LANDSAT-MSS and TM data, SPOT panchromatic and multispectral data, and LANDSAT-TM and SPOT panchromatic data merged and presented at various scales. This lithographed display also shows portions of a standard USGS orthophotoquad and a topographic quadrangle for comparison with SPOT panchromatic data, all at the scale of 1:24,000.

These data-merging techniques were used to produce a LANDSAT-TM/SPOT image map of the Viedma, Argentina, area, which is a candidate site for relocating Argentina's national capital. This image map was printed at 1:50,000 scale by USGS and the Instituto Geográfico Militar of Argentina under the auspices of the Pan American Institute of Geography and History. A 1:50,000-scale SPOT image map of the Washington, D.C., area also was prepared by merging and mosaicking SPOT multispectral and panchromatic data, and a LANDSAT-TM/SPOT merged image map was produced for Al Ayn, United Arab Emirates, using these techniques.

A 1:250,000-scale image map of the Denali National Park and Preserve, Alaska, was prepared and published using data from nine LANDSAT MSS scenes. Mount McKinley in Denali National Park has perhaps the greatest relief of any land mountain in the world, rising over 5,000 metres above its surrounding base. Although the Denali map did not have relief displacement removed, distortions due to relief displacement were minimized by modifying ground control points according to their elevation and location from satellite nadir to place control at common elevation. This image map was also printed on plastic material to withstand repeated foldings and exposure to moisture during outdoor use.

The 1:125,000-scale Great Salt Lake and vicinity, Utah, image map was produced using LANDSAT-TM data to show the lake at its highest level since 1873. The large expanse of water in the image map posed special problems for image enhancement, as the histogram standard deviation of each band of data was too large to allow adequate contrast enhancement of both water and land features at one time. This problem was overcome by digitally extracting the water area from the land, enhancing the data for each cover type separately and then combining the data prior to lithographic reproduction. The final product contained land detail from TM bands 2, 3 and 4 and water detail from TM bands 1, 2 and 4.

Significant progress was made in enhancing and mosaicking Advanced Very High Resolution Radiometer data. Data from 15 images acquired between May 1984 and May 1986 were used to produce a false-colour composite image of the conterminous United States. This image will be printed as a satellite image map at scale 1:7,500,000 during 1989. This type of product is especially useful for studying regional landscape patterns. It would have high value for natural resource assessment in developing countries where systematic map coverage and resource information are not available.

### *Side-Looking Airborne Radar*

USGS originated the Side-Looking Airborne Radar (SLAR) programme in 1980 as a result of a Congressional request "to begin the use of side-looking airborne radar imagery for topographic and geologic mapping, and geologic research surveys in promising areas". Since the programme began, SLAR data have been acquired for approximately 40 per cent of the United States.

Each mission is designed with regard to local geology and specific earth science research criteria for the area. Both high and low depression angle data are collected. Low angle data accentuate low topographic relief and subtle geologic structure while high angle data are usually preferred in mountainous terrain. SLAR also has the ability to penetrate most clouds; hence it is a nearly all-weather system.

These SLAR data are available in both strip form and mosaicked onto 1:250,000-scale quadrangle format. Since 1986, computer compatible digital tapes have also been available. Beginning in 1990, all data acquired will also be available on CD-ROMs.

### *GLORIA Sonar Image Mapping*

Over the past 9 years, USGS and the British Institute of Oceanographic Sciences (IOS) have been involved in a cooperative programme to collect, process and analyse sonar images of the ocean bottom. The side-scan sonar images have been collected by the GLORIA (Geological Long Range Inclined ASDIC) system, which was designed and built and is operated by IOS.

GLORIA was first used in 1979 to collect sonar images of selected areas along the Atlantic coast of the United States. These data were recorded only in analog format, but some digital processing was used on a few negatives. Several sonar-specific, pre-processing algorithms were developed to remove shading and geometric problems. In 1982, USGS and IOS collected GLORIA sonar data in the Gulf of Mexico, including digital image data on computer-compatible tapes. Only selected subsets of these data were processed, but new algorithms were designed and added to the pre-processing software package. In 1984, GLORIA data were collected off the west coast covering the newly declared Exclusive Economic Zone (EEZ). Owing to the increased volume of data collected and the high interest in the EEZ, software to process the GLORIA data was refined, expanded and made operational on the Mini-Image Processing System (MIPS). The 1984 west coast data were digitally processed and photomechanically mosaicked to generate 33 2° × 2° sheet mosaics. These mosaics and other data sets were published in atlas form in 1985.

During the summer of 1985 new data were collected for the remainder of the Gulf of Mexico EEZ, areas north and south of Puerto Rico, and the extreme southern portion of the Atlantic coast. These data from the Gulf and Puerto Rico and the 1982 data were digitally processed in strip form and then digitally mosaicked into 25 2° × 2° sheets and the index maps were published in 1987 in a Gulf of Mexico GLORIA atlas, and released on CD-ROM disk. Geologic interpretations and seismic and magnetic profiles were an integral part of the atlas.

Data collection has been completed in the EEZ off the United States east coast, and in the Alaskan area, and GLORIA atlases have been published for both the east coast and the Bering Sea. In addition, the east coast and Bering Sea data have been released on CD-ROM. The Hawaiian EEZ will be completed in 1991. In 1991, mapping of the deep-water EEZ mapping programme will focus on the EEZ around the American Flag Islands of the central and western Pacific Ocean, starting with the Johnston Island and Palmyra Atoll areas.

## Topographic Mapping

Topographic mapping in the United States (50 states, territories, and outlying areas) is the primary responsibility of USGS.

The principal cartographic activities of USGS can be related to the types of conventional map products—1:20,000-scale (Puerto Rico), 1:24,000-, 1:25,000- and 1:63,360-scale (Alaska) topographic maps, 1:24,000- and 1:63,360-scale (Alaska) orthophotoquads and 1:100,000- and 1:250,000-scale regional maps. There is also significant activity in land use and land cover mapping at 1:100,000 and 1:250,000 scales, in state and national small-scale base maps and in a variety of special maps including image maps prepared from high-altitude aircraft and satellite data.

The primary maps include the following categories of base map data: reference systems, hypsography, hydrography, vegetative cover, cultural features, boundaries, transportation systems, geodetic control, survey monumentation and geographic names.

Because of newly defined mapping requirements and the development of new mapping, remote sensing and photographic techniques, USGS has reorganized its cartographic and geographic activities and expanded its product lines. The following is a synopsis of progress by major categories.

### *Primary mapping and revision*

During the reporting period, 3,350 new standard topographic maps were completed in the 7.5 minute 1:24,000-scale series and the 1:63,360-scale series in Alaska. At the end of the reporting period, topographic map coverage at 1:24,000 scale (1:63,360 in Alaska) was complete for all states with the exception of small areas in Alaska.

These maps are periodically reviewed for revision with emphasis on changes in urban areas, coastal zones, airports and other high national interest areas. Since September 1987, 3,600 primary quadrangle maps have been revised and published.

### *Intermediate-scale mapping*

Intermediate-scale mapping at scales ranging from 1:50,000 to 1:100,000 continues to be a growing part of the USGS national mapping programme. With the expanding interest in energy and mineral development and federal land management, the demand for quadrangle maps at 1:100,000 scale has increased. Presently, intermediate-scale maps in quadrangle format are available or under production for the entire conterminous United States. During the reporting period, USGS produced 994 intermediate-scale maps.

### *Small-scale mapping*

Topographic map coverage of the United States is complete at 1:250,000 scale, totalling 635 sheets. The series is currently maintained by USGS. In 1987, USGS implemented a new revision policy to replace the existing series with an updated series in side panel/metric format, prepared from panelled reductions at 1:100,000-scale topographic quadrangles. Digital terrain data for the 1:250,000-scale map series are available.

Other small scale maps at 1:500,000 and 1:1,000,000 scale include state base maps and maps in the International Map of the World series.

### *Special purpose and thematic mapping*

Special purpose maps are prepared from existing map bases and information collected from various sources to meet the expressed needs of federal, state and regional agencies. Maps of national parks, monuments and historic sites, produced by USGS at various scales for the National Park Service, are examples of special maps. In addition, various thematic maps emphasizing a single topic or theme, such as geology or hydrology, are also prepared and published by USGS for the Government and the scientific community.

USGS continues to support the United States Antarctic Program by conducting geodetic ground surveys and compiling topographic maps of the continent. To date, 95 maps of Antarctica at 1:250,000 scale have been published, as well as topographic maps at 1:50,000 scale, 1:1,000,000 scale and smaller, and LANDSAT image maps at several scales.

### *Land-use and land-cover mapping*

USGS continues its involvement in preparing land-use and land-cover products for the United States. The programme provides the only systematic inventory of land-use and land-cover data that is nationwide in scope and features a uniform classification system portrayed at standardized scales. The maps and digital data are used by both governmental and private sector users to support a variety of resource management, planning, development, environmental monitoring and geographic information systems activities.

Completion of land-use and land-cover and associated maps, primarily at 1:250,000 scale, for the conterminous United States and Hawaii was accomplished in 1987. The associated maps include political units, hydrologic units, and census county subdivisions as standard products; federal and state ownership overlays were prepared under some state cooperative programmes.

The graphic products are being digitized and the data are distributed by USGS in both vector and composite-theme grid cell format. Statistical summaries, by quadrangle, are also available. About 85 per cent of the land-use and land-cover graphics for the conterminous United States and Hawaii have been digitized, with series completion scheduled for 1992. Pilot projects to update the graphic and digital products using advanced cartographic systems, possibly at 1:100,000 scale, are under way.

Since 1978, USGS has prepared LANDSAT-derived land-cover products in a variety of formats and classification schemes under cooperative agreements with federal and state resource management agencies in Alaska. In 1987, a prototype standard Alaska land-cover classification scheme, using USGS 1:250,000-scale quadrangles as a base, was reviewed by federal and state agencies in Alaska. It was decided to prepare standard Alaska land-cover products during 1989-1992 only for the areas of greatest interest to users, rather than for the entire state. To date, 14 1:250,000-scale Alaska land-cover classifications are complete.

## HYDROGRAPHY AND OCEANOGRAPHY

The National Ocean Service is charged with the primary responsibility of providing accurate and timely maps, charts, and related products to improve the efficiency and safety of marine transportation, offshore engineering, coastal zone management, naval operations, and recreational activities. During the past year, bathymetric surveys were conducted in Pacific waters for the EEZ programme; hydrographic surveys were conducted in Alaska, east coast, Gulf, Great Lakes and California waters; photogrammetric missions that support the charting programmes were also applied to many other diverse and novel problems; and new nautical charts were issued.

The DMA has the responsibility of providing nautical and marine navigational data in areas outside United States waters for national defence and to worldwide merchant marine and private vessel operators.

### *Hydrographic surveys*

In conjunction with the Naval Oceanographic Office (NAVOCEANO), DMA has continued in its pursuit of improving nautical charting coverage of Asian waters for the sake of safety of navigation. Cooperative surveying and charting programmes with Indonesia and the Republic of Korea have provided excellent hydrographic data and are contributing to the production of new charts by host nation charting agencies.

Hydrographic surveys accomplished by the National Ocean Service during the reporting period employed six ships and three field party units in the following areas: in Alaska, southern Alaska peninsula, Togiak Bay, Icy Strait, Frederick Sound, Pelican Harbor, approaches to Sitka Harbor and Sweeper Cover, Adak Island; in California, Carquinez Strait, the Sacramento River and Huntington Beach; in Texas, the south-west coast, Corpus Christi and Arkansas Bays; approaches to Cameron, Louisiana, and Sabine, Texas; in Mississippi, approaches to Biloxi and Pascagoula; in Florida, Choctawhatchee Bay and St. Andrew Bay; in Virginia, Chesapeake Bay entrance; in New Jersey, the offshore coast and Kill Van Kull; in New York, New York Bight; western Long Island Sound (New York and Connecticut); southern New England coast (New York, Connecticut and Rhode Island); and, in Michigan, St. Mary's River.

### *Hydrographic Data Acquisition and Processing System*

Implementation of NOAA's Hydrographic Data Acquisition and Processing System (HDAPS) progressed in 1989. New automated data acquisition and processing systems have replaced the old HYDROPLOT systems on all hydrographic field units. HDAPS was designed to acquire and field process data in support of basic hydrographic and side-scan sonar surveys. Six field units (ships and field parties), which include 16 data acquisition platforms, now have HDAPS capability. The types of survey vessels with HDAPS capability range from the 221-ft NOAA ship *Rainier* and its four launches to the 21-ft *MonArks* used by mobile field parties.

HDAPS employs two types of data acquisition systems (DAS). DAS used by ships and 30-ft Jensen launches are configured around Hewlett-Packard Series 9000, Model 300, computers. Currently, ships are equipped with the HP-340C (16" colour monitor) while launches are outfitted with the HP-340M (17" monochrome monitors). Peripherals include an HP 9153C 20 mbyte hard disk with high density floppy disk, a ZETA 824 8-pen colour plotter, and an HP printer. Navitronic's Hyflex 1000 is the intelligent interface between sensors and computer. Currently the HP-based DAS can accommodate sensor data from the Raytheon DSF-6000N echo-sounder, the EG&G Model 260 side-scan sonar, the HP 120C GPS, the CUBIC ARGO DM54 positioning system and various types of gyro-compasses if the vessel is so equipped.

The HP data acquisition software has colour graphic features to assist the hydrographics. Data can be recorded continuously at one second intervals. Data are logged in RAM and then downloaded to a high density floppy disk where at a later time it is uploaded to the data processing system.

The DAS employed by the field parties on small boats is based on a PC-type computer. The computer, Hyflex, and sensors are all powered by either 24 or 12 volts. The system can accommodate the Falcon 484, the Krupp-Atlas Polarfix, the DE-719B echo-sounder with Odom Digitrace, the Innerspace 448 echo-sounder, and the EG&G 260 side-scan sonar. Data are logged on to a hard disk and then downloaded to a floppy disk. During this process the data are converted from a PC format into an HP format.

The processing system is an HP-340C and can process data acquired from an HP-DAS or a PC-DAS. Data are uploaded via floppy disk on to a 300 mbyte hard drive. Graphic editing, listing and plotting of data can then be performed. Upon completion of processing, the data are transmitted to the marine centres for verification via a 32-track tape.

During 1990, HDAPS software development is focusing on methods for increasing data processing efficiency. Enhancement has been made to the side-scan sonar contact file, sounding edit functions, position recomputation function and plotting routines. In addition, Automated Wreck and Obstruction Information System (AWOIS) data have been incorporated into the HDAPS digital data base.

The Army Corps of Engineers (Coastal Engineering Research Center of the Waterways Experiment Station in Vicksburg, Mississippi) has contracted with Optech, Inc. (Toronto, Ontario, Canada) to provide an airborne laser hydrography system. This SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) system, to be deployed in a Bell 212 helicopter, is to be delivered and tested in the summer of 1992. Differential GPS will be used for positioning. The laser fires 200 pulses per second into a scanner which provides a broad, uniformly sampled swath of soundings under the aircraft. The "conceptual design" phase was successfully completed in 1989; detailed design and construction is under way. The plan is to "privatize" the system so that surveys can be provided by a commercial contractor. The "Field Working Group", an ad hoc committee composed of representatives with operational hydrographic experience from the various Corps regions, has furnished inputs to the design process and is very supportive in its enthusiasm for using the system after testing and shakedown. NOAA is providing support in the areas of hardware and software design and field testing.

### *Hydrographic applications of satellite data and imagery*

The DMA is utilizing LANDSAT imagery in a number of ways to enhance production, maintenance and data-collection efforts. For example, analog LANDSAT multispectral scanner imagery of shallow seas is being used to locate and validate reported navigational hazards. It is also used in the compilation of medium- and small-scale hydrographic charts and as a planning tool for hydrographic surveys.

Digital LANDSAT data are being used to analyse areas for hydrographic survey planning graphics. In areas with uniform bottom reflectivity, multispectral scanner-derived relative depth information has an accuracy within 10 per cent of the depth measured. Over mixed bottom types, its use is limited because only one band (green) has effective water penetration.

### *Mapping the Exclusive Economic Zone*

On 10 March 1983, a significant step was taken by the United States with respect to the exploration and management of both living and non-living marine resources when the President proclaimed the United States Exclusive Economic Zone (EEZ). This zone encompasses 3.4 million square nautical miles of the ocean and seafloor within 200 nautical miles of the United States coastline. It includes not only the United States, but also its territories. The National Ocean Service has established a major programme to determine the characteristics and resources within the EEZ by utilizing modern survey techniques to provide high-resolution bathymetric maps of areas rich in resource potential.

A joint office has been formed between NOS and USGS. The USGS provides copies of imagery data that they have acquired, which NOS uses for planning and evaluation. NOS, in turn, provides USGS with detailed bathymetry to support geological interpretation of the seafloor.

Multibeam swath sonar systems are currently installed on four NOAA ships, with plans to equip one more in fiscal year 1992. The NOAA ship *Whiting* is equipped with the Hydrochart II Swath Survey System, and surveys water depths between 150 and 1,000 metres. The NOAA ships *Surveyor, Discover,* and *Mt. Mitchell* are equipped with the Sea Beam system and can survey areas where the depths range from 600 to 11,000 metres. Thus, all of the continental shelf, slope, and upper rise are covered, as well as the deeper areas of the EEZ such as the Aleutian and Puerto Rico trenches.

More than 80,000 square nautical miles of the EEZ off the coasts of Alaska, Washington, Oregon, California, Hawaii, Louisiana, Texas and Virginia have been surveyed to date. These multibeam systems provide 100 per cent coverage of the seafloor, yielding details never revealed before in the United States continental shelf and slope areas. Navigational use of GPS to calibrate land-based navigation systems has resulted in a significant increase in ship productivity. Starfix, another satellite-based navigation system, has been used almost exclusively in the Gulf of Mexico with great success. Deployment of the full GPS satellite constellation by the Department of Defense will be critical to completion of the EEZ surveys and will be much less expensive to operate than Starfix.

In 1989, the Department of Defense rescinded its objection to the release of full resolution multibeam data for most geographic areas (97 per cent of the EEZ). Since that time, twelve 1:100,000-scale multibeam bathymetric maps have been published. Plans are under way for the orderly dissemination of digital data beginning in fiscal year 1991.

### *New charting products*

One new chart was issued in 1990 covering the San Joaquin River and the Stockton deep-water channel from Medrod Island to Stockton, California. NOAA now has a total of 987 charts on issue, of which 470 were published as new editions. Of these, 158 depict the 12-mile limit (formerly the contiguous zone, now the territorial sea), 56 show the 200-mile EEZ limit, 28 show the Natural Resources Boundary (3-league limit), 282 depict LORAN-C, and 24 contain Omega navigational information.

Implementation of the new adjustment of the NAD 83 in the nautical charting programme began in May 1985. This adjustment involves shifting the existing charted projection and/or adding datum reference and transformation notes to nautical charts. Through the end of fiscal year 1990, 670 charts had been adjusted to NAD 83.

The DMA's "Notice to Mariners" is a weekly publication issued to advise mariners of matters affecting navigational safety, including new hydrographic discoveries, changes in channels and modifications to navigational aids. It presents corrective information affecting charts as well as "Coast Pilots", "Sailing Directors", "Fleet Guides", catalogues and nautical charts, "Light Lists", "Radio Navigation Aids" and such other publications that from time to time require updating. The "Notice to Mariners" is produced in an easy-to-use format with the aid of automated data processing and typesetting equipment, thus minimizing production costs and expediting dissemination. "Sailing Directors" are designed to assist the navigator in planning a voyage of any extent, particularly if it involves an ocean passage. This world-wide series of DMA publications is compiled by ocean basin, i.e. North Atlantic, South Pacific, Indian Ocean etc. A planning guide for each area describes oceanography, meteorology, countries and routes, and is accompanied by two or more *en route* publications describing approach and coastal information. The group consists of 46 electronic navigational and communication equipment. Graphic directional displays supplement textual material and provide mariners with recommendations for approaches to channels, harbours and anchorages. Photographs, coastline displays, and navigational aid drawings are also used to assist in the identification of landmarks.

### *Nautical Chart Manual*

Editing of the *Nautical Chart Manual* (seventh edition) is nearing completion. This new edition contains 11 chapters outlining current NOS nautical charting procedures, specifications, and standards. Chart features and symbols, such as sounding, depth curves, landmarks, land contours and navigational aids, are discussed in detail.

The seventh edition includes historical information, NOS general policy guidelines, an overview of NOS internal organizational structure and an outline of the NOS relationship with international charting agencies.

Metric equivalent values are included with all specifications throughout the manual.

A comprehensive glossary of nautical charting and navigational terms and an appendix of many useful illustrations, diagrams and tables complete the seventh edition.

### *Photogrammetric surveys*

The photogrammetric surveying mission of NOAA, performed by the Photogrammetry Branch, provides new coastal and special survey data in graphic and digital form, and associated information for the production of nautical and aeronautical products. Photogrammetric survey data and aerial photographs are available to other federal, state and local agencies, and the public. Programme activities include aerial photogrammetric surveys, coastal mapping, shoreline surveys, location of aids to navigation, nautical chart revisions, airport obstruction surveys, obstruction chart production, submerged aquatic vegetation mapping, marine sanctuary boundary demarcation, glacier mapping and Alaska Boundary Working Group projects.

During the year, two air-photo missions supply the necessary photographs to meet the requirements for photogrammetric survey projects for the following year and beyond. Airport photography is secured throughout the conterminous United States, while aerial photographs required for new shoreline mapping during fiscal year 1991 were acquired in Alaska, Texas, Virginia, Michigan, Wisconsin, Ohio and North Carolina.

Aerial photographic surveys are also completed in support of several reimbursable projects. The projects included highway photography for the Alaska Department of Transportation; photography of the Columbia, Taku and Wolverine Glaciers for the Ice and Climate Office, USGS; photography of Bulkana and Prince William Sound, Alaska, for the United States Bureau of Land Management; and selected photographic coverage in the Gulf of Alaska for the Alaska Boundary Working Group and the Mineral Management Service, Department of the Interior.

In 1987, the Office of Charting and Geodetic Services agreed to assist the National Marine Fisheries Service with its project to inventory the submerged aquatic vegetation of the Gore, Pamlico, Albemarle, and Currituck Sounds for North Carolina. Core Sound was photographed in 1987. Albemarle and Currituck Sounds were photographed in 1990, and planning is in progress for photographing Pamlico Sound in 1991. Aerial photographs can capture the location and extent of submerged seagrass quickly and accurately. Ultimately, the extent, distribution, and density of the submerged aquatic vegetation will be mapped. These maps will be used as a research tool to better understand the environment of this area and as a baseline study tool from which comparison studies can be made in the future.

Total surveying and mapping accomplishments for fiscal year 1990 include 129 airport surveys, 44 special navigational aid surveys, publication of 166 Airport Obstruction Charts, 160 Obstruction Data Sheets, and completion of 9 shoreline mapping projects consisting of 70 maps. The shoreline mapping projects (70 registered maps) provide coverage in the following areas: South Carolina (26), Alaska (9), Texas (9) and Michigan (26).

GPS was utilized in an increasing trend for the establishment of horizontal control stations. Nearly 75 per cent of the control established between March and October was accomplished through the utilization of GPS. GPS-controlled photogrammetry took on a new meaning this year. Not only is the targeted control positioned by GPS methods, but also the exposure station of the camera. With the exposure station data applied to the photogrammetric process, the amount of ground control and panelling will be reduced in future projects. The Photogrammetry Branch will become more responsive to the mapping needs of NOAA as a result. With a reduction in the requirement for traditional ground control density, periodic coverage of the entire coastline on a 5- to 10-year cycle can be a reality. Two major tests were planned this year in cooperation with the State of North Carolina. The first test demonstrated the capability of calibrating the airborne photogrammetric systems operated by both agencies. The second test demonstrated the practical application of GPS-controlled photogrammetry in two practical missions. The implementation of this technology is expected to be phased in over the next two years as the GPS constellation of satellites is put into full operation.

### *Electronic navigation*

Eight Omega electronic navigation stations, namely A-Norway, B-Liberia, C-Hawaii, D-North Dakota, E-Réunion, F-Argentina, G-Australia and H-Japan, provide world-wide continuous radio-navigation coverage of medium accuracy. Operating at 10 kilohertz (kHz) of frequency, they provide hyperbolic lines of position computed by phase comparison of very low frequency radio signals. There are 126 Omega plotting charts issued in the 7600/7700 series, which are designed to give global coverage on Mercator projection with a scale of 1:2,187,400 overprinted with Omega zero phase-difference contours for standard propagation conditions. On these plotting charts, the line of position (LOP) for a corrected receiver reading of a station pair is constructed by graphical linear interpolation between the charted LOPs.

There are 255 Omega lattice tables and 175 Omega propagation correction tables for the 10.2 kHz transmission frequency. Additionally, there are 75 tables for the 13.6 kHz frequency, and an Omega coverage diagram publication giving the positions of the stations, areas of coverage and accuracy data.

The LORAN-C system consists of long-range, low-frequency (100 kHz) radio navigation signals for time-difference comparison. There are 17 LORAN-C chains worldwide that comprise a total of 67 stations. There are 23 additional secondary factor correction charts and 14 LORAN-C reliability diagrams published by DMA. Further, there are 51 LORAN-C lattice tables and 55 additional secondary factor correction tables presently in the system.

## Aeronautical charting

The aeronautical charting programme of NOS consists of the compilation, printing, and distribution of charts and digital files of the United States and its territories to meet the requirements of civilian and military aviation. Approximately 10,000 aeronautical charts are produced annually for use by air flights in the National Airspace System. The continuous process of chart and file maintenance is required to support the regularly scheduled update cycle for the programme.

The aeronautical charting programme is divided into four main activities: visual, instrument, special products and digital aeronautical data management.

### *Visual programme*

The visual programme produces 182 different charts that provide information to pilots flying under Federal Aviation Administration (FAA) visual flight rules. These charts are revised every 6 to 12 months, with approximately 2,500,000 copies distributed each year. The following additional tasks were performed by the visual programme during fiscal year 1990.

New multi-colour Terminal Area charts for Memphis, Orlando, Phoenix, Salt Lake City and Tampa were developed and are available to the public. Three-colour VFR Flyway Planning charts for high-density areas surrounding Detroit and Phoenix were produced, and a special edition of the Seattle sectional chart was prepared to depict temporary prohibited airspace due to the 1990 Goodwill Games.

Several helicopter route charts have been revised, and new charts are being planned to accommodate the increased concentration of helicopter activity around major metropolitan areas. In addition, the dimensions of several Terminal Area charts are being expanded to include the revised and expanded Terminal Control Areas in large metropolitan areas.

Visual aeronautical charts are flight-checked once every three years by a rotating crew of NOAA commissioned officer pilots flying a Government-owned twin-engine "Shrike" Commander aircraft. During fiscal year 1990, the flight check programme reviewed selected aeronautical sectional charts and their associated terminal area charts, as well as 92 minimum safe altitude warning areas in the conterminous United States. These flight checks contributed more than 1,400 potential base feature changes and in excess of 900 aeronautical changes for chart compilation. More than 243 photographic sites were compiled and 927 obstacles were measured. Of these obstacles, 224 were found to be new obstructions not previously contained in the obstacle data files; 57 obstructions were found to have been dismantled and were therefore relabelled in the current files; and 690 obstacles were reverified for horizontal position and vertical accuracy. This combined photograph and stereoplot operation yielded an outstanding 90.9 per cent usable data return. The flight check programme permits the resolution of source data inconsistencies and provides pilot input to the compilation and design of visual aeronautical chart products.

*Instrument programme*

The instrument programme provides more than 8,900 charting items and publications that are used by pilots flying under FAA instrument flight rules. Approximately 7,800,000 copies of instrument charts and publications are distributed annually. Nearly 80 per cent of these publications must be revised every 56 days.

To support this effect, a cross reference programme was developed in 1986 that lists all terminal charts affected by a data change. The instrument approach procedure Digital Cross Reference File has been enhanced to include special use airspace and take-off minimums. In addition, the file supports the FAA in determining which terminal procedures must be revised.

In 1988, NOS eliminated 6,400 secondary plates on instrument approach procedure (IAP) charts and instrument departure charts by compositing the secondary plate with the primary, thereby increasing productivity and reducing costs.

In an effort to maintain high product and service standards in support of contracting the negative maintenance of instrument approach procedure charts, 17 desk guides were written. These reference documents contain detailed specifications, standards, and procedures, and it is the first time that this information has been brought together in one place. The desk guides were used to prepare the performance work statements for management studies and will become a significant portion of the IAP negative maintenance contract.

Inertial Navigational System orientation information has been added to the standard terminal arrival charts and to all standard instrument departure charts. NOS is on line to the FAA's Instrument Approach Procedure Automation (IAPA) programme data based in Oklahoma City, Oklahoma. Of all procedure changes 50 per cent are now generated by IAPA.

During fiscal year 1990, the accomplishments described below were realized.

A programme was initiated to convert the *En Route* Low Altitude Chart series from two to four colours. The Alaska Low Altitude Chart series was produced by automated methods, converted to four colours, and printed in January 1990. The Low Altitude series is in the prototype stage with no release date determined.

Over 1,000 Radar Video Maps (RVMs) were produced for the 233 FAA facilities being served. The RVMs depicted on radar displays are entirely specified by the air traffic control facility. Each map represents an accurate stable representation of the airways, fixes, boundaries and runway extension lines which meet the unique requirement of each facility.

A new Digital Bright Radar Indicator Tower Equipment (DBRITE) system is being developed by NOS. The system will provide for the video maps to be generated and displayed digitally. Instead of a 2.3-inch place, the data will be on a Programmable Read Only Memory (PROM) chip. Hardware is being procured, programs are being written and the conversion of 1,396 analog RVMs to digital files for loading to the PROMs is under way. The first DBRITE is scheduled for delivery in December 1990.

Publication of a new product called the United States Terminal Procedures Publication (TPP) began in December 1990. The TPP combines Standard Instrument Departure charts, Standard Terminal Arrival charts, and Instrument Approach Procedure charts into one product. The TPP consists of 16 volumes and a Change Notice. At the same time, the Terminal Alaska book will become the Alaska Terminal Procedures Publication with a cover similar to the TPPs.

*Special products and services*

The special products and services programme provides controller charts, obstruction charts, radar video overlays and digital data, and information on possible airport obstructions. To provide this information, NOS maintains an automated database containing obstacle information and other data. Nearly 2,500 different charts are produced annually, with revision cycles varying from 28 days to 2 years. Approximately 170,000 copies were produced last year. The following are some of the major accomplishments for fiscal year 1990.

Compilation of 212 FAA-sponsored Minimum Safe Altitude Warning System sites was completed. The project is now directed towards the continuous maintenance of six-month intervals and recompilation of various sites for relocations and magnetic variation changes.

The Digital Obstacle File has grown to over 60,000 structures affecting air navigation. Heights and locations of these obstructions are continually verified and maintained in a unique digital database which is available to the public in hardcopy only.

Subscriptions for the NOS digital NAVAIDS file have doubled in the past year. The NAVAID file contains data fields including: the NAVAID identifier, name, NAVAID type, geographic positions, frequency, channel, elevation, magnetic variation and the state or country. This data supports both civil and military navigation systems.

The Digital Aeronautical Chart Supplement (DACS) is now available in both hardcopy and digital formats. The DACS is a composite of information used in conjunction with aeronautical charts. Its main function is to provide ground coordinates needed by air traffic controllers, aviation system developers and the general aviation community for flight planning.

Digital Special Use Airspace files are currently being prepared. This database will give ground coordinates necessary for graphic portrayal of regulatory and non-regulatory airspace. Alert areas, prohibited areas, restricted areas, airport radar service areas, transition areas and control zones are among this airspace. Completion of these data is projected for late 1992.

### Geographical names

The United States has continued to be active in programmes to standardize domestic and foreign geographical names. These programmes are carried out under the authority of the interdepartmental Board on Geographic Names. During the past few years, gazetteers of several states and foreign countries have been published under the direction of the Board. In addition, guidelines on names automation, alphabetical sequencing of names and other topics related to standardization have been prepared. The Board also has participated in United Nations programmes on geographical names, and has provided on-the-job training on geographical names in the past several years to students from Thailand, Indonesia and China.

The United States has inaugurated a programme by the United Nations Group of Experts on Geographical Names to evaluate how United Nations resolutions on names are being applied by countries and to determine how the Group's programmes can assist developing countries more effectively. Several countries have answered a survey on the topic and additional responses are hoped for. Although further information on the topic is required, most responding nations agree that the standardization of names at the international and national levels requires the following steps: (*a*) national cartographic agencies should support the creation and operation of names authorities; (*b*) United Nations regional cartographic conferences should add names issues items to the agenda; and (*c*) the United Nations and other international agencies should provide technical training in names standardization at the national and regional levels.

DMA has initiated a programme to convert its file of 4.5 million geographical names of foreign areas to a format suitable for automatic data processing. This work is being carried out in collaboration with the Board on Geographic Names. By 1992, it will be possible to update the geographical names file and publish gazetteers using fully automated methods. In the past two years, DMA has produced gazetteers of Antarctica, Chad, China, Denmark and the Faeroe Islands, Iraq, Jordan, Madagascar, Panama, Peru, Philippines, Senegal, the Sudan and Sweden, and of undersea features.

An automated information system, the Geographic Names Information System (GNIS), was designed by USGS in 1975 to meet the need for a database of official geographical names. GNIS is presently capable of providing basic information for about 2 million names used in the United States and its territories. During the period of this report, activities at USGS have included a number of projects consisting of standardization of geographical names and the development and maintenance of the national GNIS. Although the primary purpose of the database is in support of the mapping activities of USGS, a wide variety of users apply the information in situations requiring the use and analysis of geographical names data. The second phase of data compilation is well under way and another 2 million names will be gathered from a wide variety of sources over the next 10 years.

The GNIS information is available interactively at the USGS information offices nationwide. Special reports and database searches are available in addition to standard products for each state and territory. As the official names depository for the United States of America, an automated maintenance program allows continuous updating and addition of material.

Specifically, GNIS staff is involved in a number of research efforts, including automation of Board on Geographic Names domestic operations, the development of a microcomputer-based topographic map names database, and automation of the Antarctic Names file.

In November 1982, the New Jersey volume was published as the first volume of the *National Gazetteer of the United States of America*. All volumes of the *National Gazetteer* will be published as part of USGS Professional Paper 1200, including an abridged volume containing names of major places, features, and areas for the United States. Each state gazetteer contains the official name, feature class, official status of the name, county in which it is located, geographic coordinates, elevation of place or feature and the name of the USGS topographic map on which the feature is found. Published volumes include New Jersey, Delaware, Kansas, Arizona, Indiana and South Dakota. Completed state files scheduled to be published include North Dakota, Florida, Alabama, Mississippi and Utah. State files in preparation include Massachusetts, Pennsylvania, District of Columbia, North Carolina, Tennessee, Missouri, Iowa, Utah, Nevada and Oregon. The remaining states and territory files will be researched, processed, and scheduled for completion by 1998.

### Digital cartography

Since 1979, USGS has collected and archived digital cartographic data from its standard map products and from aerial photographs as part of its National Mapping Program (NMP). The digital cartography programme has rapidly become the central focus of the National Mapping Program. Most mapping research within the USGS is now aimed at expanding automated cartographic data collection, processing, revision and product generation capabilities, enhancing digital line data by adding feature layers to existing topology, and increasing data utilization through applications employing geographic information systems.

The digital cartography programme produces and archives two basic types of data: digital line graphs (DLGs) and digital elevation models (DEMs). Both types are essential elements in the implementation of automated digital revision and product generation procedures being developed. They are also key data layers for numerous land and resource management and geographic information systems applications by federal, state and local agencies and the private sector.

#### *Digital line graphs*

The digital line graph (DLG) is a digitized map data set representing points, lines, and areas in vector form. The

DLGs are topological structures with identifiers that express the spatial relationships between map features appearing on a printed map. They are also encoded with attributes representing topographic map symbology. DLG data are now derived from the USGS primary map series at 1:24,000 scale (1:63,360-scale in Alaska), the 1:100,000-scale map series, and the 1:2,000,000-scale sectional maps. DLG data layers now being produced include the Public Land Survey System (PLSS), boundaries, hydrography, transportation, hypsography (contours), man-made features, survey control, vegetative surface cover and non-vegetative features.

At present, the collection of boundary, hydrography, and transportation DLG data is complete for the entire 1:2,000,000-scale *National Atlas* sectional map series. Hydrography and transportation data have been collected at 1:100,000 scale for the conterminous United States and Hawaii, with completion of PLSS, boundaries, and hypsography planned for the mid-1990s. At present, about 36,000 DLGs have been prepared and archived for the 1:24,000- and 1:63,360-scale map series.

### *Digital elevation models*

The Digital Elevation Model (DEM) is a sampled array of elevation values portrayed at regularly spaced intervals along south to north profiles that are ordered from west to east. The DEMs are referenced horizontally to either a Cartesian UTM or to a geographic coordinate system. Units of coverage for DEMs produced by the USGS include 7.5- and 15-minute blocks for 1:24,000- and 1:63,360-scale quadrangles and 30 × 30-minute blocks from the 1:100,000-scale map series. The USGS also distributes DEMs produced by the Defense Mapping Agency covering 1 × 1-degree blocks from the 1:250,000-scale map series. Most 7.5-minute DEMs have been prepared from automated or manual scanning of high-altitude aerial photographs, although they are derived increasingly from digitized map contours.

DEM data referenced to the 1:24,000-scale map series have been produced for about 40 per cent of the conterminous United States and Hawaii. Preparation of DEMs referenced to the 1:63,360- and 1:100,000-scale series began on a production basis in 1988. Completion of nationwide DEM coverage at the two larger scales is planned for the year 2000. Preparation of DEMs at 1:100,000 scale is at present requirements-oriented, and no national coverage goal has been established. The Defense Mapping Agency DEM data distributed by the USGS is available nationwide.

### *National Digital Cartographic Data Base*

Digital cartographic data sets reside in a centralized USGS archiving and distribution system, the National Digital Cartographic Data Base (NDCDB). The data are stored on magnetic tape in separate DLG and DEM databases for each major map series. The data are distributed through the USGS Earth Science Information Center and are available on 9-track tapes at either 1600 or 6250 bpi density. DLG data are distributed in either a standard or optional format. The standard format, which limits topological linkages to line elements only, is oriented toward generating map graphics. The optional format includes linkages for all lines, nodes and areas. This allows for the creation of a polygon data structure useful in geographic information systems applications. All DEM data are distributed in a fixed block format containing all data elements. USGS data archiving and distribution activities are being expanded to include other mapping organization data not meeting national database standards and thematic data referenced to USGS maps. The development of products on CD-ROM is also under way.

To accelerate the collection of data for the National Digital Cartographic Data Base, the USGS has entered into cooperative data collection initiatives with other federal and state agencies and has begun contracting out some phases of data collection to private sector firms. Guidelines have been developed for acceptance of base category DLG data produced by other agencies into the NDCDB. One example of a cooperative programme between the USGS and the Bureau of the Census was the completion of 1:100,000-scale hydrography and transportation data nationwide. The data were needed by the Bureau of the Census to support the 1990 Decennial Census of Population and Housing. Production of 1:100,000-scale hypsography data is currently being accelerated under a cost/share agreement with the DMA. The USGS is working with the Forest Service to topologically structure and archive large amounts of 1:24,000-scale digital line-map data, which the Forest Service is collecting to support geographic information systems development for forest management.

Both the Forest Service and the Bureau of Land Management are now producing large numbers of DEMs to USGS standards under work/share agreements. All these activities serve to expand the NDCDB in support of USGS digital revision and product generation, to minimize duplication of effort and to make available to the user community large amounts of quality digital cartographic data for land and resource management and geographic information systems activities.

### *Advanced cartographic system developments*

The advent of the computer has changed the focus of mapping requirements in the United States. For more than 40 years the USGS has provided map users with primary quadrangle map coverage of the United States at 1:24,000 scale in the lower 49 states and at 1:63,360 in Alaska. Initial national coverage of the graphic products for the lower 49 states was completed in 1990. The Alaska coverage is scheduled for completion by 1991. In recent years, however, it has become apparent that digital versions of these maps must also be produced to support the needs of a computer-oriented society.

In 1979, the USGS received funding appropriations that formally initiated the National Mapping Division's Digital Cartography Program. More recently, the Division has begun a major new system development effort called Mark II that will implement advanced technologies and production procedures to satisfy National Mapping Program requirements through the year 2000. The most critical of these requirements is population of NDCDB with digital data representing the content of primary map series and other smaller-scale series. This database will serve two major functions: (*a*) as a central archive for the dissemination of digital data to the user community for information systems analysis; and (*b*) as a working database for production and revision of digital and graphic map products.

To accomplish this ambitious digital database development and population goal, a series of development tasks are being implemented: to expand and improve mass digitization capabilities; to modify data structures to support increased content and access requirements; to develop digital revision capability; to develop product generation capability for standard, derivative and digital products; to improve quality control; and to support programme and data management.

Specific requirements for the NDCDB contents and related production processes have been identified in order to satisfy the overall Mark II objectives. These requirements cover sources of data, categories of data, levels of data integration, data revision, data quality and both digital and graphic products to be produced from the NDCDB.

To evaluate the existing systems and to facilitate the identification of new and improved capabilities, Mark II was divided into four functional components, each addressing a specific portion of the production process. The data production component addresses all phases of data collection, editing, data processing, and quality control prior to entry into the NDCDB. The database component is developing several levels of databases: operational databases to support ongoing mapping centre production and product generation requirements, an archival database to support the NDCDB, other digital data and sales and distribution of products. The product generation component is designed to provide the cartographic products required to support the National Mapping Program. The production management component is being designed primarily as a two-way interface between the Mark II production system and existing production systems to meet the programme and production requirements of the National Mapping Program.

For procurement purposes, the components are combined into segments. The data production and product generation components have been grouped as the digital cartographic production segment, and the database and production management components have been grouped as the programme and data management segment. These procurements are being conducted under the auspices of the DMA in a cooperative effort.

### *Geographic information systems*

The past five years, geographic information systems (GIS) technology has gone through a period of steady evolutionary development and refinement. Indications are that we may now be at the starting point of an acceleration in the applications curve; revolutionary changes may occur in the next few years. The driving force behind this anticipated change is the availability of increasingly cost-efficient computer hardware, combined with increasingly sophisticated use of digital technology in base map compilation and revision, and a growing capability to integrate, visualize, and model geophysical, geochemical, hydrologic, socio-economic, demographic, and other thematic layers within a common digital geographic context.

USGS currently operates about 100 minicomputers nationwide, with 400-500 scientists making daily use of GIS technology. It is anticipated that over the next five years the current systems will be phased out and replaced with individual engineering work stations and networked file servers, each having processing speeds two to four times greater than the present minicomputers. Concurrently, the in-house GIS user community could grow to as many as 2,000-3,000 scientists.

Much of the GIS applications development activity in the next few years will be related to global change research; the National Mapping Division is just beginning what will probably be at least a decade-long effort to characterize the land surface in support of the broader USGS global change research effort. The "intelligent database" will provide a built-in capability for rescaling and/or statistically aggregating all appropriate thematic layers. The output from the database will feed dynamic process models, which may be at scales ranging from field, landscape, region and continent to global. This effort will require close cooperation with modelling specialists in other disciplines; exploitation of supercomputers; and use of advanced techniques such as fractal analyses, neutral networks, artificial intelligence and automatic discovery. It will entail a significant research role for the academic community.

Currently, USGS is completing work with the National Center for Health Statistics to integrate data sets never before evaluated in a spatial context.

Environmentally related start-up activities include a wetlands restoration, protection and research initiative; the International Decade for Natural Disaster Reduction; and development of new production techniques for 1:100,000-scale land use/land cover mapping, using a combination of aerial photography, existing digital base and thematic data files, manual interpretation and automatic classification of satellite and other imagery.

Recent prototype developments include digital revision of the 1:500,000-scale State of New Jersey base map, with base category, land use and other thematic data extracted and generalized from existing 1:100,000- and 1:250,000-scale digital files. This project is a significant early component of a major activity that has been initiated to develop techniques for product generation from digital data. Other recent prototypes developed with GIS techniques include the digital line graph (DLG) format and a soon-to-be completed county-based prototype of base and thematic layers, also for CD-ROM distribution.

In the area of three-dimensional visualization, a video tape was recently produced showing subsurface tectology within an area of the Soviet Union used for atomic testing. The video images were derived from image, seismic, terrain and detonation data, some of it supplied by the Soviets. Ongoing research in three-dimensional visualization includes the mapping of urban areas utilizing "what if" analysis and a 50-year look-ahead at infrastructure trends, dynamic time series modelling of the San Francisco (Loma Prieta) earthquake and stacked display and analysis of hyperspectral data in anticipation of 128-band multispectral data from the EOS satellite.

### *Development of rules for automated mapping*

To meet increasingly sophisticated user requirements for spatial information in both digital and graphic forms, and at the same time develop greater operating effectiveness, USGS has embarked on a programme to modernize the most fundamental aspects of its cartographic data production, database development and product generation operations. The programme takes advantage of the latest theoretical and technological advances in cartography. To accomplish this goal, implementation specifications are required to explain how the data are described and manipulated. Implementation of an automated product generation capability requires objective standards that are internally consistent, unambiguous, and well documented. Specifications are currently being developed for the 1:24,000-scale map series and include: delineation specifications which describe what the feature looks like on the ground; extraction specifications which describe when a feature is collected from source for inclusion in the database; representation rules describing how the feature will be represented in the database; product specifications describing when a feature from the database is included on the graphic; and a variety of product generation rules that provide for symbolization, generalization, conflict detection and resolution, and names and label placement for graphic production.

### *Digital line graph-enhanced data model*

With ever more powerful computer technology available to collect geographical information, USGS faces a difficult task in providing users with up-to-date digital data, while at the same time enhancing the structure of that data to meet the needs of a sophisticated user community. No longer is it sufficient in itself to automate the map-making process for reproducing graphics; spatial data users require a data structure that can support complex queries and analysis of thematic information to seek answers to national (and global) problems.

To address this need, the Geological Survey has moved beyond its present digital line graph (DLG) data structure and created a modernized and enhanced version termed DLG-enhanced (DLG-E). This new structure is feature-based to closely resemble the way humans perceive their physical surroundings. The features shown on a map, such as roads, streams or buildings, are represented by corresponding "features" encoded in the digital file. Over 200 types of features exist in the DLG-E data model, each derived from the types of features portrayed on USGS topographic maps. These features are further described by attributes that define such characteristics as name or function, and relationships that describe such interactions between features as flow through a network or features that bound one another.

Ultimately, all features in the DLG-E world are linked to the spatial components that comprise them: polygons, chains and nodes. The expression of topology occurs at the spatial level in the file, just as is presently the case for existing DLG files. The current DLG files, however, also encode feature-level information at the spatial level through a series of attribute codes attached to each spatial element. This limitation serves to point out the most important advantage of DLG-E: the separation of spatial components from non-spatial components for more flexibility in manipulating the database.

Although much work remains to be done before DLG-E becomes a reality, work is under way now to develop a prototype DLG-E production system. This prototype system will generate test data sets which will be utilized to further refine the data structure. The DLG-E data model provides USGS with a flexible tool to support the nation's fast-growing spatial data needs into the next century. DLG-E will continue to evolve as the needs of the data users themselves change.

### *The proposed Spatial Data Transfer Standard*

In March 1987, USGS formed the Digital Cartographic Data Standards Task Force (DCDSTF) to develop a single proposed standard for digital cartographic data by merging draft standards developed by the National Committee for Digital Cartographic Data Standards (NCDCDS) and the Standards Working Group of the Federal Interagency Coordinating Committee on Digital Cartography (FICCDC-SWG). Chaired by USGS and comprising 15 members (including key architects of the NCDCDS and the FICCDC-SWG draft standards), the DCDSTF met on four occasions during the summer of 1987, and in October 1987 issued a merged document entitled "The proposed standard for digital cartographic data" that was subsequently published in the January 1988 issue of *The American Cartographer*.

To develop the merged document, the DCDSTF adopted NCDCDS Report 8, "A draft proposed standard for digital cartographic data", as a baseline and incorporated desirable characteristics of the federal geographic exchange format developed by the FICCDC. The resulting proposed standard consists of four components:

(*a*) *Definitions and references*, containing definitions of fundamental cartographic objects that serve as conceptual building blocks for the standard;

(*b*) *Transfer specification*, describing the logical file structure for the transfer of the data;

(*c*) *Data quality*, outlining the form of a quality report;

(*d*) *Cartographic features*, presenting a model for classifying and defining cartographic features, along with an initial set of proposed standard definitions.

The prescribed method of implementation of the proposed standard is the standard specification for a data descriptive file for information interchange (ISO 8211), which was adopted in 1985 by the International Organization for Standardization (ISO), and which is also an American National Standards Institute (ANSI/ISO 8211) and a Federal Information Processing Standard (FIPS PUB 123).

Since the publication of *The American Cartographer*, the effort to finalize the standard has been coordinated by USGS. A Technical Review Board (TRB) was appointed and given the responsibility for finalizing the standard for promotion to NIST for approval as a FIPS. The Board includes representatives from the federal Government, the commercial sector and the university community.

Empirical testing and refinement have been the focus of SDTS development activities during the period 1988-1990. USGS, the Bureau of the Census, and DMA participated in Phase 1 testing by encoding test data into the format specified by the standard. Encoded files were exchanged and decoded by each participating agency. Suggested improvements resulting from this exercise were documented and presented to the TRB for evaluation. In the second phase of testing, other federal agencies and private sector organizations were asked to test the concepts presented in the SDTS (as revised, following Phase 1 testing) and report their findings. The suggestions and recommendations raised during Phase 2 testing were presented to the TRB, and were utilized to further revise the SDTS prior to formal submittal for consideration as a Federal Information Processing Standard.

The SDTS was delivered to NIST in July 1990 for consideration as a FIPS. Ongoing activities include: (*a*) review of SDTS for conformance to FIPS and ANSI style; (*b*) development of conformance criteria and procedures through an agreement with NIST; and (*c*) development of a suite of software to support requirements including: file browsing and structural summary, diagnostic capabilities, plotting and display, and possible conversion to other file formats such as relational database structures. This includes rules development, software support and procedures for testing to determine whether data sets produced by agency and vendor systems conform to SDTS specifications. Conformance testing may also include evaluation of receiving systems in terms of ability to process SDTS data.

### *Federal coordination*

USGS chairs two major federal-level digital cartography coordinating committees. The Interior Digital Cartography Coordinating Committee (IDCCC) was established in 1982 by the Secretary of the Interior to provide a forum within the Department of the Interior to facilitate coordination of collecting digital cartographic data and to realize multipurpose use and exchange of data. The IDCCC consists of a steering committee with representatives from each of the Department of the Interior bureaux, three working groups and two regional subcommittees.

The Federal Interagency Coordinating Committee on Digital Cartography (FICCDC) was established in 1983 at the request of the Director of the Office of Management and Budget. The FICCDC is composed of a steering committee with representatives from 12 federal departments and independent agencies, five working groups and one task group. The purpose of the FICCDC is to recommend procedures and programmes that would facilitate coordination of federal agencies' digital cartographic activities and to establish and promulgate standards and specifications for the production of digital cartographic data. In 1990, the FICCDC proposed the revision of Office of Management and Budget Circular A-16. The revised circular, recently approved by the Office of Management and Budget, expands the breadth of coordination of spatial data, assigns Government-wide leadership roles to federal departments for coordinating these data and establishes a new interagency coordinating committee, named the Federal Geographic Data Committee, which has the objective of promoting the coordinated development, use, sharing and dissemination of surveying, mapping, and related spatial data. The new committee will supersede the FICCDC.

### *Other mapping organizations*

USGS has in place "Guidelines for acceptance of digital cartographic data into the National Digital Cartographic Data Base" with the intent of facilitating and encouraging cooperative efforts among federal, state and other organizations to produce and share digital cartographic data. A variety of interagency agreements now exists for exchanging digital data, including an agreement with the Forest Service for producing and/or exchanging DEM and DLG data. Other similar examples include agreements with the Bureau of Land Management and DMA, the State of Washington Department of Natural Resources and the Idaho Transportation Department.

## GLOBAL CHANGE: CHALLENGES FOR GEOGRAPHY

The United States Global Change Research Program is a coordinated effort involving seven departments and agencies of the Government and numerous academic research institutions. It sponsors studies of the atmosphere, oceans and land surface; the physical, chemical and biological processes that occur in these environments; and the linkages between them. The programme includes components of (*a*) observation and monitoring; (*b*) enhancement of scientific understanding; (*c*) development of models, especially predictive models; and (*d*) management of environmental data. The programme emphasizes interdisciplinary studies and development of an integrated understanding of large-scale environmental processes and causes of environmental change.

Environmental process models exist in two forms: (*a*) global models that treat land processes as functional "boxes" with little or no allowance for the diversity, structure, or location-dependence of land characteristics and processes; and (*b*) site to landscape-scale models that better account for geographic reality but which are limited in geographical extent. The National Mapping Division is contributing to environmental modelling with the following activities:

*Land characterization*, which develops geographical data resources for use in landscape to regional-scale environmental modelling. These efforts are linked to academic studies of long-term ecological research (LTER) sites, funded principally by the National Science Foundation, and to basin-scale hydrological studies being undertaken by the Water Resources Division of USGS. The strategy of this effort is to expand geographical coverage from a small set of LTER-site "nuclei" to regional coverages that will, in approximately a decade, merge to provide continental-scale coverage. GIS software systems will be ported to the most capable available computer environments in support of this work;

*Pilot data-set development*, which generates continental-scale data sets of satellite greenness-index observations, soil maps, and other information that will help global "box" modellers to incorporate greater geographical realism into their models. This information will combine naturally with data from land characterization activity when its geographical coverage expands to a sufficient extent.

In both of the foregoing activities, the Division is developing methods for obtaining and managing geographic information at multiple scales and linking land-characteristics statistics between those scales.

The availability of geographic data to the global-change research community is sometimes limited by difficulty of access to information about data holdings, data quality and other "metadata". Community access to data is being improved by the following activity:

*Global Land Information System*, which will provide information about geographic data holdings via network access from a personal-computer environment. Flexible queries by date, location, and data type and quality will be supported and some classes of information will be portrayed graphically on the user's computer.

The National Mapping Division is also working to preserve a unique and consistent set of observations of land characteristics and conditions obtained over the last 20 years:

*LANDSAT data conversion* is an effort to convert the LANDSAT multispectral scanner and thematic mapper data archive from high-density tape to longer-life computer-compatible media.

The annexes contain information on selected digital cartographic capabilities and systems supplied by the principal federal agencies that have contributed to this report. The agencies may be contacted for additional information on their activities.

## ANNEX I

### Defense Mapping Agency Automated Cartography

The Defense Mapping Agency (DMA) is undergoing a mandatory conversion of present production processes. This programme, called the Digital Production System, is implemented in two phases, MARK 85 and MARK 90.

The first phase, MARK 85, modified and supplemented existing production equipment to provide an interim capability to exploit new source materials. The MARK 85 has six segments that support the existing DMA production procedures and operates primarily in a hardcopy environment.

The MARK 85 provides computer software to implement photogrammetric models to a variety of existing DMA hardware as well as to modern interactive workstations capable of semiautomatic terrain and interactive feature extraction. This system also provides for the inventory of all DMA source holdings In addition, MARK 85 provides the functionality for production programming and planning for all of the Defense Mapping Agency

The second phase, MARK 90, provides the end-to-end digital production system that replaces most of the DMA production line and significantly enhances productivity The MARK 90 is being developed in five segments When linked together, they provide a fully integrated production capability Three segments of the MARK 85 are included in the MARK 90 development to support required production capabilities

The MARK 90, to be delivered in 1992, will build upon the MARK 85 to further enhance production and programme management This system will accomplish automatic terrain extraction and semi-automated feature extraction. Feature delineation and attribution are facilitated using knowledge-based engineering. All extracted data will be stored in a database where these data can be generalized and segregated to produce a defined set to DMA products

## ANNEX II

### Mark II: The next step in digital systems development at the United States Geological Survey

The National Mapping Division of the United States Geological Survey (USGS) has begun a major new system development effort, Mark II. The goal of this programme is to implement advanced technologies and production procedures that will satisfy project requirements of the National Mapping Program through the year 2000. At that time, the National Digital Cartographic Data Base will be fully operational when its contents are based essentially on digital data These data will represent the 7 5-minute, 1:24,000-scale map series, as well as other smaller-scale series, and will be the central focus of the Division's mapping activities

To accomplish this ambitious goal, a series of development tasks are being implemented to (*a*) expand and improve mass digitization capabilities; (*b*) modify data structures to support increased content and access requirements; (*c*) develop digital revision capability; (*d*) develop product generation capability for standard, derivative and digital products; (*e*) improve quality control; and (*f*) support advanced analysis and applications. Development of the Mark II system has begun, and implementation over the next few years will lead to full production of the 1:24,000-scale digital data collection in the mid-1990s

The design, development, and implementation of the Mark II system represents a major development activity within the USGS. It will exploit state-of-the-art mapping technology, resulting in a highly responsive digital cartographic production system. The National Mapping Division believes that the timing of this effort is appropriate and necessary to meet requirements, and that the state of available technology will support the effort. The Division also feels that the future needs of the users of these data will be fully met

The development of the Mark II system will assure that the long-term goal will be met, and the National Digital Cartographic Data Base will support the product and process requirements of the National Mapping Program Attainment of this goal will allow the Division to be responsive to national requirements for up-to-date cartographic data and map products that are produced more quickly and efficiently.

## ANNEX III

### National Ocean Service automated chart production

#### Nautical charts

In September 1988, the Nautical Charting Division (NCD) of the National Ocean Service (NOS) contracted with Intergraph, Inc , to design and develop the second generation automated nautical charting system. With this contract, NCD has embarked on a modernization effort that will eventually lead to the automated production of its entire suite of nautical charting products

A detailed design of the proposed system is currently under way. This design is being done by an on-site Intergraph design team working under the guidance of the NOS Automated Nautical Charting System II (ANCS II) project team. Although details of the design are not complete, the following describes the general architecture of the system

Under ANCS II, data management and product generation will be accomplished at Intergraph work stations Plans call for about 40 workstations, consisting of a mix of Intergraph's 200 series and 300 series workstations, to process a variety of different types and sizes of documents and jobs The 300 series machines support SYSIWYG graphic displays and any other cartographic functions that are computationally intensive The 200 series machines will support less complex graphics and functions Some of the workstations in the ANCS II system will be of the 200 series InterPro variety. These are desktop, single-screen machines However, the system will also contain a number of the 300 series InterView variety (dual screen with full size digitizing tables) These will support collection of data for database maintenance. Unlike the equipment used in the earlier Automated Information System, both series of machines can exist in a normal office environment and will eventually be distributed throughout the work space currently occupied by NCD's Mapping and Charting Branch. The workstations will be linked together using Ethernet; coaxial cable is used within individual buildings and fiber optic cable between buildings The final ANCS II hardware configuration will also contain a number of InterServe central storage nodes for the data within the system and will also serve as controllers for on-line plotting capabilities and other peripherals. All the hardware share identical architecture and are based on Intergraph's CLIPPER chip.

The detailed design phase of the ANCS II project was completed in July 1990, and the resultant design is undergoing Critical Design Review (CRD). During CRD, design issues that emerge will be resolved. This phase will be followed by development and system testing which will include a six-month trial production phase involving 50 of the 1,000 NOS charts, system acceptance, implementation within the NCD and eventual expansion to include all NOS nautical charts and related products Initial operating capability for the system is scheduled for 1992

#### Aeronautical charts

Aeronautical charting requirements have grown steadily over the past decade while the number of ACD employees has decreased, even though most of ACD's products must be revised every 56 days To meet these growing demands, ACD has been applying automated techniques to a number of cartographic functions The Aeronautical Chart Automation Project (ACAP) is dedicated to improving the efficiency of the cartographic process through automation Although similarities exist between the automation efforts in both nautical and aeronautical charting, each has unique requirements that can best be met by two somewhat different approaches to automation. For the present, each system will evolve essentially independent of the other. Common use of compatible equipment will be utilized whenever possible.

The goal of the ACAP project is to produce and implement an overall system containing a central host computer interfaced with graphic workstations and special digitizing subsystems Unique digitizing capability is important to the overall system concept with regard to later upgrades of the host computer. Past experience has shown that specially configurated and modified computers, and their unique operating systems that frequently incorporate turnkey digitizing systems, can be impossible to expand or upgrade at a later date The current ACAP plan envisions the modular implementation of a comprehensive system in support of all major aeronautical charting products. This includes the automated production of chart overlays suitable for direct use in the reproduction process

Although the automation of the topographic base for large charts was never a goal, the Aeronautical Information Data Base of ACAP will be capable of directly supporting graphic overlay compilation, overlay production, and generalized support for all products

Realization of the ACAP concept will allow for the automated production of the Air Route Pilot System, Quality Control Pilot System, radar video maps, IAP Management Control System, Controller Chart System, IAP Chart System, *en route* chart automation, SID/STAR chart implementation, AIB Compaid automation, and Visual Chart Automated Assistance System The new system is installed at the Rockville, Maryland, site of

ACD and supports 20 alphanumeric terminals, five graphic workstations and two precision proof-plotters.

The final system configuration includes a Digital Equipment Corporation (DEC) VAX 750 and VAX 780. Amortization of the original purchase cost over a three-year period will result in considerable cost savings over the cost of the time-sharing charges on the National Oceanic and Atmospheric Administration UNIVAC. The VAX mainframe CPUs will support more than 40 alphanumeric terminals, plus more than 20 interactive graphic workstations. Included in the hardware will be five precision proof-plotters, and ultimately a high-quality chart-output device.

# FOUNDATION, BUILDING AND DEVELOPMENT OF GEODESY AND CARTOGRAPHY WORK IN VIET NAM*

*Paper submitted by Viet Nam*

## RÉSUMÉ

Pour assurer le redressement, l'édification et le développement du pays, le Viet Nam a créé à la fin de 1959 le Département d'Etat de géodésie et de cartographie, dont la fonction principale est d'organiser les activités menées dans ce domaine à l'échelle nationale et de gérer le secteur pour le compte de l'Etat.

At the end of 1990, a national scientific seminar on the history of cartography in Viet Nam was held for the first time in Hanoi on the occasion of the 500th anniversary of the "Atlas Hong Duc".

Several thousands of years ago, the Vietnamese made maps by carving on the marbles in the region of Sa Pa mountain of Hoang Lien Son province. This is a complex of marbles consisting of some 1,000 stones on which regional maps and drawings of human activities were carved. In the fifteenth century, the Vietnamese had edited the first atlas—"Atlas Hong Duc". In the following centuries, this atlas was enhanced for national administration and defence purposes. From the end of the nineteenth century to the middle of the twentieth, the French authorities constructed an astronomic-geodetic network covering the whole of Indo-China in order to make topographic and cadastral maps of the agricultural regions. Between the end of the 1960s and the beginning of the 1970s, the United States founded a system of base maps at 1:50,000 scale, covering the whole of Indo-China. With a view to recovering, building and developing the country, from the end of 1959, Viet Nam founded the State Department for Geodesy and Cartography. The main task of this Department is to organize geodesy and cartography work on a nationwide scale and to establish State management in the domain of geodesy and cartography.

### THE SCIENTIFIC-TECHNICAL CADRE FORCE

So as to ensure a capable scientific-technical cadre force for full exercise of geodesy and cartography work, an institute and some professional high schools of geodesy and cartography were opened, and a number of students were sent abroad for training. After 30 years of training, there is now a large contingent of scientific-technical cadres: 7 doctors of science, 50 masters of science, 1,000 engineers and 5,000 working specialists. Apart from these, there is a large body of technical workers with high professional skills and rich experience. With such contingents, we have met every demand of research, training and production at an advanced level of technology, as required by the Department for Geodesy and Cartography. In recent years we have sent our specialists to work in various countries: Algeria, Hungary, the Lao People's Democratic Republic and Poland. Now the Department is operating three research centres, an enterprise for plotting aerial images, three geodetic-topographic unions, a map-printing unit, a transfer of technology and export company and two professional high schools of geodesy and cartography. Also, in ministries and localities there are many production units serving their own needs in this field.

### TECHNICAL EQUIPMENT

Technical equipment and instruments enable the exercise of various missions of geodesy and cartography: geodesy control network, levelling network, gravimetric network, aerial images, cartographic aerial images and map-printing.

*Existing equipment.* AU-01, AU-2/10, DKM 3-A, AGA-600, GRANAT, CT-5, DI-20, tellurometer, Wild T3, Wild T2, UVK, THEO-010, GPS receiver, Trimble Navigation 4000 ST surveyor, NI-004, N3, KONI 007, NI-030, AFA-141, MRB-152, RC-8, AN-30, AN-2, Topokart, Stereometrograf, Stereoplotter, Planikart, Wild A8, PSK-2, Diskometer, Stereometer, MSP-4, SEG-6, Retimat-C, offset press (monocolour and double colour), rotary press, AT-386, laser printer, plotters, digitizers, scanners.

### ACHIEVEMENTS IN GEODESY AND CARTOGRAPHY

#### *Astronomic-geodetic network*

Several decades ago French and United States technicians constructed a control and levelling network over the whole of Indo-China. This network proved to be not very accurate; its landmarks are nearly worn out, and, in fact, it is of no use. In serving research and production needs of the geodetic and cartographic branch, the Department for Geodesy and Cartography has reconstructed the control network, the levelling network and the gravimetric network over the whole territory of Viet Nam, all of which have high accuracy

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and point density meets the demands of science and production.

In the past 30 years, the following tasks have been completed:

(*a*) A control network consisting of triangulation of first and second order, traverse of second order ensuring the density of one point/150 sq km; the distance accuracy of first order, scale 1:300,000; and that of the second order, scale 1:220,000. This network also bears two astronomical base points, 13 baselines and the Laplace azimuth. In addition, the Doppler-satellite network connects with each geodetic point on mainland and islands;

(*b*) A levelling network consisting of traverse of first, second and third order dominating and covering the whole territory;

(*c*) A gravimetric network consisting of two gravity base points and other gravimetric control points of first and second order.

The above geodetic network system ensures sufficient accuracy and density to serve scientific research, to make large-scale maps at 1:2,000 and to realize various economic projects.

### *Topographic maps and cadastral maps*

*Topographic maps*

The Department for Geodesy and Cartography of Viet Nam produces various topographic maps scaled from 1:2,000 to 1:25,000 by means of direct mapping on aerial images. Smaller scaled topographic maps are generalized from the former. Before 1975, in war-time conditions, a new system of topographic maps covering the whole country could not be produced. Therefore, maps printed by the French and United States personnel for their own use were reproduced. In a number of important economic zones topographic maps at scales 1:10,000 and 1:25,000 were published.

After national reunification in 1975, the Department for Geodesy and Cartography planned to make a new system of topographic maps at scale 1:5,000 for rural areas; scales 1:500 and 1:2,000 for urban centres; scale 1:10,000 for highlands; scale 1:25,000 for a number of mountainous areas where large economic projects are in operation; and scale 1:50,000 covering the whole country. On this plan, we have made the topographic maps at scale 1:2,000 for Hanoi capital, Ho Chi Minh City and Haiphong City. Already in hand are the topographic maps at scale 1:5,000 for the Red River delta and a part of the Mekong delta. For the area where there would be construction of a hydropower station, topographic maps at scales 1:10,000 and 1:25,000 are available. For nationwide maps, we are updating the topographic map at scale 1:50,000 made by the United States by means of materials on space images.

*Cadastral maps*

In an attempt to review, master and plan land-use, we have established a system of cadastral maps by two scale groups:

(*a*) Scales 1:10,000 and 1:25,000 for highlands and mountainous areas;

(*b*) Scales 1:2,000 and 1:5,000 for cultivated areas.

### *Thematic maps*

At present there is an urgent need for various thematic maps in Viet Nam. Therefore, work has been directed towards the following:

*General atlases and map series for domestic and international use*

*Atlas Viet Nam*, 1964 (14 pages, 50 × 40 cm)

*Atlas Viet Nam: Natural Resources, Economy and Society*, 1983 (40 pages, 60 × 50 cm)

Series of maps, scale 1:1,000,000, 16 sheets published and republished 1968-1990

Series of world maps, scale 1:2,500,000 (Viet Nam is in charge of editing and updating its territorial part)

*National Atlas of Viet Nam*, edited 1985-1989, for publication 1990-1992 (140 pages, 15 chapters, 53 × 38 cm)

Series of Lao regional maps for the International Mekong Committee

*Regional atlases and map series*

*General Atlas of Lai Chau Province*, 1975

*Atlas: Natural Resources, Economy and Society of Dak Lak Province*, 1985

Series of maps of general investigation of the High Plateau, Red River delta, Mekong delta and the Plain of Reeds

Administrative and tourist maps of provinces and cities

*Economic atlases and map series*

*Atlas of Climate*, 1971

Maps of communication in Viet Nam, scales 1:500,000 and 1:1,000,000, 1988-1989

*Atlas of Meteorology, Atlas of Hydrology, Atlas of Oceanography*, edited 1989

Series of geology maps, land-use maps, soil maps and forest maps

*Educational maps*

The system of educational maps consists of various types of maps for use in education from kindergarten to higher institutes.

*Tourist maps*

The system of tourist maps includes various types of maps for national and regional use and for tourist centres, serving tourists at home and abroad.

*Popular maps*

This system consists of atlases and globes intended to improve general knowledge under the motto: "Maps for every home".

### *Space images for mapping purposes*

Since 1980, the remote sensing method has been experimented with and applied in Viet Nam. In the 1990s this method will be widely used for various aims, of which the most useful will be to establish topographic and thematic maps.

Using LANDSAT and COSMOS images of medium resolution, we have updated the topographic map at scale 1:1,000,000. At present we are updating the topographic maps at scales 1:50,000 and 1:100,000 with colour COSMOS images of 5m resolution and with the LANDSAT-TM images. In the future, the SPOT images of high resolution will possibly be used in making topographic maps of medium scale. In the field of thematic maps, we have been making maps on nature and on natural resources as well as a set of general maps. Following are our concrete products: geology map of Tuyen Quant Province, scale 1:200,000; geological structure map of Viet Nam, scale 1:1,000,000; forest maps, scales 1:100,000 to 1:250,000;

soil maps, scales 1:50,000 and 1:100,000; agri-ecological map of Mekong delta, scale 1:250,000; map on fluctuation of coastline and river-mouths, scales 1:50,000 to 1:250,000.

At present satellite and aerial images are being used to establish other maps for the proper use of natural resources and for the preservation of nature. Concretely, we have made a series of maps on natural resources of the Thanh Hoa area, at scale 1:200,000; and other maps on various subjects, as follows: forecast of deposited ores and minerals; water-surface resources; soil and soil-evaluation for agricultural and forestry development; present use of land; botanic carpet; ecological landscapes; environmental fluctuation; general evaluation of natural resources; and proposals for natural resources exploitation and natural preservation. LANDSAT and COSMOS images form the basis for the above series of maps.

### International cooperation

In the 1960s Viet Nam conducted cooperation with the National Bureau of Surveying and Mapping of China to establish the astronomic-geodetic control network in North Viet Nam. In the mid-1970s, the Main Administration of Geodesy and Cartography of the USSR helped us in constructing the gravimetric control network of first and second order in the whole country. In the 1980s, the United Nations granted aid to us by means of two projects on technological transfer of geodesy and cartography.

In the past five years we have cooperated with the Soviet Union to accomplish the astronomic-geodetic network on nationwide scale.

Besides these, a number of international organizations and countries, such as Sweden, Australia, France etc., have aided particular branches and localities of Viet Nam in training cadres in geodesy and cartography, and in providing them with modern equipment in order to improve the quality of Vietnamese geodetic and cartographic enterprises.

From the end of the 1970s close cooperation has existed between the two Departments for Geodesy and Cartography of the Lao People's Democratic Republic and Viet Nam. Viet Nam has sent its experts to help the Laos, trained Lao technical cadres and carried out a levelling project from the sea to the height base point of Laos.

### Orientation and tasks in the years to come

In the past years the State astronomic-geodetic network has been nearly accomplished (blanks are the Minh Hai rural area and the High Plateau). The large-scale maps have covered only major parts of the Red River delta and the Mekong delta. Hence, our task ahead is not a small one. Following are our tasks in the time to come:

(*a*) Accomplish the measuring and adjustment of the astronomic-geodetic control network within two years;

(*b*) Take aerial images covering all the rural areas, and on that basis continue making topographic maps at scale 1:5,000 and cadastral maps at scale 1:5,000;

(*c*) Update the system of topographic maps at scale 1:50,000, 1:100,000, 1:250,000 and 1:500,000 covering the whole territory by using space images;

(*d*) Publish the *National Atlas of Viet Nam* in 1992;

(*e*) Publish various thematic maps for education, tourism, culture-society and for exchanges in the international arena;

(*f*) Develop the technology for plotting maps of underground projects in cities and urban centres;

(*g*) Develop the technology for making maps on natural resources and environmental fluctuation on the basis of space images;

(*h*) Start marine geodetic work in two directions: study the surface of the sea and measure and draw the topology of the sea bottom and the continental shelf;

(*i*) Cooperate with neighbouring countries in determining national borders on land and on sea.

Apart from duties of our own, we have enough technical and human power to undertake bids for geodetic and cartographical projects proposed by foreign countries and international organizations.

In international cooperation, our work will be directed as follows:

(*a*) To exchange specialists with a view to exercising themes of scientific research and technical advances; special attention is to be paid to South-East Asian and Asian-Pacific countries;

(*b*) To admit students from other countries for training technical cadres at different levels (engineer, master's, doctoral) and post-graduates, through training courses at production enterprises of geodesy, cartography, and remote sensing in Viet Nam;

(*c*) To conduct all-sided cooperation between the State Department for Geodesy and Cartography of Viet Nam with other competent organizations of other countries in management, training, production and scientific research;

(*d*) To cooperate with other countries in exchanging materials, journals and products of cartography;

(*e*) To sign contracts, by part and parcel or overall project, on geodesy and cartography proposed by other countries and international organizations;

(*f*) To cooperate with organizations for geodesy and cartography of other countries to carry out common geodetic and cartographical work for our region or for their own regions.

Besides problems and points mentioned above relating to our ability, we would like to propose the following foreign support to the geodetic and cartographical branch of Viet Nam:

(*a*) The USSR, the United States and France to provide Viet Nam with materials of space images for remote sensing;

(*b*) International organizations and developed countries to continue their aid to our geodetic and cartographical branch, focusing on the transfer of advanced technology and modern equipment to Viet Nam;

(*c*) The State Department for Geodesy and Cartography of Viet Nam, as well as the Viet Nam Association for Geodesy, Cartography and Remote Sensing, to receive frequent invitations to international conferences on geodesy and cartography. Viet Nam is ready to take part in the activities of all international and regional organizations for geodesy and cartography.

## REPORT OF THE INTERNATIONAL HYDROGRAPHIC ORGANIZATION*

*Paper submitted by the International Hydrographic Bureau*


### RÉSUMÉ

La communication donne un aperçu des travaux et objectifs de l'Organisation hydrographique internationale (OHI), qui a rendu, depuis sa création en 1921, de précieux services consultatifs et techniques aux Etats qui en sont membres et aux milieux hydrographiques et maritimes du monde entier. On y souligne l'importance de l'hydrographie et sa contribution au développement socio-économique des pays côtiers. On y indique les activités de l'OHI qui sont menées principalement par correspondance et celles des divers comités tels que le Comité de normalisation des cartes marines, le Comité sur les SEVCM (COE), le Comité sur l'échange des données numériques et le Comité directeur mixte COI/OHI de la Carte générale bathymétrique des océans. Deux tableaux donnent l'un la liste des 56 Etats membres de l'OHI et, l'autre, la liste de 13 ouvrages publiés par cette organisation. Enfin, l'on y indique brièvement les procédures à suivre pour adhérer à l'Organisation.


### Background

The International Hydrographic Bureau (IHB) was founded in 1921. In 1970, an intergovernmental Convention entered into force, changing the IHB's name and legal status and creating the International Hydrographic Organization (IHO) with its secretariat, the IHB, remaining in the Principality of Monaco. The IHO is of purely technical and consultative nature and currently has a membership of 56 member States (see annex I). It is not a United Nations agency, but works closely with all associated United Nations bodies.

The aims of IHO are:

(*a*) To coordinate the activities of national hydrographic offices;

(*b*) To standardize the collection of hydrographic data;

(*c*) To standardize the symbols, styles and formats used for nautical charts and related publications;

(*d*) To standardize the training of hydrographic surveyors and nautical cartographers;

(*e*) To assist developing countries to establish and/or strengthen their hydrographic capabilities;

(*f*) To assist in the coordination of developments in the handling and formatting of digital data and Electronic Chart Display and Information Systems (ECDIS).

Official representatives of member States meet in Monaco at five-yearly intervals to review the progress made by the IHO and to adopt a budget and programmes of work for the next five years. A Directing Committee of three senior hydrographers is elected to guide the work of the total staff of 20 people in the IHB. In between the five-yearly Conferences, the regional hydrographic commissions meet to discuss common problems and activities; various technical committees and working groups also help to resolve technical, administrative and financial matters.

### Importance of hydrography

Hydrography is that part of the United Nations definition of the science of cartography which relates to the measurement and depiction of those parameters necessary to describe the exact nature and configuration of the seabed and the characteristics and dynamics of the sea. These parameters include bathymetry (or depths), tides, currents, waves, physical properties of sea water, geology, geophysics etc.

Until the 1950s, the world's major hydrographic offices were able to devote sufficient effort to the collecting of data to satisfy the needs of international shipping, then the main customers. Within the last 30 years, there have been many changes including:

(*a*) Increased draughts and changing patterns of shipping, requiring more precise data about previously unexplored sea areas and the approaches to new or enlarged ports;

(*b*) Improved technology leading to the exploration and exploitation of hydrocarbons and non-renewable marine resources at greater depths and further offshore;

(*c*) Imminent ratification of the United Nations Law of the Sea Convention requiring States to assume responsibility for very large areas of their continental shelves and economic zones;

(*d*) Appreciation of the economic benefits to be obtained from improved methods of fishing, recreational use of the sea and management of national maritime resources;

(*e*) Appreciation of the need to conserve the marine ecology by reducing the risks of pollution following the stranding of vessels on uncharted dangers;

(*f*) The gaining of independence by developing countries left with no hydrographic capacities but with new requirements and responsibilities for collecting data and maintaining nautical charts of their large offshore areas.

### Activities of the IHO

The IHO carries out its work mainly by correspondence and by various committees and working groups, as shown below.

(*a*) The *Chart Standardization Committee (CSC)*, having developed a set of specifications for nautical charts which are now being adopted by all IHO national hydrographic offices, continues to review the specifications and to review future trends in nautical charting and related information dissemination services. Another significant achievement has been the production, by volunteering hydrographic offices, of two small-scale (1:3,500,000 and 1:10,000,000) International (INT) Charts series covering the world's oceans. Good progress is now being made by IHO member

*The original text of this paper appeared as document E/CONF 83/L 3.

States with series of medium- and large-scale INT Charts to cover all the world's major shipping routes and ports.

(*b*) The *Committee on ECDIS (COE)* has worked with the International Maritime Organization IMO-IHO Harmonizing Group of ECDIS to produce provisional performance standards for electronic chart display and information systems (ECDIS) for the guidance of manufacturers of ECDIS; COE's work continues, through six working groups, to examine and develop specific aspects of the provisional standards.

(*c*) The *Committee on the Exchange of Digital Data (CEDD)* works closely with the COE to develop standards for the exchange of digital data in terms of the format to be used and object and attribute coding.

### *Training*

Together with the International Federation of Surveyors (FIG), a joint FIG/IHO International Advisory Board on Standard of Competence for Hydrographic Surveyors has published a set of standards for the training of various categories of hydrographic surveyors for the guidance of academic establishments throughout the world. The Board meets annually to review courses submitted to it, which are evaluated against the standards and awarded certificates of recognition when appropriate. The IHO is now studying the standardization of training in nautical cartography. The IHO publishes a compendium giving information on courses available on hydrographic surveying and nautical cartography (SP-47).

### *Ocean bathymetry*

To contribute towards the scientific knowledge of the oceans, volunteering IHO hydrographic offices maintain a World Series of 1:1,000,000 Bathymetric Plotting Sheets, which are used to produce the General Bathymetric Charts of the Oceans (GEBCO) under the supervision of a joint IOC/IHO Guiding Committee for GEBCO. The Guiding Committee has sub-committees on geographical names and nomenclature of ocean bottom features and on digital bathymetry. The IHO also works closely with the editorial boards for larger-scale international bathymetric charts and overlay sheets for various maritime areas and has recently established an IHO Data Centre for Digital Bathymetry at the National Geophysical Data Center (NGDC) of Boulder, Colorado, United States of America.

### *Tidal constituents*

Tidal data is used in various aspects of navigation, and measurement and prediction of tides is a fundamental element of hydrography. To assist in this work, a Tidal Constituent Bank has been established in recent series as a parameter in the prediction of the effects of global warming.

### *Technical assistance*

Recognizing the very inadequate data available in many parts of the world and the lack of any hydrographic capability in many developing countries, IHO has allocated limited funds to enable it to send experts to any country—whether an IHO member State or not—which requests such visits. During such a visit, the IHO expert will visit all the various national organizations with marine responsibilities to discuss the present situation, the benefits to be derived from establishing a hydrographic capability, the procedures to be adopted in order to prepare a project formulation framework and a draft UNDP project document, and how to obtain UNDP or bilateral assistance. In 1990, an IHO expert visited the Kingdom of Tonga, Republic of Seychelles and Pakistan in the Asia and the Pacific region.

### *Publications*

In addition to the semi-annual *International Hydrographic Review* and the monthly *International Hydrographic Bulletin,* IHB produces a series of special publications, each in the two official languages of IHO, English and French. A catalogue of IHO publications is available (free) from the International Hydrographic Bureau, BP 445, MC 98011, Monaco. Details of some of the available IHO publications are in annex II.

## MEMBERSHIP IN IHO

A Government wishing to become a member of IHO should apply through diplomatic channels for accession to the intergovernmental Convention on IHO to the Government of the Principality of Monaco, the Depository Government for the Convention, indicating the tonnage of the country's registered fleets. This figure is obtained by adding six sevenths of the displacement tonnage of ships of war exceeding 100 tons to the gross tonnage of all their other vessels over 100 tons. When two thirds of the existing IHO member States have signified to the Government of Monaco their approval of the application, the acceding Government will be asked to deposit an instrument of accession with the Government of Monaco.

Annual contributions to IHO are based upon the reported shipping tonnages and vary between a basic 2 and a maximum of 27 shares. In 1991, the value of each share was 1,852.48 SDRs (Special Drawing Right units of the International Monetary Fund), or about $US 2,500.

## ANNEX I

**Member States of the International Hydrographic Organization: November 1990**

| | | |
|---|---|---|
| Argentina | Iceland | Singapore |
| Australia | India | South Africa |
| Belgium | Indonesia | Spain |
| Brazil | Iran (Islamic Rep. of) | Sri Lanka |
| Canada | Italy | Suriname |
| Chile | Japan | Sweden |
| China | Malaysia | Syrian Arab Rep |
| Cuba | Monaco | Thailand |
| Democratic People's Rep. of Korea | Netherlands | Trinidad and Tobago |
| Denmark | New Zealand | Turkey |
| Dominican Rep | Nigeria | USSR |
| Ecuador | Norway | United Kingdom of Great Britain and Northern Ireland |
| Egypt | Oman | United States of America |
| Fiji | Pakistan | Uruguay |
| Finland | Papua New Guinea | Venezuela |
| France | Peru | Yugoslavia |
| Germany | Philippines | Zaire |
| Greece | Poland | |
| Guatemala | Portugal | |
| | Republic of Korea | |

Applications pending: Cyprus, Mauritania, United Arab Emirates

## ANNEX II

**Selected IHO publications**

PP-05 *IHO Yearbook*
MP-001 *Basic Documents of IHO*

| | |
|---|---|
| MP-004 | *Chart Specifications of the IHO* |
| MP-005 | *Standards of Competence for Hydrographic Surveyors* |
| MP-006 | *Reference Texts for Training of Hydrographic Surveyors* |
| SP-32 | *Hydrographic Dictionary* |
| SP-44 | *IHO Standards for Hydrographic Surveys* |
| SP-47 | *Training Courses in Hydrography* |
| SP-50 | *IHO Tidal Constituent Bank Station Catalog* |
| SP-51 | *Manual of Technical Aspects of the Law of the Sea* |
| SP-52 | *Provisional Standards for ECDIS* |
| SP-55 | *Status of Hydrographic Surveying Worldwide* |
| BP-0008 | *Gazetteer of Geographical Names of Undersea Features* |

## SURVEYING AND MAPPING IN HONG KONG: 1987-1991*

*Paper submitted by Hong Kong*


### RÉSUMÉ

Le Bureau de topographie et de cartographie est l'un des trois bureaux du Département de la construction et de l'aménagement du territoire, les deux autres étant le Bureau du matériel de construction et le Bureau de l'administration foncière. Il est chargé de réaliser l'un des objectifs importants du Département, à savoir : «Maintenir un système de topographie, de cartographie et d'information foncière bien conçu et à jour pour le territoire.» Il assume donc l'autorité en matière de levé et d'établissement de cartes.


### Survey and Mapping Office

The Survey and Mapping Office is one of three offices of the Buildings and Lands Department, the other two being the Buildings Ordinance Office and the Land Administration Office. It has the responsibility of carrying out an important objective of the Department, which is "to maintain a sound, up-to-date land survey, mapping and land information system for the territory".

The Office thus carries the responsibility of both survey and mapping authority within the territory.

### Developments in the surveying field

#### *Geodetic control*

The geodetic network covering the territory, known as the Hong Kong 1980 Geodetic Datum, has been well maintained at the primary and secondary levels. Third-order control has been more difficult to maintain owing to the rapid pace of development. Preservation of the benchmark network has also been maintained. Preliminary investigation is about to begin into GPS applications.

#### *Cadastral surveying*

The majority of boundary definition surveys and the maintenance of all official cadastral records are carried out by the Survey and Mapping Office. Only limited private practice participates in this area.

#### *Survey ordinance*

A draft Land Survey Ordinance has been under preparation for several years, and it is hoped that this will pass into legislation within the next year or so. Such legislation controlling the land surveying profession will enable greater participation by private practitioners in cadastral work.

#### *Topographical surveying*

Hong Kong is well covered by a basic mapping series at 1:1,000 scale. From this series of approximately 3,000 sheets, all other smaller scales of topographical maps are derived. Revision at the basic scale is difficult to maintain owing to limitations in staff resources and the rapid pace of development. However, action is in hand to develop a system of continuous revision. This is essential in order to meet the requirements of the land information system (LIS) being introduced in the Survey and Mapping Office.

#### *Land information system*

The Land Information Centre in the Survey and Mapping Office is developing a LIS which will be based on the 1:1,000 map series for its geographical database. The system is an ARC/INFO application supplied by the Environmental Systems Research Institute (ESRI) of the United States, and the basic development of the customized programme is close to completion. Input of data for the Kowloon region is well advanced, and it is estimated that the capture of data for the whole territory will take another two to three years. The Office has recently installed an intergraph scanner which will be utilized to speed up the input process as much as possible.

The extension of the basic system to cover additional data, such as engineering records and utility companies data, will be developed in parallel, in order to establish a comprehensive LIS.

#### *Mapping production*

The Office has developed a full range of mapping products. With the development of the computerized LIS, the development of computer-assisted cartography will be introduced in step with the development of a comprehensive LIS.

Printing of map products is carried out by the Government Printer, or by private printing firms, under the supervision of Office cartographic staff.

#### *Hydrographic charting*

Currently, all nautical charts of Hong Kong waters are produced from data collected by surveyors of the Civil Engineering Services Department, by the British Admiralty. Action is now in hand to establish a charting organization in Hong Kong and to produce local charts in Hong Kong.

#### *Engineering surveys*

Professional land surveyors from the Survey and Mapping Office are seconded to a number of engineering departments (e.g. highways, civil engineering and water

*The original text of this paper appeared as document E/CONF.83/INF.48.

supplies), where they supervise the technical staff carrying out engineering surveys for development, construction and maintenance.

Consulting engineering firms and a small group of private practice land surveyors also provide professional and technical survey services in respect of a wide range of engineering development.

### *Special services*

The Office maintains an air survey and photogrammetric unit which enables it to provide a wide range of data from both aerial and terrestrial photography. The unit assists in map revision and the supply of detailed mapping for engineering development. Stereo- plotters, including an analytical plotter, utilize RC10 or RC10A photography taken by Office staff from aircraft maintained by the Hong Kong Auxiliary Air Force.

In the mapping field the Office produces a range of special products to meet specific requirements. These include aeronautical charts for civil aviation, maps for census and statistics, electoral boundaries, and thematic maps for specific purposes.

## CONSULTANCY STUDY OF THE SURVEY AND MAPPING INDUSTRY

Late in 1990 the Hong Kong government commissioned a management consultant firm to carry out an all-embracing study of the survey and mapping industry in Hong Kong, including hydrographic survey and charting requirements.

This study has progressed to a point where the Steering Group under the chairmanship of the Director of Buildings and Lands is considering the contents of a draft final report. The consultants' final report was due to be presented before the end of March 1991.

# AGENDA ITEM 5

## Cartographic data acquisition and supporting activities*

### (a) *Conventional and satellite geodesy*

## POSITIONING WITH THE DORIS SYSTEM: PRESENT STATUS AND FIRST RESULTS**

*Paper submitted by France*


### RÉSUMÉ

DORIS est un acronyme qui signifie Doppler Orbitography and Radiopositioning Integrated by Satellite. Le système DORIS est mis en place grâce à une collaboration entre trois groupes français : le Centre national d'études spatiales (CNES), le Groupe de recherche en géodésie spatiale et l'Institut géographique national (IGN). Le premier récepteur du système a été lancé en janvier 1990 par la fusée européenne Ariane en tant que charge utile du satellite SPOT 2 (satellite de téléobservation de la Terre). Un réseau mondial de près de 40 balises de poursuite est maintenant totalement opérationnel, et les premières mesures Doppler sont déjà disponibles.

L'objet du présent document est de faire succinctement le point du système DORIS et de décrire en particulier les premières applications dans le domaine de la localisation. On examine également les premiers résultats obtenus à des fins de localisation au moyen des données en temps réel fournies par le système.


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The future French–United States oceanographic mission Topex-Poseidon, planned to be launched in 1992, assumes that it will then be possible to determine the position of a low orbiting satellite (1,335 km of altitude for Topex) at the 10-cm level or better for the radial component. The orbit determination of Topex will be performed from the United States side by using the Satellite Laser Ranging System (SLRS). Furthermore, as an experiment, a GPS receiver will also be located on board the satellite in order to accurately monitor the orbit at this high level of precision. In order to fulfil these stringent precision requirements of the Topex-Poseidon orbit determination, France has designed and developed a new Doppler system named DORIS (Doppler orbitography and radiopositioning integrated on satellite). To prepare the Topex-Poseidon mission, as a proof of concept and feasibility test, a first DORIS receiver was launched on 22 January 1990, as a payload of the SPOT 2 satellite (Système probatoire d'observation de la terre).

The purpose of this paper is to review the concepts and the state-of-the-art of the DORIS project and, more specifically, to give the first preliminary positioning results using the DORIS system.

### THE DORIS SYSTEM

DORIS is being developed through the cooperation of three French groups: the Centre national d'études spatiales (CNES), groupe de recherche en géodésie spatiale (GRGS) and the Institut géographique national (IGN).

The main purpose of DORIS being orbit determination, DORIS is an uplink Doppler system. This means that, by opposition with the TRANSIT/NNSS system, the signal is transmitted from the ground (dense tracking network of beacons) to the satellite (on board receiver). The Doppler measurement is integrated on a 10-second integration time. Figure 1 gives an overview of the DORIS system.

In order to determine precisely the propagation effect in the ionosphere, two frequencies are used: 2 GHz and 400 MHz. The main difference between these two frequencies allows a precise monitoring of the ionospheric delay. As a by-product, this also allows the determination of better ionospheric models, which can be used with benefit for other geodetic space techniques. In particular, it will be used during the oceanographic Topex-Poseidon mission to correct the measurements from the French altimeter, which is a newly designed solid-state single frequency altimeter.

At present, the space segment of the DORIS system consists only in one satellite. The first DORIS receiver is already flying on the SPOT 2 satellite (heliosynchronous satellite at 832-km altitude). In the future, several receivers will fly at the same time. For precise positioning of low-orbiting satellite, one of the major aspects is an improved knowledge of the Earth gravity field. Within the DORIS project, a new gravity field (GRIM4SD) has been computed by GRGS in collaboration with the German group Deutsches Geodätisches Forschungs Institut. This gravity field model has been established by using previous satellite geodetic measurements (optical measurements, TRANSIT/NNSS, SLR etc.) and also a four-month data set of DORIS measurements on the SPOT 2 satellite. These results are of course preliminary and incomplete but they already show a significant improvement (Biancale and others, 1990) in gravity field determination.

*Sub-items on which no papers were submitted are not listed.

**The original text of this paper, prepared by experts of the Institut géographique national, the Observatoire midi-Pyrénées, the Centre national d'études spatiales and the Collecte localisation par satellites, appeared as document E/CONF.83/INF.24.

Figure 1. The DORIS system: block diagram

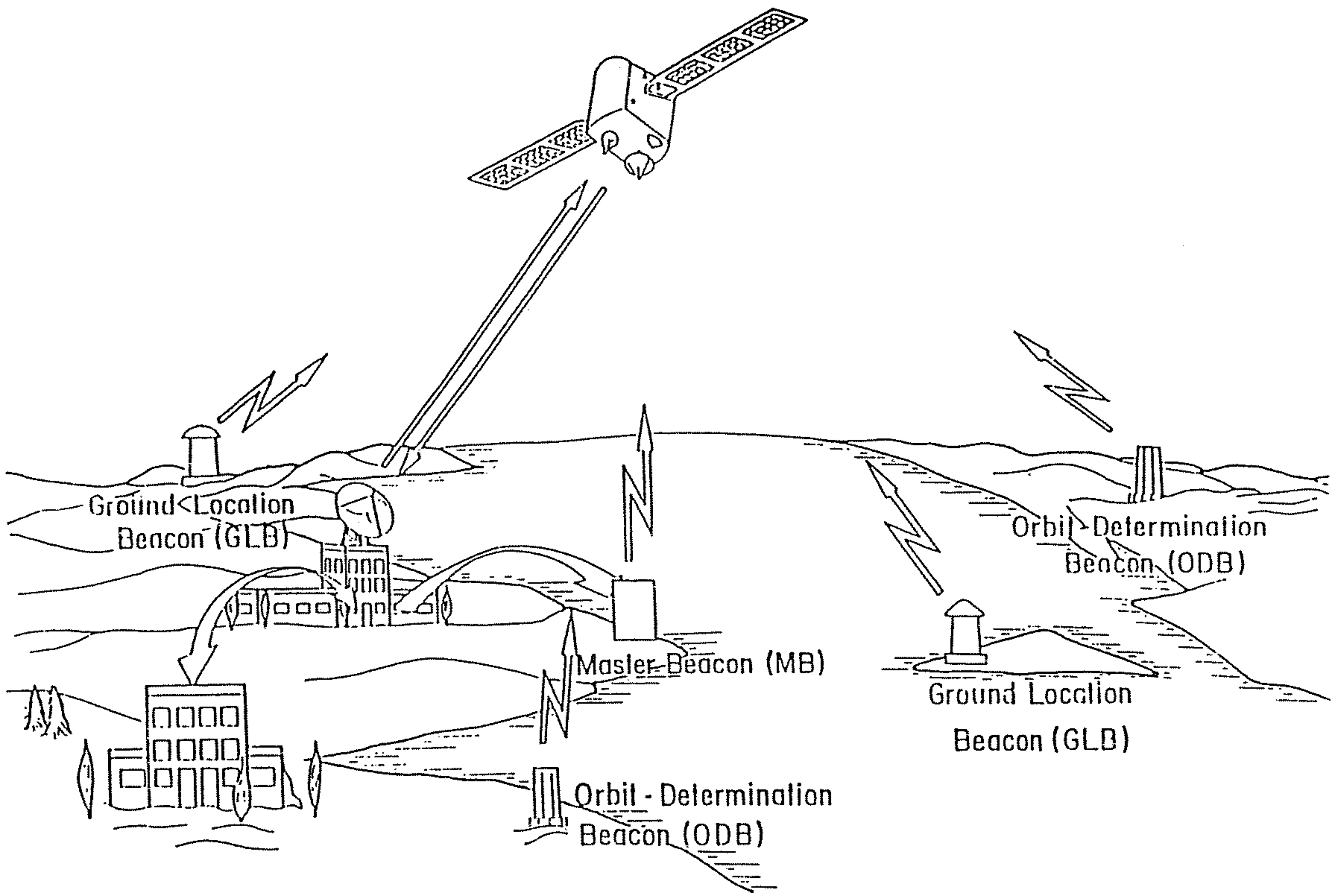
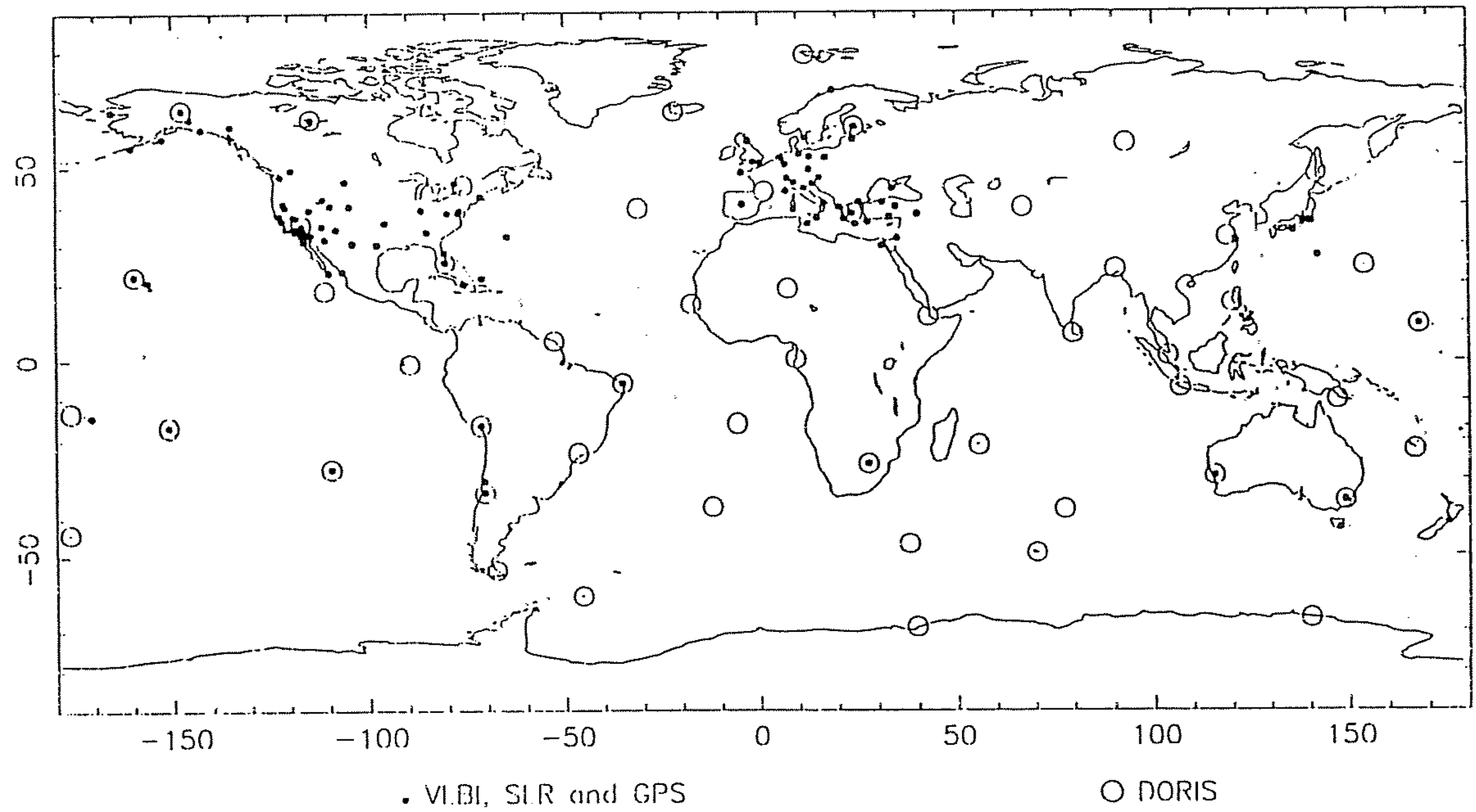


Figure II. The DORIS tracking network



Great care has also been taken in selecting the permanent sites for the tracking beacons in order to achieve a dense orbitographic network of DORIS beacons, colocated, as much as possible, with stations determined with other geodetic space techniques. Figure II shows the future geographical location of these orbitography beacons and also the colocations with other techniques. In this figure, all the selected DORIS locations are displayed with other techniques: very long baseline interferametry (VLBI), SLRS (permanent or mobile stations), Global Positioning System (GPS) permanent stations of the CIGNET network. At present, 36 beacons have already been deployed by IGN all around the world (Etat du réseau orbitographique DORIS, 1990) thanks to large international cooperation. The final tracking network should consist of almost 50 stations, geographically well distributed.

Another aspect of DORIS is the potential positioning capability for ground beacons (P. Willis and others, 1989). As far as the system is able to provide a precise orbit of the satellite from the DORIS data coming from the operational tracking network, it is then able to determine other ground beacons. Precise positioning can be seen as an obvious by-product of the DORIS system. Smaller field beacons, called positioning beacons, have been developed by CNES for this purpose and are actually used in the field in Djibouti (Valette, 1990). In order to avoid Doppler interferences at the satellite receiver when several beacons are present in the same region of the globe, the transmission of the beacons has to be automatically sampled in order to avoid two close beacons transmitting at the same time. This figure of the systems could be changed in the future, if needed, by allowing the receiver in the satellite to simultaneously receive the signal transmitted from several beacons. Such a modification requires a new development and is not foreseen in the near future.

To validate the positioning performances of the DORIS system, several pilot experiments have been selected and are actually in progress. These field experiments have been chosen with regard to several scientific interests: Djibouti (active tectonic area), Hawaii (volcanic zone), Japan (geodetic test of accuracy), France (landslide). The test experiment in Djibouti, has already started in February 1990. The one in France is presently in progress. The one in Hawaii (Lenat and others, 1990) should begin in September 1990.

## Positioning results with the DORIS system

Since the successful launch of the SPOT 2 satellite in January 1990, a lot of DORIS data have been gathered and analysed by CNES, GRGS, CLS and IGN. Here, the point is to present the very first results obtained concerning the positioning capabilities of the DORIS system for ground beacons.

A dedicated software has been designed by IGN and developed and implemented by the Collecte localisation par Satellites (CLS), a subsidiary of CNES long responsible for operational positioning with the French Argos system. At present, this software is based on a standard geometrical algorithm. The orbit of the satellite is neither estimated nor improved (using short arc technique). The orbit used comes from CNES and is computed on an operational basis using all the DORIS data of the tracking network processed with the ZOOM software (Labrune and others, 1986).

The DORIS beacons coordinates are determined in an absolute positioning mode. Nevertheless, it is also possible to position two beacons in a relative mode (selecting only the common passes, as was already done with the TRANSIT/NNSS system). At present, the beacons in operation (mainly, the 36 tracking stations) are too far apart to really test this possibility, except in the Djibouti area (Valette, 1990). This will change rapidly when all the pilot experiments are started. For this reason, in this paper only absolute positioning results are presented.

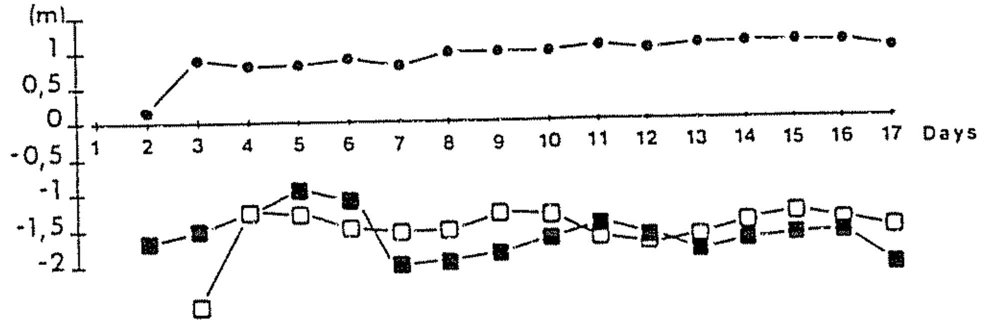
Figures III and IV present typical results of DORIS positioning obtained for two stations of the DORIS tracking network: Hartebeesthoek (South Africa) and Arequipa (Peru). In order to show the convergence of the DORIS solution, the same period of 17 days has been used for both stations. Each point of these graphs relative to day "n" corresponds to the DORIS solution obtained by taking into account only the first "n" days of the arc. The differences in longitude, latitude and height are referred to *a priori* values (obtained using previously TRANSIT Doppler positioning). In the case of Hartebeesthoek, the DORIS solution is very stable after the first four days of measurements. In the case of Arequipa, the DORIS solution is stable only after a longer period of time (it can be seen that fewer DORIS measurements were available for this beacon for this arc).

At present, a "good" DORIS solution can be typically obtained from 3 to 10 days of observation. This duration depends on the latitude of the station to be located (the latitude of the beacon is directly related to the number of passes of the SPOT 2 satellite per day) and the performance of the beacon (amount of lacking data due to the losses of data because of interfering parasitic radion-electric transmissions). It must be noted that the difference between the estimated DORIS solution and the reference (which can be, in these two cases, up to 2 m) gives a first indication of the exactitude of the DORIS solution (both references are known to the 10 cm level). This point will be discussed again in detail.

In order to test the repeatability of the DORIS solution, 10 stations, each providing three full months of DORIS data (May to June 1990), have been selected. For all these 10 beacons, three independent monthly DORIS solutions have been computed. Table 1 displays these three monthly solutions, referred to their mean value. To estimate the month-by-month repeatability of the DORIS solution, we have compared each monthly solution to its three months mean value and we have also computed the root-mean-square (RMS) from these 9 independent values (3 months times 3 difference of coordinates). The month-by-month repeatability of the DORIS solution is between 0.23 m and 0.40 m (for absolute positioning).

Figure V shows the dependence of this RMS with the latitude of the station. As the SPOT 2 satellite is a heliosynchronous satellite, a polar station will experience more passes (and then, will provide more DORIS data) than an equatorial station. It is then rather logical to obtain a slightly better repeatability for high latitude stations simply because they provide more DORIS data. For the data set presented in table 1, three histograms were established (figure VI for longitude, figure VII for latitude and figure VIII for height). We assume that the errors between two stations are decorrelated, because they are too far apart (several hundred to several thousands of kilometres). From these plots, we can see that the repeatability of the DORIS solution is rather better than for the other two components. This can be explained by the fact that, in this computation, the major cause of error source is the along-track error of the satellite. Such an error will have little effect on the determination of the height of the station.

Figure III. Convergence of the DORIS solution with regard to the *a priori* position: Hartebeesthoek, 1-17 May 1990

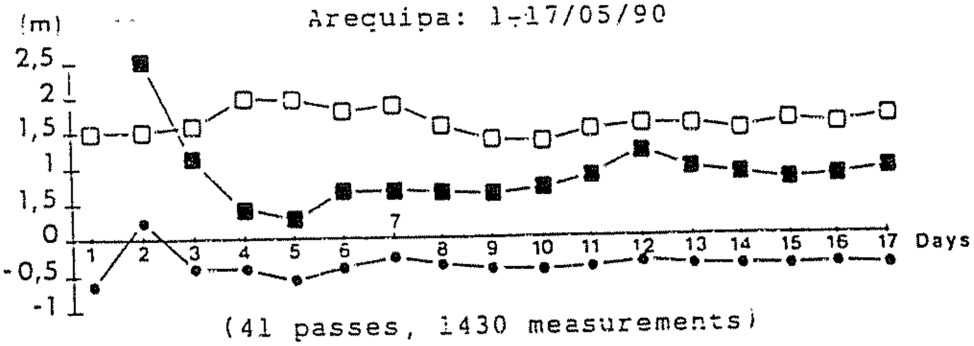



□ Difference in longitude (m)

■ Difference in latitude (m)

• Difference in altitude (m)

Figure IV. Convergence of the DORIS solution with regard to the *a priori* position: Arequipa 1-17 May 1990




□ Difference in longitude (m)

■ Difference in latitude (m)

o Difference in altitude (m)

TABLE 1. STUDY OF THE DORIS POSITIONING RESULTS: MONTH BY MONTH REPEATABILITY

| *DORIS site* | *Latitude* | *Month (1990)* | *Longitude (m)* | *Latitude (m)* | *Altitude (m)* | *RMS (m)* |
|---|---|---|---|---|---|---|
| Metsahovi | 60°15 | April | 0.43 | −0.26 | 0.13 | |
| | | May | −0.14 | 0.00 | 0.06 | 0.25 |
| | | June | −0.29 | 0.26 | −0.20 | |
| Toulouse | 43°33 | April | −0.45 | −0.05 | 0.30 | |
| | | May | −0.16 | 0.54 | 0.00 | 0.40 |
| | | June | 0.61 | −0.48 | −0.29 | |
| Goldstone | 35°20 | April | 0.38 | −0.17 | 0.14 | |
| | | May | −0.47 | −0.27 | −0.07 | 0.30 |
| | | June | 0.10 | 0.45 | −0.07 | |
| Purple Mountain | 32°04 | April | 0.16 | 0.37 | 0.08 | |
| | | May | −0.07 | 0.43 | 0.02 | 0.35 |
| | | June | −0.10 | −0.79 | −0.09 | |
| Djibouti A | 11°32 | April | 0.44 | −0.06 | 0.27 | |
| | | May | −0.12 | 0.32 | −0.10 | 0.27 |
| | | June | −0.33 | −0.25 | −0.17 | |
| Djibouti B | 11°32 | April | 0.46 | 0.30 | −0.04 | |
| | | May | −0.42 | 0.05 | −0.13 | 0.28 |
| | | June | −0.04 | −0.34 | 0.16 | |
| Arequipa | −16°28 | April | 0.53 | −0.32 | 0.40 | |
| | | May | −0.49 | −0.09 | −0.21 | 0.36 |
| | | June | −0.05 | 0.40 | −0.19 | |
| Hartebeesthoek | −25°53 | April | 0.10 | 0.19 | −0.07 | |
| | | May | −0.30 | 0.31 | 0.01 | 0.26 |
| | | June | 0.21 | −0.49 | 0.06 | |
| Santiago | −33°23 | April | 0.09 | −0.26 | 0.16 | |
| | | May | −0.22 | −0.21 | −0.12 | 0.23 |
| | | June | 0.14 | 0.46 | 0.03 | |
| Rio Grande | −53°47 | April | −0.26 | 0.36 | −0.26 | |
| | | May | 0.32 | −0.07 | 0.01 | 0.36 |
| | | June | −0.06 | −0.30 | 0.25 | |

The station positions have been estimated by the CLS/IGN software over three months of DORIS data (April to June 1990) using SPOT 2 ephemerides produced by CNES. This ephemeris adjustment uses the ZOOM software applied on 2-day arcs, with the GEM.T1/T2 models and a station coordinate set provided by IGN (JCODO). This set includes 10 stations colocated with IERS sites, for which the JCODO stations are estimated better than 10 cm, mainly based upon BTS 87 system (epoch 1984.0). These stations are shown as colocation DORIS/IERS in the map of figure II. This CLS/IGN solution is labelled C1, and consists of coordinates of 25 stations at epoch 1990.3.

In addition to C1, two other results have been used, both computed by GRGS/CNES with the GIN/DYNAMO software:

(*a*) Solution G6 uses 4 months of data on 38 stations, with the GEM T2 gravity field with a few adjusted coefficients (March to June 1990) (Soudarin, 1990);

(*b*) Solution G4 (almost) the same data set as G6, but with full adjusted gravity field model GRIM4SD (Biancale, 1990). The full station coordinate set includes also other types of tracking (SLR, Doppler, optical). In addition to the 38 DORIS positions in G4, some SLRS stations at colocation sites (Huahine, Metsahovi, Dionysos, Easter, Goldstone, Arequipa) are of particular interest for comparisons. Local survey ties have been included in G4 for these 6 sites between SLRS and DORIS.

Several computations were performed:

(*a*) To assess realistic errors to various sets, not only formal errors produced by least-squares adjustments;

(*b*) To estimate possible transformation parameters between C1, G6, G4 and IERS;

(*c*) To make an external accuracy estimation;

(*d*) To derive an improved station coordinate set to be used by CNES for orbit computation.

First an update of JCODO was done for IERS sites (10 sites) using ITRF89 (Boucher *et al.*, 1990) and epoch 1990.3.

Then a global combination of JCODO, C1, G4 and G6 was done to achieve goals (*a*), (*b*), and (*d*). *A priori* standard deviations were given to 0.9 m to C1, 0.8 m to G6 and 0.5 m to G4. Transformation parameters are given in table 2.

Finally, the three solutions C1, G6 and G4 were corrected from these parameters and compared to the 10 IERS sites of JCODO. RMS residuals are displayed in table 3.

These results show that the overall accuracy is at the metre level with GEM T2, with repeatability at 30 cm level. Most of the errors come from the orbit. This can be further illustrated by comparing C1, G6 and G4 two by two. Results are shown in table 4. One solution admits a 7-parameter adjustment, the other uses fixed 7-parameter values coming from table 2.

Comparisons between G4 and G6 or C1, which are both with GEM-T2, show an improvement of 20 cm of rms: 0.5 to 0.3 m for G4; 0.95 to 0.75 m for G6 and 1.1 to 0.9 m for C1. But for C1.G6, a much better improvement of 70 cm can be found (1 m to 0.3 m for C1, 0.95 to 0.25 m for G6).

Preliminary use of GRIM4SD shows a gain of a factor of 2: from 1 m to 50 cm. Previous simulations (De Moegen and others, 1985) estimated accuracy to 10 cm with orbital error

Figure V. Month-by-month repeatability of the DORIS solution

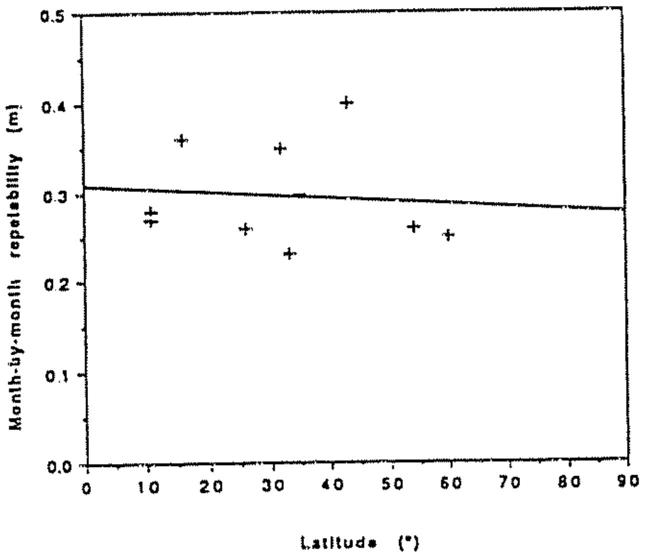



Figure VI. Month-by-month repeatability in longitude

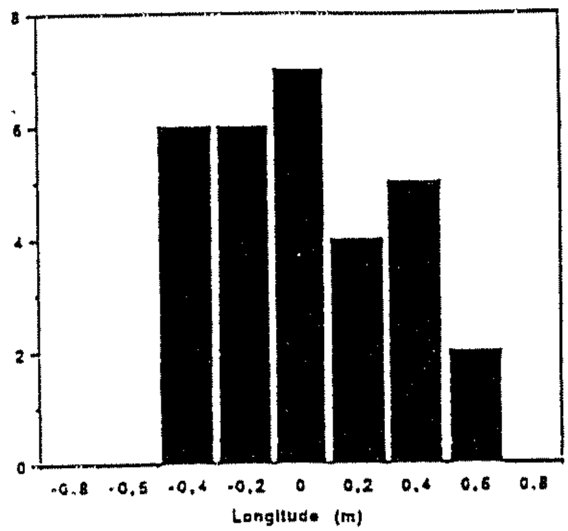



Figure VII. Month-by-month repeatability in latitude

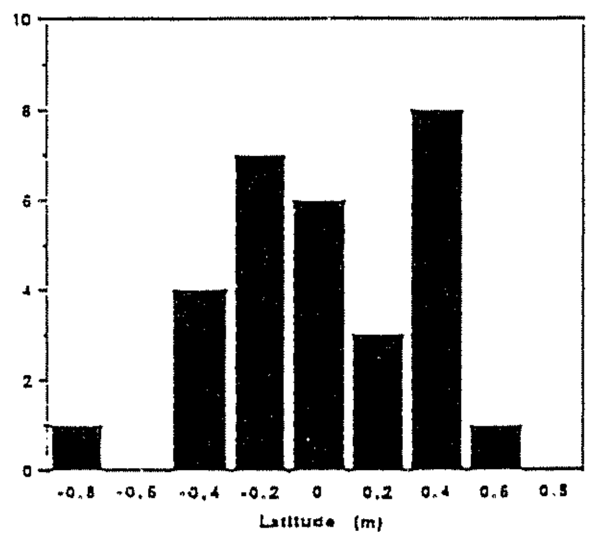



Figure VIII. Month-by-month repeatability in height

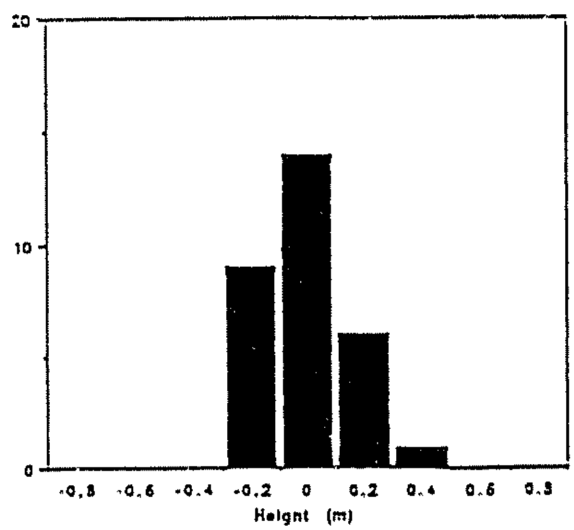


TABLE 2. TRANSFORMATION PARAMETERS/JCODO

| *Solution* | *TX (m)* | *TY (m)* | *TZ (m)* | *D (ppm)* | *EX (")* | *EY (")* | *EZ (")* |
|---|---|---|---|---|---|---|---|
| C1 | 0.66 | −0.31 | −0.08 | −0.114 | −0.035 | 0.010 | 0.044 |
| | ±0.20 | ±0.20 | ±0.16 | ±0.031 | ±0.008 | ±0.008 | ±0.008 |
| G6 | 0.44 | −0.54 | −0.12 | −0.009 | −0.032 | 0.003 | −0.058 |
| | ±0.16 | ±0.16 | ±0.16 | ±0.024 | ±0.006 | ±0.006 | ±0.006 |
| G4 | −0.02 | −0.05 | 0.00 | −0.003 | 0.001 | −0.004 | 0.009 |
| | ±0.05 | ±0.04 | ±0.04 | ±0.006 | ±0.002 | ±0.002 | ±0.002 |

TABLE 3. RMS RESIDUALS

| | *C1* | *G6* | *G4* |
|---|---|---|---|
| Without transformation parameters | 1.37 | 1.31 | 0.51 (0.46)* |
| With transformation parameters | 1.09 | 0.94 | 0.46 (0.43)* |

*Without GRIM4 SLR sites

to better than 1 m, while current estimates from orbit overlaps and GEM.T2 are 3 m. Gain, both from gravity field and non gravitational force modelling, should make orbital and positioning results converge towards this level of accuracy.

In summary, the present accuracy of C1 is estimated at 1 m, with a stationary station-dependant of 70 cm (in which 50 cm should be gained by adopting GRIM4SD in place of GEM.T2) and a noise of 30 cm (also shown in repeatability over 3 months).

For the best estimate G4, transformation parameters to ITRF are inferior to 10 cm, except a longitude rotation of 0."009, which is reasonable considering the way that the longitude origin is fixed in GRIM4.

## CONCLUSIONS

All these results will be significantly improved in the near future as soon as a more precise orbit is available. It is obvious from these results that the major improvement will come from a better gravity field model. Results will be significantly improved (by a factor of 2 or 3) by using new gravity models, as was shown by using GEM-T2, PGS3250, then GRIM4SD. The positioning results of ground beacons should then decrease around the 10 cm level for absolute positioning, as previously shown in simulation studies conducted at IGN (De Moegen and others, 1985).

On the other hand, the major cause of error, in the error budget, comes from uncertainty on the satellite position. This means that relative positioning (obtained by selecting only the common passes of the satellite relative to two beacons) should allow a few centimetre accuracy. At present, the available beacons composing the operational tracking network of the 36 stations are too far apart (several thousands of km) to provide enough common view passes. The relative positioning capabilities of the DORIS system will be extensively evaluated when all the pilot experiments are started and when more positioning DORIS beacons are operating in close vicinity (several tens or a few hundreds of kilometres).

In the future, the DORIS system will also fly on the SPOT 3 (1993), SPOT 4 and the Topex-Poseidon satellite (mid-1992).

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TABLE 4. TRANSFORMATION PARAMETERS

| *Solutions* | RMS *C1* | RMS *G6* | RMS *G4* | *TX (m)* | *TY (m)* | *TZ (m)* | *D (ppm)* | *EX (")* | *EY (")* | *EZ (")* |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) G4»G6 | — | 0.75 | 0.31 | 0.47 | −0.47 | −0.03 | −0.015 | −0.035 | 0.006 | −0.065 |
| | — | 0.75 | 0.31 | 0.46 | −0.49 | −0.12 | −0.006 | −0.033 | 0.007 | −0.067 |
| (2) C1»G4 | 0.93 | — | 0.27 | −0.73 | 0.17 | −0.02 | 0.124 | 0.035 | −0.012 | −0.037 |
| | 0.93 | — | 0.27 | −0.68 | 0.26 | 0.08 | 0.111 | 0.036 | −0.014 | −0.035 |
| (3) G6»C1 | 0.34 | 0.27 | — | 0.11 | 0.15 | −0.02 | −0.122 | −0.004 | 0.007 | 0.101 |
| | 0.34 | 0.27 | — | 0.22 | 0.23 | 0.04 | −0.105 | −0.003 | 0.007 | 0.102 |
| Closure (1)+(2)+(3) | | | | −0.15 | −0.15 | −0.07 | −0.013 | −0.004 | 0.001 | −0.001 |

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# UTILISATION DU GPS EN MODE CINÉMATIQUE DE PRÉCISION*

*Document présenté par la France*

## SUMMARY

The precision kinematic positioning technique already has numerous applications, and their number is bound to increase with the advent of the latest GPS satellites.

However, this technique is harder to use than the differential GPS, which is ideally suited to most navigational applications because of its accuracy.

This paper identifies four distinct operating methods, describes the results obtained with them and explores future prospects for the process.

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Le système GPS (Global Positioning System) a déjà démontré depuis quelques années de grandes applications dans le domaine du positionnement statique de précision. Les meilleurs résultats sont obtenus en traitant les phases de battement GPS en mode doubles différences (récepteur-récepteur et satellite-satellite). L'équation de mesure des doubles différences s'écrit :

$$D^2\phi = -\frac{f}{c}D^2\rho + \frac{f}{c}D^2(\Delta\rho_{prop}) + K(\lambda)$$

où $k$ est l'ambiguïté entière de la double différence. Cette valeur est inconnue mais constante dans le temps, ce qui permet de la déterminer, ainsi que les inconnues de positions, en cumulant les mesures enregistrées par les deux récepteurs pendant plusieurs dizaines de minutes.

Pour des besoins de navigation, le GPS a été utilisé en mode cinématique (une antenne fixe et une antenne mobile) en utilisant les mesures de pseudo-distances (lissées ou non par la phase). De nombreux auteurs ont déjà démontré les possibilités de ce GPS différentiel. Le but de cet article est de montrer qu'il est possible d'obtenir un positionnement cinématique beaucoup plus précis en utilisant exclusivement les mesures de phases GPS (mesures les plus fines) et de mettre en évidence quelques applications qui nécessitent un positionnement cinématique centimétrique.

### PROCÉDURES OPÉRATOIRES

Pour obtenir un positionnement cinématique à partir, uniquement, des mesures de phases GPS, il est indispensable de connaître les ambiguïtés entières $K$ de l'équation (1). Dès que ces ambiguïtés entières sont connues et tant qu'elles ne changent pas (voir le problème des sauts de cycles que nous aborderons plus tard), il est possible de réaliser un positionnement cinématique à partir des mesures de phases quasi simultannées de quatre satellites (3 doubles différences). On peut donc obtenir ainsi, en différé, une localisation instantanée (localisation déterminée à partir des mesures d'une seule époque).

Nous distinguons ici quatre types de procédés opératoires permettant de déterminer les ambiguïtés GPS.

#### *Calibration sur une base connue*

On commence par observer une ligne de base GPS pendant suffisamment longtemps (entre 30 et 45 minutes) pour pouvoir traiter ces mesures de phases GPS en mode statique et déterminer ainsi les positions relatives des deux stations de la ligne de base ainsi que les ambiguités entières. Cette méthode est très facile à mettre en œuvre mais implique une perte de temps de 30 à 40 minutes avant le premier déplacement du recepteur mobile. Cette perte de temps est actuellement très pénalisante vu la faible période d'utilisation du GPS dans son état actuel (peu de satellites en orbite). Lorsque la constellation GPS sera complète, cet inconvénient devrait diminuer en permettant une plus longue utilisation du GPS cinématique par rapport au temps perdu pour calibrer les ambiguïtés entières.

#### *Permutation des antennes*

Dans cette méthode originale, préconisée par B. Remondi (1986), on échange très rapidement, au début des opérations, les antennes stationnées sur les deux points initiaux. Il n'est alors plus nécessaire d'observer pendant plusieurs dizaines de minutes : quelques secondes suffisent. On montre par le calcul qu'au cours de cette opération de permutation des antennes les dérivées partielles par rapport aux coordonnées changent de signe dans l'équation (1) alors que les dérivées partielles par rapport aux ambiguïtés entières restent constantes (égales à 1). Il suffit donc d'avoir une position très approchée des deux points de départ pour déterminer les ambiguïtés entières. Cette solution semble très intéressante car elle permet un gain de temps substantiel. Néanmoins, elle reste difficile à mettre en œuvre, spécialement lorsque l'on dispose de plus de deux récepteurs GPS.

#### *Pseudo-cinématique*

Il existe, de plus, une autre méthode, beaucoup plus facile à mettre en œuvre. Elle consiste à réobserver, à la fin des

*The original text of this paper, prepared by P. Willis, Institut géographique national, appeared as document E/CONF 83/L.41.

TABLEAU 1. DIFFÉRENTES MÉTHODES D'OBTENTION DU GPS CINÉMATIQUE

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Calibration sur une base connue* | | | | | | | |
| Récepteur A | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Récepteur B | 2 | 2 | 3 | 4 | 5 | 6 | 7 |
| *Permutation des antennes* | | | | | | | |
| Récepteur A | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Récepteur B | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| *Pseudo-cinématique* | | | | | | | |
| Récepteur A | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Récepteur B | 2 | 3 | 4 | 5 | 6 | 7 | 2 |
| *Cinématique total* | | | | | | | |
| Récepteur A | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Récepteur B | 2 | 3 | 4 | 5 | 6 | 7 | 8 |

mesures, un point déjà stationné précédemment au cours du déplacement. Il suffit alors de traiter en premier uniquement les mesures provenant de cette ligne de base en mode statique classique pour déterminer les positions de stations et les ambiguïtés entières. En effet, ce problème revient à traiter avec un logiciel de GPS statique un fichier de mesures de doubles différences dans lequel toutes les mesures à l'exception de celles de la première et de la dernière époque ont disparues. Cette méthode s'appelle pseudo-cinématique car elle nécessite de pouvoir restationner un même point physique au cours du déplacement de l'antenne mobile. Si cette contrainte est facile à surmonter pour des besoins de géodésie ou de topométrie pour lesquels les points sont des points matérialisés (bornés), il n'en est pas de même pour le cas d'un véhicule qui ne peut s'arrêter (avion, dans le cas de la photogrammétrie).

### *Cinématique total*

Enfin, il existe une dernière méthode, encore en cours de mise au point, qui ne nécessite plus de restationner un point et que j'appelle ici cinématique total. Dans le cas où le récepteur peut enregistrer plus de cinq satellites simultanément, cette méthode est possible. Il suffit de compenser toutes les mesures disponibles par moindres carrés. On montre alors qu'avec un temps de mesures suffisant, on peut à la fois déterminer les ambiguïtés entières et les inconnues de position. L'inconvénient de cette méthode, ainsi que celle du pseudo-cinématique, est qu'elle nécessite un traitement en différé des mesures de phases. Il est donc possible que certains problèmes ne soient pas détectés au moment des observations mais seulement plus tard après calcul. Cet inconvénient est aussi amené à disparaître avec l'utilisation de micro-ordinateur portatif qui permettent un calcul en léger différé sur le terrain.

## EXEMPLE DE RÉSULTATS OBTENUS

Afin de valider les concepts présentés plus haut et d'évaluer la qualité des résultats dans ce mode cinématique de précision, plusieurs campagnes tests ont été organisées à l'IGN.

L'une de ces campagnes de mesures GPS s'est déroulée sur le site de Saint-Mandé les 24 et 25 juin 1988 à l'aide de 2 récepteurs NR52 de la firme Sercel. Un récepteur était fixé sur le toit de la tour, tandis que le deuxième récepteur était déplacé successivement de pilier en pilier, sur le toit de la logistique (voir fig. I). Le 24 juin, les 5 points de la logistique ont été stationnés chacun 5 fois. Le 25 Juin, les 5 points ont été stationnés 10 fois. Ceci nous conduit donc, pour chacun des 5 points de la logistique, à déterminer sa position 15 fois en GPS cinématique de précision.

Les calculs ont été réalisés à l'aide du logiciel GDVS développé à l'IGN. Le tableau n° 2 montre les différences entre les positions estimées du pilier 2 (à partir des mesures d'une seule époque) et les positions estimées en cumulant toutes les mesures GPS disponibles. Chaque ligne du tableau est donc une estimation indépendante des erreurs du GPS cinématique. De plus, il faut noter que l'écart entre les coordonnéees obtenues par compensation de toutes les mesures GPS et les coordonnées estimées à partir des mesures de géodésie classique différaient au maximum de 1,1 cm (les distances sont de l'ordre de 100 m). Les résultats présentés dans le tableau n° 2 montrent des écarts allant jusquà 4,6 cm. De manière plus synthétique, la figure n° II montre la répartition des écarts observés sur les trois coordonnées des cinq points de la logistique. Cet histogramme montre que tous les résultats sont meilleurs que 5 cm (en tolérance) et que, de plus, les probabilités sont de 82 % pour que l'erreur soit inférieure à 2 cm (en valeur absolue).

TABLEAU 2. LIGNE DE BASE 2-11 : COMPARAISON ENTRE LES SOLUTIONS PAR SESSION ET LA SOLUTION GLOBALE (LONGUEUR DE LA LIGNE DE BASE D = 111 558 M)

| *Jour* | *Session* | *DX (m)* | *DY (m)* | *DZ (m)* |
|---|---|---|---|---|
| 24/05/88 | S1 | | *Mesures trop bruitées* | |
| 24/05/88 | S2 | −0,035 | −0,004 | 0,046 |
| 24/05/88 | S3 | 0,036 | 0,026 | 0,009 |
| 24/05/88 | S4 | −0,007 | 0,004 | 0,033 |
| 24/05/88 | S5 | | *Pas de mesures* | |
| 25/05/88 | S1 | 0,009 | 0,007 | 0,002 |
| 25/05/88 | S2 | 0,005 | 0,008 | −0,005 |
| 25/05/88 | S3 | 0,029 | 0,007 | −0,007 |
| 25/05/88 | S4 | −0,008 | −0,001 | −0,027 |
| 25/05/88 | S5 | | *Pas de mesures* | |
| 25/05/88 | S6 | 0,013 | 0,001 | 0,013 |
| 25/05/88 | S7 | 0,000 | −0,007 | −0,002 |
| 25/05/88 | S8 | −0,011 | −0,023 | −0,017 |
| 25/05/88 | S9 | 0,002 | −0,011 | 0,014 |
| 25/05/88 | S10 | −0,002 | −0,023 | 0,006 |

Test IGN du 24 et 25 mai 1988.

Figure I. Répartition géographique des points stationnés : expérience cinématique des 24 et 25 mai 1988 IGN, site Saint-Mandé

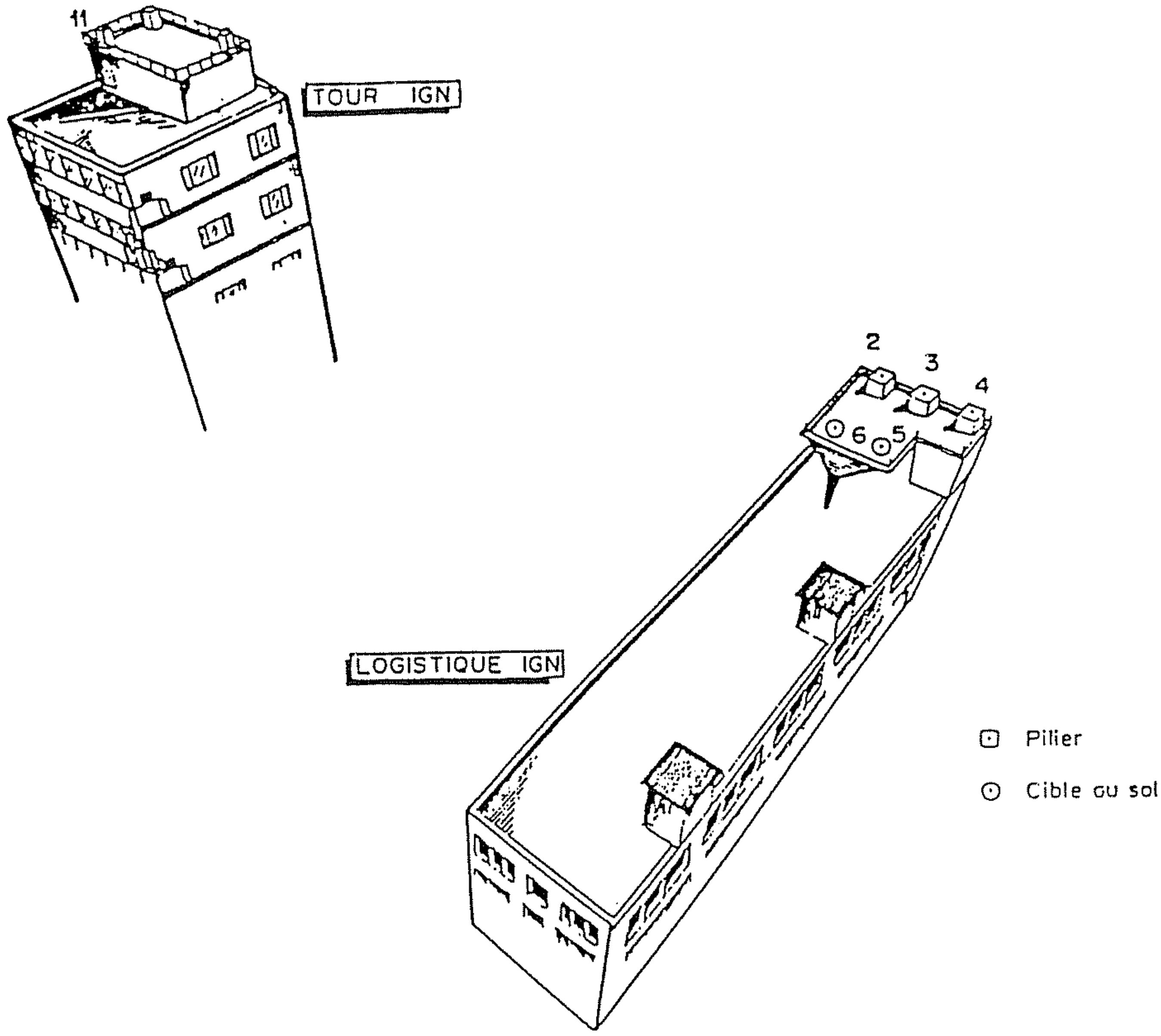
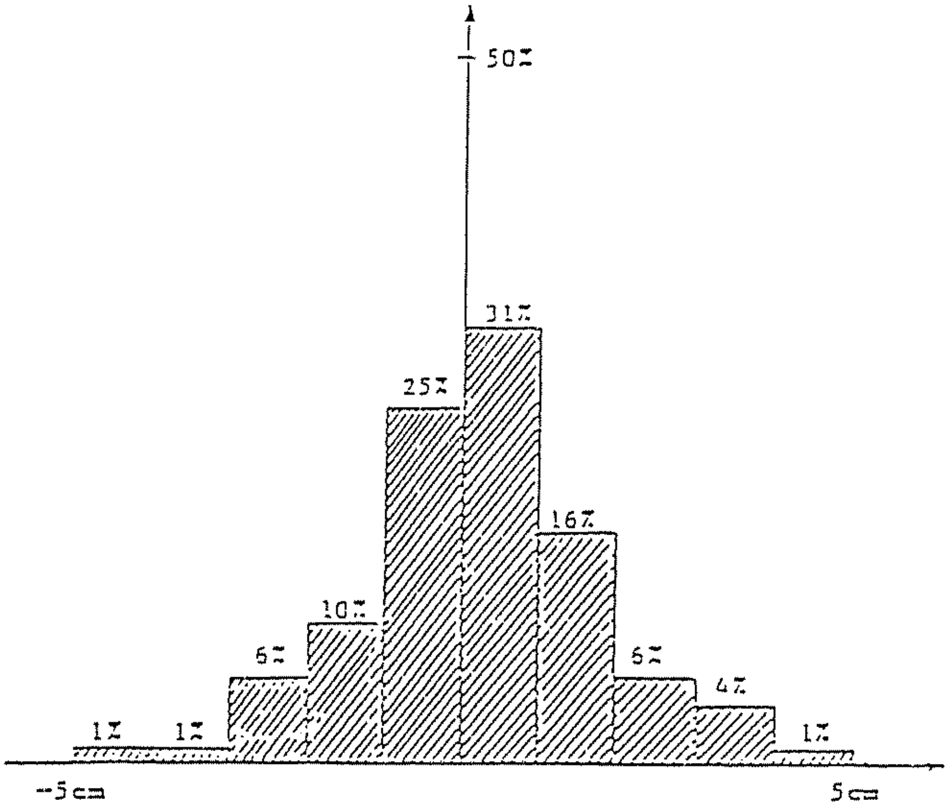


**Figure II. Histogramme des écarts entre le GPS cinématique par ligne de base et par session et l'estimation globale dans les 3 composantes**




Enfin une analyse fine des résultats a montré que les écarts les plus importants sont dûs au fait que l'estimation est effectuée à partir de 4 satellites seulement et non de 5 (mauvaise réception d'un satellite). On voit donc que cette précision centimétrique n'a rien à voir avec les résultats du GPS cinématique obtenu par les pseudo-distances seules ou par les pseudo-distances lissées (Doppler Integrated Pseudo-Ranges).

## Le problème des sauts de cycles

Néanmoins, il convient de tempérer cet optimisme, pour évoquer les possibles problèmes rencontrés au cours du traitement des mesures. L'ennemi numéro un du GPS cinématique de précision, c'est le saut de cycle.

Un saut de cycle est dû à l'arrêt temporaire du compteur de tour de phases du récepteur GPS. Certains sauts de cycles sont dûs à un problème interne au récepteur (certains récepteurs ne permettent pas de faire du GPS cinématique de précision car dès que l'on déplace l'antenne, on perd la phase). Certains récepteurs, comme le NR52 de Sercel, n'ont pas ce problème et sont particulièrement bien adaptés au positionnement cinématique. Les autres sauts de cycles sont dûs à un masque radioélectrique passager entre un satellite GPS et le récepteur.

Chaque saut de cycle rajoute une nouvelle inconnue dans le système d'équations à résoudre. Une des manières de résoudre ce problème délicat est d'enregistrer plus de satellites simultanément avec le récepteur. En effet, avec 4 satellites (3 doubles différences) on obtient un positionnement cinématique non redondant, avec 5 satellites on peut détecter la présence d'un saut de cycle, mais on ne peut pas savoir quel satellite, avec 6 satellites on peut détecter un saut de cycle et aussi déterminer le satellite en question. On voit donc que l'avenir du GPS cinématique nécessitera l'utilisation de récepteurs pouvant enregistrer au moins 5, voire 6, satellites simultanément.

Enfin, ce type de localisation précise deviendra vraiment financièrement intéressant lorsque la constellation finale du GPS sera en orbite, permettant ainsi de travailler en tout endroit du monde, à toute heure. Il faut néanmoins noter que lorsque le saut de cycles peut être détecté en temps réel par le récepteur lui-même (ce qui est technologiquement possible et déjà réalisé pour certains récepteurs), il est alors possible, au cours des observations, de réobserver une ligne de base déjà connue (calibration sur une base connue), de permuter les antennes (permutation des antennes) ou de restationner plus tard la station du saut de cycle (pseudo-cinématique). On voit donc que tout en étant un problème sérieux pour le positionnement cinématique de précision, le saut de cycle est un problème que l'on peut résoudre soit au moment des observations soit au moment du calcul en différé.

## Applications potentielles et perspectives

On voit donc que le positionnement cinématique de précision est possible avec des récepteurs GPS bien adaptés. Les résultats obtenus sont de bonne précision (centimétrique) et se comparent avec ceux du GPS statique. Néanmoins, il est parfois plus difficile à mettre en œuvre (à cause des sauts de cycles éventuels) que le GPS différentiel obtenu à partir des mesures de pseudo-distances lissées ou non par la phase. Pour cerner les applications de cette technique, il convient donc de s'interroger sur les besoins de localisation cinématique nécessitant une précision meilleure que la cinquantaine de centimètres (à $1\sigma$).

Une des premières applications est l'utilisation pour la constitution d'un réseau de faible dimension (inférieur à 20 ou 30 kilomètres) et comportant une grande densité de points à localiser et pour lesquels on recherche une précision de quelques centimètres. Cette technique permet alors un gain de temps appréciable par rapport au GPS statique qui nécessiterait plusieurs jours d'observation. Il faut néanmoins noter que cette technique sera très difficile à mettre en œuvre dans les villes et dans les zones boisées (ou sur les routes bordées d'arbres comme souvent en France). Elle sera particulièrement adaptée aux sites dégagés en campagne (constructions d'autoroutes ou de voies ferrées) et aux périphéries des villes (aménagement urbain). De plus, pour que cette application du GPS soit justifiée du point de vue de la mise en œuvre et du coût, il faudra que dans les années à venir ce type de matériel devienne de plus en plus miniaturisé et de moins en moins coûteux. C'est probablement le challenge que relèveront de nombreux constructeurs de récepteurs GPS dans le monde.

Dans le cas de l'IGN, une autre application est la constitution d'un réseau proche de points auxiliaires pour les bornes du réseau géodésique national. Ces points peuvent servir à retrouver la borne (ou la remplacer). Ils peuvent aussi servir de points d'orientement pour les géomètres qui utiliseraient des techniques de géodésie classique. En effet, dans le cas d'un réseau national refait à partir des mesures GPS, la condition d'intervisibilité des points du réseau devient caduque. Il convient donc de placer à proximité de la borne un point auxiliaire servant d'orientement pour les mesures d'angles lorsqu'aucun autre point n'est visible. Ce deuxième point pourrait être réalisé très rapidement en déplaçant l'antenne GPS, sans éteindre le récepteur, à la fin des mesures GPS statiques.

Enfin, pour des besoins de photogrammétrie à grande échelle, nécessitant une grande précision sur la position du centre de prise de vue de la caméra, le GPS cinématique précis peut être utilisé. Néanmoins cette méthode nécessite l'utilisation au sol d'un récepteur GPS à proximité immédiate de la zone survolée. Cette application n'a pas encore été testée en vraie grandeur à l'IGN car les précisions exigées pour la restitution photogrammétrique se contentaient du GPS différentiel (trajectographie SERCEL) et que, de plus, la présence sur la zone de prise de vue d'un deuxième récepteur GPS était difficilement envisageable.

En conclusion, le positionnement cinématique de précision par GPS possède de nombreuses applications qui ne feront que croître avec l'arrivée des nouveaux satellites GPS disponibles. Néanmoins, cette technique est plus difficile à mettre en œuvre que le GPS différentiel qui répond parfaitement, de par les précisions atteintes, à la plupart des applications de navigation. Il existe pourtant, pour le géomètre, des applications directes qui nécessitent la haute précision. De plus, cette technique peut être couplée avec d'autres systèmes de localisation comme la technique inertielle. L'inertiel permettrait alors d'obtenir des résultats temps quasi réel (avec un dispositif adapté de télétransmission) elle permettrait aussi de prendre le relais du GPS en cas de defaillance de la méthode (saut de cycle) et de vérifier les résultats obtenus. Le GPS servirait, pour sa part, à fournir à l'inertiel des points de calage très précis et très nombreux. Il est fort probable que les systèmes d'avenir de localisation utilisables par les géomètres soient des "boîtes noires", constituées de plusieurs systèmes différents de localisation parmi lesquels le GPS aura certainement une part importante.

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## THE NEW EUROPEAN REFERENCE SYSTEM: STATUS REPORTS ON THE GPS CAMPAIGNS OF 1989 and 1990, AND THE VLBI CAMPAIGN OF 1989*

*Paper submitted by Germany*

### RÉSUMÉ


On met actuellement en place en Europe un nouveau système de référence géodésique (EUREF) qui utilise la télémétrie laser par satellite et les méthodes VLBI (interféromètre à très longue base) et GPS (système mondial de localisation). Dans le présent rapport, on dresse notamment le bilan des campagnes GPS de 1989 et 1990 et de la campagne VLBI de 1989 réalisée grâce à une unité mobile.


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In order to establish a new European Reference System (EUREF) the International Association for Geodesy (IAG) formed a EUREF Subcommission. During the first meeting of the Subcommission, in October 1988 in Munich, it was decided to perform in May 1989, in close cooperation with Working VIII of CERCO (Commission européenne des responsables de cartographie officielle), a first EUREF GPS Campaign, which then could be used:

*The original text of this paper, prepared by the Institut für Angewandte Geodäsie, appeared as document E/CONF 83/INF 19 (*a*) To investigate the possibilities of GPS towards the establishment of a new, possibly GPS-oriented, European reference system;

(*b*) To transform digitized cartographic data from the national or European reference systems into WGS 84;

(*c*) To transform WGS 84 coordinates into the European or the national reference grid.

During the 1988 meeting in Munich a EUREF GPS Steering Committee was set up to prepare and execute the campaign, with members from France, Germany, Norway, Switzerland and the United Kingdom. A small international advisory group was also appointed to assist in operations.

The Steering Committee met twice, on 13 December 1988 in Munich and on 2-3 March 1989 in Frankfurt, to discuss and determine all basic principles of the planned campaign. Details were then worked out and collected in observation guidelines for the field teams during a meeting in Wettzell from 16 to 18 February 1989. Particular regulations were set up to collect all the required site information (documentation, survey, meteorological data etc.) and to guarantee a common mode of observation of each receiver.

During the February 1989 meeting a small GPS test-campaign was performed in Wettzell on neighbouring well-determined positions with different receivers:

2 TI 4100

2 Trimble 4000 SLD (SXD)

2 MINIMAC and

2 Wild-Magnavox 102

This test-campaign was thought to produce an optimal data set in order to compare the antennae phase centres of the different types of receivers and to test newly developed software for transforming the raw data sets into a receiver-independent exchange format (RINEX), developed by Werner Gurtner in Bern, which was adopted by the GPS world community during a symposium held in Las Cruces/New Mexico in March 1989.

Each country has been asked to nominate a national representative for the EUREF GPS campaign. These representatives met in Frankfurt in April 1989 in order to agree on details of the field activities.

## The reference system

As the WGS 84 is based on NNSS Doppler-results only, its absolute accuracy is only of the order of 1 metre. For medium- and small-scale cartography this accuracy is of course acceptable. On the other hand the different geodynamic programmes and the modern methods of cadaster surveys require positions with a precision on the order of ±1 cm.

During the conference of the IAG/EUREF Subcommission in Florence, Italy, in May 1990, it was decided to combine all the modern requirements to create *one* future European Reference System of very high precision. Owing to its well known limitations this cannot be the WGS 84 but it should be a system that agrees with WGS 84 within ±1m. Therefore, the International Terrestrial Reference Frame (ITRF) 1988 has been adopted as a basic reference system for EUREF. It shows a precision of approximately 15 mm over western Europe.

After having completed the 1989 EUREF GPS solution, the following different sets of transformation parameters are to be determined:

ITRF 88 to WGS 84 and reverse

ED50 and ED79/ED87 to WGS 84 and reverse

National reference systems to WGS 84 and reverse

ITRS 88, ED50 and ED79/ED87 to national reference systems and reverse

## The EUREF mobile VLBI campaign

At present the most precise GPS solutions are obtainable by using reference observations with respect to fiducial stations of very high accuracy. For the European area many such stations are available as a result of very extended laser-ranging and VLBI activities.

In Europe a lack of such precise positions was only detected in some northern parts. To overcome this situation a special activity has been performed by renting the MVIII mobile VLBI unit from the National Geodetic Survey of the United States in the period from June to September 1989. MVIII has observed at 6 sites on five days for 24 hours each.

Altogether 120 hours have been observed at each new site with the mobile VLBI unit. Using as base stations the VLBI telescopes in Wettzell, Germany, and Noto, Italy, at the new VLBI stations, a precision of better than 1 cm in position and of about ±3 cm in height has been obtained.

Station by station the sigmas are:

| | *Latitude (mm)* | *Longitude (mm)* | *Height (mm)* |
|---|---|---|---|
| Hohenbünstorf, Germany | 6.2 | 5.8 | 26 |
| Metsahovi, Finland | 8.3 | 7.0 | 38 |
| Tromsö, Norway | 14.5 | 7.8 | 25 |
| Carnoustie, United Kingdom | 6.6 | 6.8 | 13 |
| Brest, France | 4.0 | 7.5 | 14 |
| Grasse, France | 1.6 | 3.6 | 15 |

The costs of this project, DM 1 million, were shared by the Finnish Geodetic Institute, Statens Kartverk of Norway, the Ordnance Survey of the United Kingdom, the Institute géographique national (IGN) of France, the Niedersächsisches Landesverwaltungsamt-Landesvermessung, Hannover, and the Institut für Angewandte Geodäsie (IfAG) Germany.

## The EUREF GPS campaign, 1989

To prepare the EUREF GPS campaign 1989 the responsible agencies in all CERCO member countries (except Iceland) were asked to propose GPS stations at positions of first-order triangulation at distances of about 300 to 500 km. Based on these proposals the Steering Committee then made a final selection of stations. Especially in Central Europe, with many smaller countries, a certain concentration of stations could not be avoided. Finally, a total of 93 stations were accepted.

A survey of the 2-frequency GPS receivers available in Western Europe in the spring of 1989 resulted in the following:

21 TI 4100

29 Trimble 4000 SLD (SXD)

4 MINIMAC

15 Wild-Magnavox 102

Seven receivers were kept in reserve in some of the European metropolitan areas and 62 receivers were available for the field programme.

The total network of 93 stations were subdivided into phases A and B, which were observed for six days each with observation windows of five hours:

Phase A: 16-21 May 1989 with 62 sites

Phase B: 23-28 May 1989 with 55 sites

The duration was scheduled in order to collect a sufficient amount of data and to ensure—even in the case of problems arising with the receiver for one or two days—that sufficient data were available for precise positioning.

During both phases, 23 sites were measured. These were 16 laser-ranging and VLBI sites, which will be used as reference stations and 7 other overlapping positions which were occupied twice in order to stabilize the network and to tie both phases together.

Seven receivers failed during the campaign; they all have been replaced within 24 hours by one of the seven instruments kept in reserve. Fortunately none of the teams asked for additional reserve equipment after the complete reserve was sent into the field. In the end, all sites were observed successfully; although for many of the Trimble sites it was reported that the L2-observations were not so successful as they should have been.

### THE EUREF NORTH-WEST CAMPAIGN, 1990

The EUREF North-West GPS campaign was carried out in order to extend the EUREF GPS campaign, 1989, to the North Atlantic islands—Iceland, Spitzbergen, Greenland, Jan Mayen, Faröes etc—and for connecting EUREF to the North American networks.

The observations were carried out in the period July 23 to August 1 1990. During this observation period 11 NAVSTAR-satellites (including 5 block II satellites) were available and healthy. Because of the increasing ionospheric refraction in the northern area and because of the long intercontinental baselines the planning group of this campaign had to place a lot of restrictions on the observation schedule, e.g., high measurement interval (15 sec.); measurements during nighttime (if possible); baselines shorter than 1,000 km if possible; minimum of five hours simultaneous observations for a baseline (therefore all stations on Greenland had to be occupied nine hours per day).

This network consists of 39 stations, including permanent tracking stations like Wettzell, Yellowknife, Westford etc. A sufficient number of 2-frequency receivers were available to avoid a splitting of this campaign into several phases.

As in EUREF GPS 89 different receiver types were used in this campaign. Additionally to the 1989 campaign, new receiver types (ASHTECH, Trimble 4000 SST, Rogue) were used. Therefore a new calibration campaign was performed in Wettzell in March 1990.

### DATA PRE-PROCESSING AND FINAL SOLUTIONS

Twelve pre-processing centres were established to screen the data, convert the data into the receiver independent exchange format (RINEX) and to provide the data. From the pre-processing centres, the data tapes then were sent to the University of Bern, supporting the pre-processing by making available the necessary software for data conversion.

The following agencies have expressed willingness to participate in the final data reduction:

University of Bern

A combined team from IfAG and the University of Bonn

University of Hannover

University of Delft (for parts of the network)

University of Nottingham (probably)

University of the German Armed Forces in Neubiberg (probably)

Institut géografique national, Paris.

For some of the groups listed above, the final decision is still under discussion.

The RINEX-raw data files for EUREF 1989 have been ready for delivery in Bern since January 1990. In Bern in February 1990 the processing of these data was started as a joint programme with the Astronomisches Institut of the University of Bern, IGN Paris and the Bayerische Erdmessungs-kommission. A number of data-processing problems were sorted out. RINEX-files were corrected where possible and an error list was appended to the RINEX dataset.

The entire dataset contains nearly 700 raw data files with 4 satellite observations and 500 epochs per satellite and file, so that the total number of observations during EUREF 1989 was 1.4 million phase measurements.

Because of this huge dataset the campaign was split into 6 parts. One part contains all laser and VLBI sites; this part was used for an orbit determination to get the best fit for Europe during this period. The other files were split into smaller local networks to get good results on shorter (200-500 km) baselines.

Some reference stations, mainly in the Scandinavian area, were occupied by 4-channel TI-4100 receivers. Therefore the main problem for orbit determination was that this determination failed for some satellites, e.g. SV-8.

A second problem depends on the L2-frequency of the Trimble 4000 SLD receivers. Nearly 80 per cent of the receivers failed with 50 to 80 per cent on L2. That means, to get enough observations the ionospheric-free L3 linear combination cannot be used. This effect can cause day to day differences within a few decimetres. We are still busy solving that problem by means of ionospheric models and shorter baselines. At this stage, the stations that have to be reoccupied cannot be omitted.

At this moment the dataset is 70 per cent free from cycle slips. But there are some problems left and a fixed schedule for a draft or final solution cannot be given at the moment.

### FUTURE PLANS

Turkey was connected to the EUREF network through special Turkish GPS activity as a joint operation of the Turkish Military Command of Mapping and IfAG for three weeks, from 15 August to 7 September. An extension is planned to Hungary, Czechoslovakia and Poland.

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# ESTABLISHMENT OF MARINE GEODETIC CONTROLS AND THE WORLD GEODETIC SYSTEM*

*Paper submitted by Japan*

## RÉSUMÉ


Avec le développement récent des systèmes mondiaux de navigation par satellite qui offrent des techniques précises de localisation sur toute la surface du globe, l'OHI a adopté diverses résolutions techniques concernant le système de référence géodésique des cartes marines. Ces résolutions indiquent que : *a*) les cartes marines doivent reposer essentiellement sur le Système géodésique mondial, constitué des systèmes actuels de navigation par satellite, à savoir les NNSS et le GPS (résolution TR B1.1); et *b*) lorsqu'on utilise le système géodésique régional classique pour les cartes marines, il faut faire figurer des indications concernant les valeurs de conversion sur les cartes d'échelle réduite supérieure à 1/500 000 (résolution TR B2.10). Ces valeurs de conversion doivent être ajoutées aux positions déterminées par les systèmes de navigation par satellite sur le Système géodésique mondial afin que les positions puissent être reportées sur les cartes.

Conformément aux résolutions de l'OHI, le Département japonais d'hydrographie a donné des indications relatives aux valeurs de conversion entre le Système géodésique mondial et le système géodésique japonais sur les cartes récemment publiées ou révisées. Ces travaux se fondent sur les résultats des observations géodésiques précises faites par le Département au moyen des techniques de géodésie par satellite.

La détermination du rapport entre le système géodésique régional, qui est le système de référence adopté pour les cartes marines, et le Système géodésique mondial joue un rôle important, non seulement pour assurer une navigation sans risque au moyen de systèmes modernes mais aussi pour répondre aux besoins nés de la récente Convention des Nations Unies sur le droit de la mer. Comme il faut notamment clarifier les rapports entre les systèmes de référence géodésique des pays voisins afin de fixer les lignes médianes qui les séparent, il est essentiel de localiser précisément les terres et îles territoriales sur le Système géodésique mondial et de développer les techniques nécessaires à cette localisation. Les activités menées par le Département japonais d'hydrographie dans ce domaine sont décrites dans le rapport.


### WORLD GEODETIC SYSTEM AND NAUTICAL CHARTS

With the recent development of global satellite navigation systems, which provide us with precise positioning techniques all over the world, IHO adopted some technical resolutions (TR) on the geodetic reference system of nautical charts. The resolutions concerned stipulate (*a*) that nautical charts should be based principally on the world geodetic system (WGS), which is realized by the current satellite navigation systems, i.e. NNSS and GPS (TR B1.1); and (*b*) that when the conventional regional geodetic reference system is adopted for nautical charts, some comments on conversion values should be given on the charts of reduced scale larger than 1:500,000 (TR B2.10). These conversion values are to be added to the positions derived from satellite navigation systems on the world geodetic system, in order to plot the positions on the relevant charts.

The Hydrographic Department of Japan (JHD) has been giving such comments on conversion values between the world geodetic system and the Japanese geodetic system on the charts recently published or revised, in accordance with the IHO resolutions mentioned above. These works are based on the results of precise geodetic observations made by JHD using techniques of satellite geodesy.

Determination of the relation between the regional geodetic system, which is adopted as the geodetic reference system of the nautical chart, and the world geodetic system plays important roles not only for safe navigation with modern navigation systems but also for the circumstances under the newly-agreed United Nations Convention on the Law of the Sea. Especially, since it is necessary to clarify the relation between geodetic reference systems of the neighboring countries in order to establish median lines between countries, precise positioning of the territorial lands/islands on the world geodetic system is very important and the techniques of such positioning should be developed.

### MARINE GEODETIC CONTROLS OF JAPAN

#### *Use of satellite laser-ranging technique*

JHD is conducting geodetic surveys for the precise determination of the main lands of Japan and her smaller islands with reference to the world geodetic system for the purpose of making accurate charts, which is necessary not only for safe navigation but also for delineating the waters under the nation's jurisdiction and median lines between those of its neighbouring countries under the circumstances of the new Law of the Sea.

A fixed satellite laser ranging (SLR) station was installed at the Simosato Hydrographic Observatory (SHO) located at Simosato, Wakayama Prefecture, in 1982. The station has been operated in order to make clear the relation between the Japanese geodetic system and the world geodetic system. The SLR observations of geodetic satellites such as LAGEOS, a United States geodetic satellite, have been made in cooperation with the world SLR stations. SHO acts as the fundamental fiducial point in the marine geodetic controls around Japan, and as one of the most important SLR stations in the western Pacific area among the world SLR network.

JHD developed a new programme for processing and analysing satellite orbit by using SLR data. The programme

*The original text of this paper appeared as document E/CONF 83/L.11.

Figure I. World-wide plate motions derived from LAGEOS SLR data, computed by HYDRANGEA

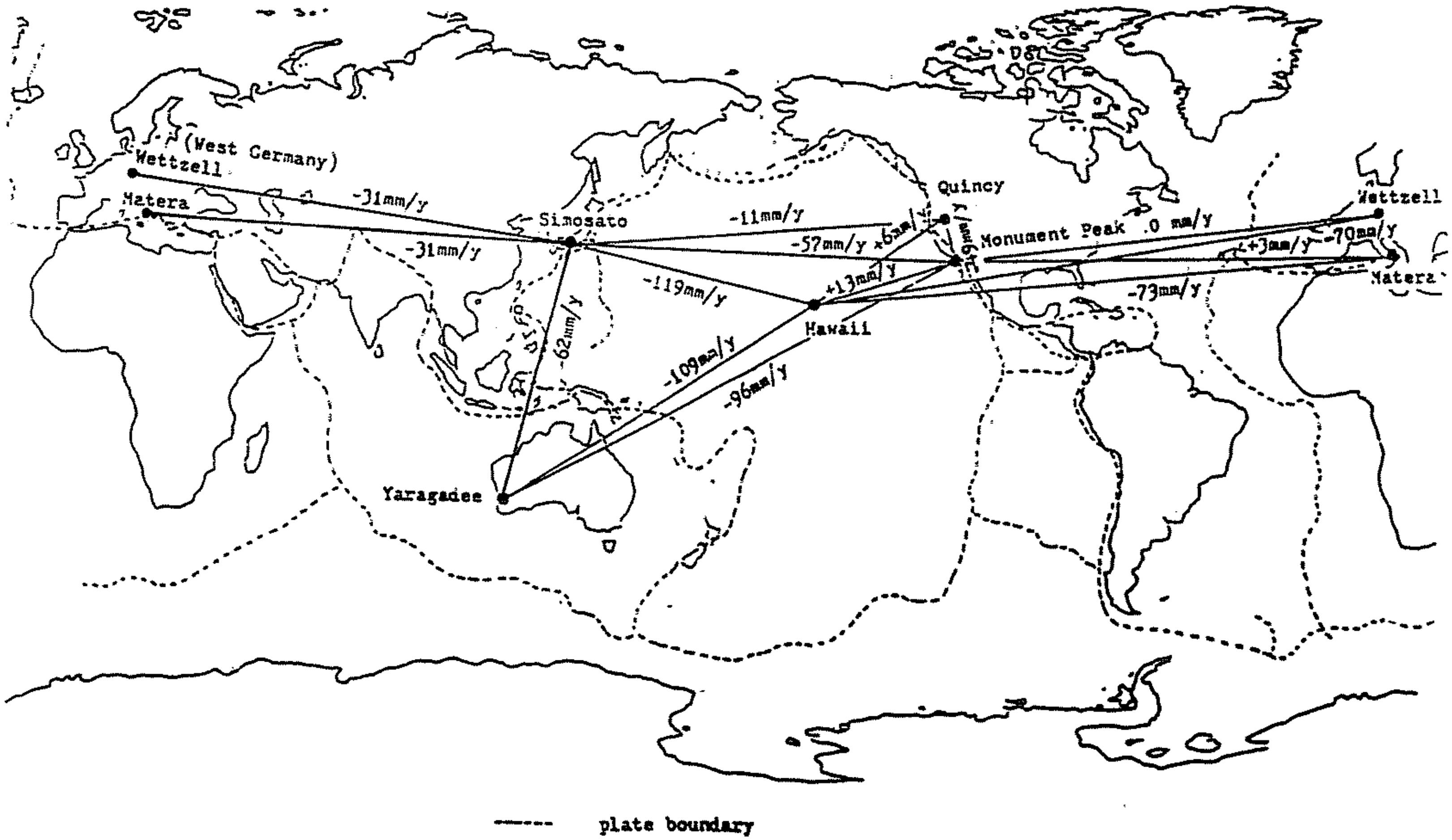


Figure II. The mobile SLR station "HTLRS"

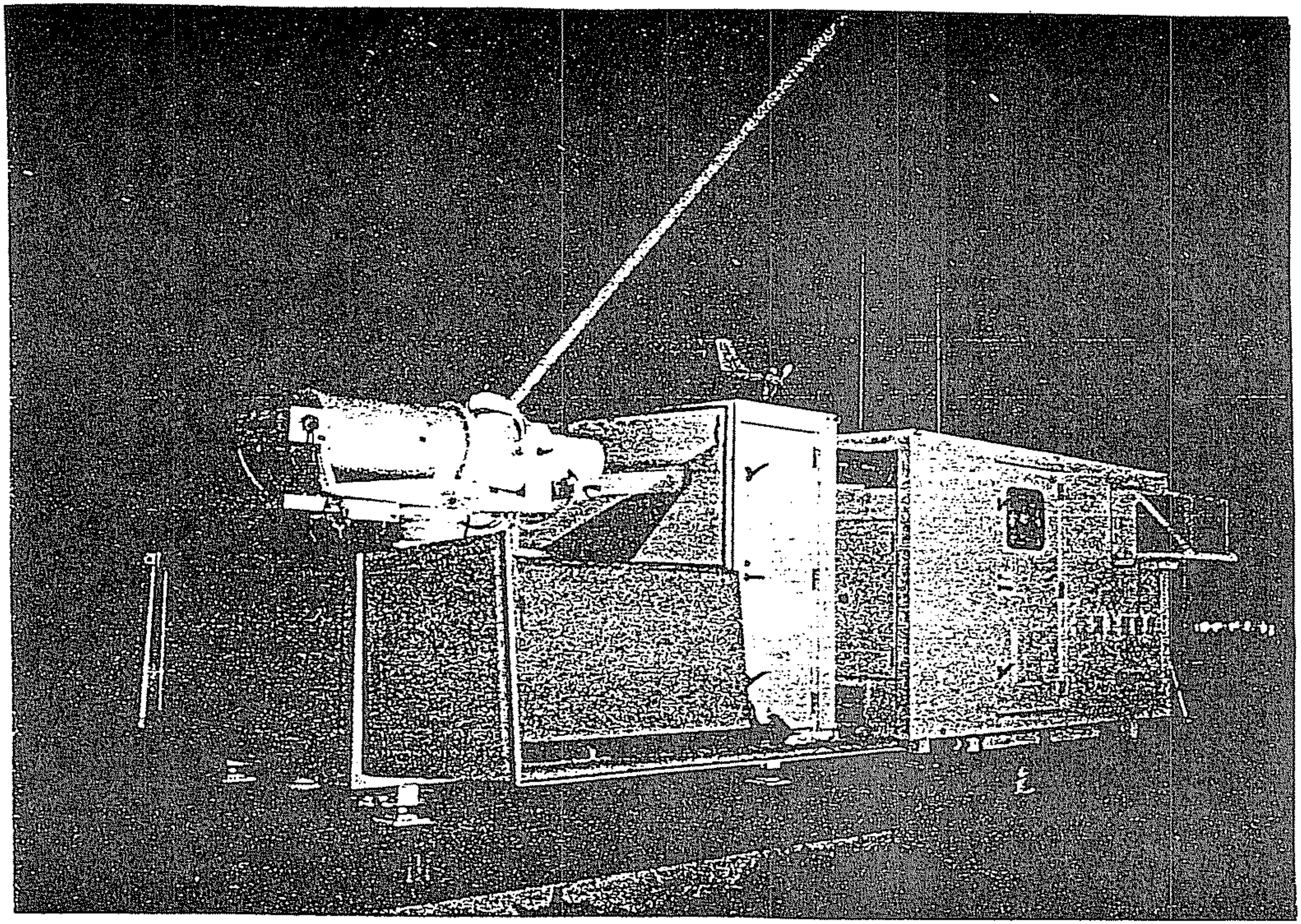
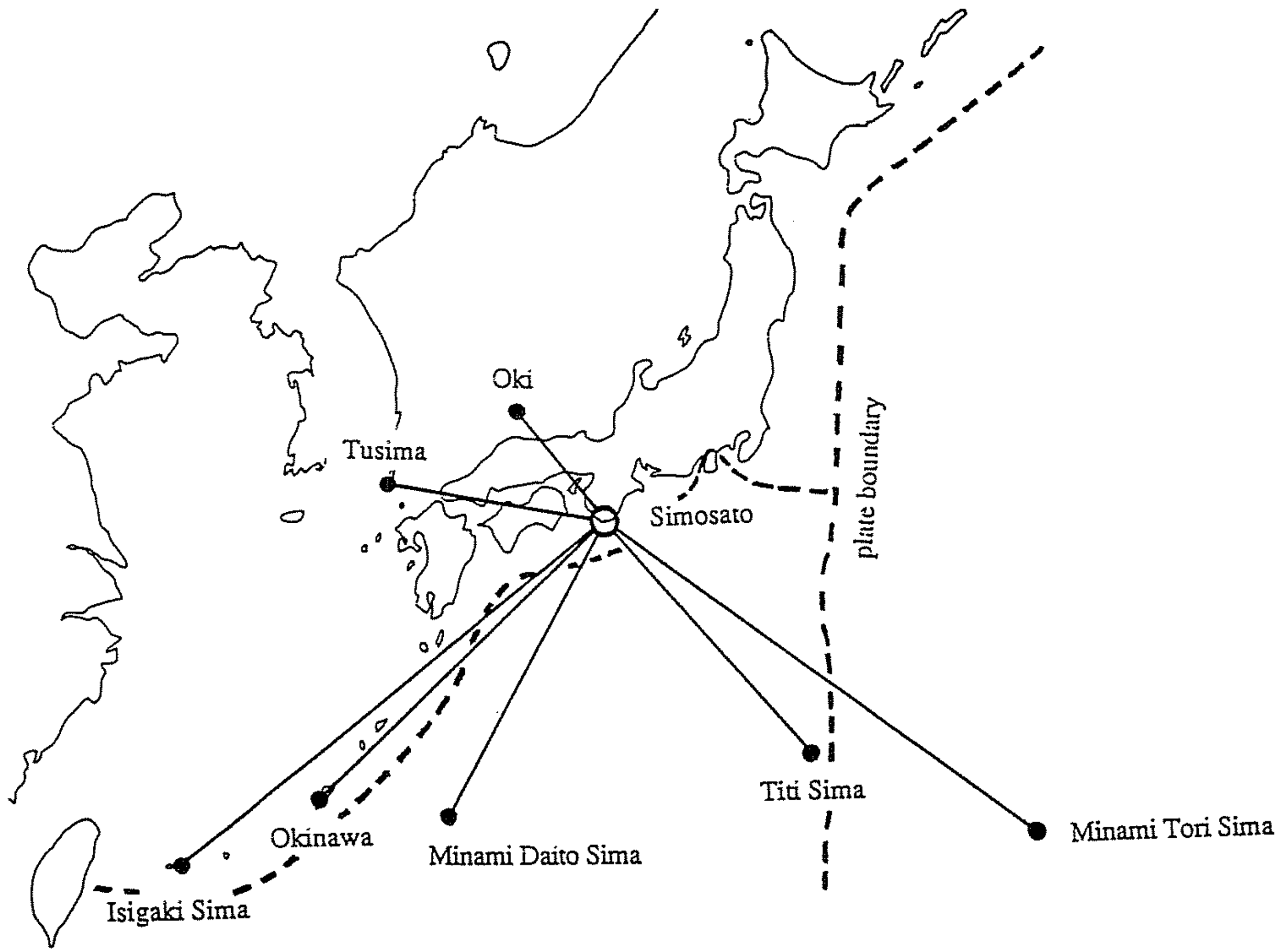


**Figure III. First-order fiducial points connected to Simosato by SLR observations since 1987**



is named "HYDRANGEA" (*HY*drographic *D*epartment *RANGE* data *A*nalyzer)(Sasaki, 1990). The SLR data taken at SHO and world SLR stations are analysed by HYDRANGEA, and the position of the fiducial point at SHO is located precisely in the world geodetic system. Consequently the Japanese geodetic reference system, the Tokyo Datum, is connected to the world geodetic system. The present values of the transformation parameters in the geocentric coordinate system from the Tokyo datum to the world geodetic system derived from SLR data are as follows:

$$DU = -146\text{m},\ DV = 508\text{m},\ DW = 682\text{m}.$$

The SLR data are used for computing precise baseline length between world SLR stations, which are located on different plates, and changes of the baseline length imply the relative motion between plates. Some results of changes of baseline lengths derived from SLR data for five years computed by using HYDRANGEA are as follows (fig. I):

| | | |
|---|---|---|
| Simosato (Eurasia plate) | —Quincy, United States (North America plate) | −11(−19) mm/y |
| Simosato | —Monument Pk., United States (Pacific) | −57(−64) |
| Simosato | —Hawaii, United States (Pacific) | −119(−99) |
| Simosato | —Wettzell, Germany (Eurasia) | −31(0) |
| Simosato | —Yaragadee, Australia (Indian) | −62(−77) |

Numbers in parentheses are those geologically estimated by AM0-2 of Minster and Jordan (1978).

A mobile SLR station named "HTLRS", (*H*ydrographic Department *T*ransportable *L*aser *R*anging *S*tation) whose specifications are given in table 1, was constructed in order to connect major islands to the SHO station, on the mainland of Japan, by using the Japanese geodetic satellite, AJISAI, which was launched in August 1986. The system of the HTLRS is housed in two shelters (fig. II). The mobile SLR station is transported by a surface ship or a cargo airplane to the major islands, called first order control points. AJISAI is observed simultaneously by the fixed SLR station at Simosato and the mobile SLR station located at an island, and then the relative position of the island to SHO is determined. The HTLRS was transported to several isolated major islands (fig. III), and the relative positions of the islands to the fiducial point at SHO were determined. Especially, the baseline length between each island and SHO was determined very precisely within an accuracy of a few centimetres. These results are useful for the detection of plate motions and inner plate deformations by repeat observations.

### *Use of satellite navigation systems by their geodetic applications*

The geodetic use of NNSS by means of simultaneous observations is applied for the connection of secondary islands, called second-order control points, to the first-order control points. The translocation technique is employed in this case. More than 30 islands were connected to the first-order control points by this technique.

A new satellite navigation system, GPS, is being established by the United States. The application of GPS to geodetic observations is performed by simultaneous observations for several hours with two or more GPS receivers in the differential mode, and the positions of the receivers are

TABLE 1. SPECIFICATIONS OF THE HTLRS

| *Subsystem* | *Specification* |
|---|---|
| Laser | Nd:YAG 50 mJ; 100 ps pulse width, 5 pps |
| Mount | Elevation over azimuth, Coude path |
| Transmitter/Receiver | A common flat plate for elevation, 10 cm diameter for transmitter, 35 cm diameter for receiver |
| Receiving electronics | Micro-Channel-Plate PMT, 20 ps resolution |
| Mount control | DC servo, torque motor/tachometer/encoder |
| Clock/Frequency standard | Rubidium oscillator calibrated by multi-Loran C waves and GPS |
| Meteorological sensors | Temperature, humidity, pressure, wind speed/direction |
| Shelters | 2 shelters, 2.1×2.3×3.5 m and 2.1×2.3×3.8 m, air conditioners |
| Power generator | 20 kW for AC 200 V; 7.5 kW for AC 100V |

determined relative to the reference receiver located at a fiducial point whose precise position is known beforehand. The simultaneous observation is repeated several times, and the results are averaged to obtain the most reliable data. This technique is becoming one of the effective geodetic positioning techniques, and it will be able to be used for our project of constructing the marine geodetic controls of Japan. The special application of GPS to a very precise observation of baseline length in the differential mode is employed to try to detect local crustal deformations in the active areas of earthquakes and volcanos.

### COOPERATION IN SATELLITE GEODESY

The application of satellite techniques to world-wide geodetic observations is indispensable and very effective. The world geodetic system is defined by the result of these observations under the cooperation among world-wide observation stations. The establishment of a precise geodetic reference system is important in the global earth sciences such as researches on the rotation and the orientation of the earth, plate motions, earth interior, global ocean dynamics and earth's environment. The determination of the relation between the geodetic reference system of each country and the world geodetic system is necessary to make a unified geodetic system for safe navigation with precise worldwide navigation systems and for the new circumstances under the Law of the Sea.

International cooperation in this field is necessary, naturally, and the cooperation can be made in exchange of technical information on precise geodetic surveys by means of satellite geodesy, exchange of personnel for training and research on satellite geodesy, carrying out cooperative observations in the Pacific region by using GPS techniques and developing advanced geodetic satellite techniques. The first step of the cooperation may be to exchange information on the geodetic reference systems on which nautical charts of respective countries are based.

### REFERENCES

Minster, J. B., and T. H. Jordan (1978). Present-day plate motions. *J. Geophys. Res.*, No. 83, pp. 5331-5354.
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# WORLD GEODETIC SYSTEM 1984: A MODERN AND ACCURATE GLOBAL REFERENCE FRAME*

*Paper submitted by the United States of America*

## RÉSUMÉ

La Defense Mapping Agency (DMA) des Etats-Unis a établi le Système géodésique mondial 1984, qui constitue un système de référence de pointe construit à partir des données, techniques et technologies dont elle disposait au début de 1984, le cadre de référence, le modèle gravitationnel, la géoïde et les paramètres de conversion des surfaces de référence (accompagnés des niveaux de référence locaux) sont plus précis et rattachés à un plus grand nombre de systèmes de référence (83 contre 27 auparavant).

Tous ces progrès permettent d'obtenir des cartes terrestres et marines plus précises, d'améliorer le positionnement géodésique de mieux déterminer les niveaux de la géoïde et les orbites des satellites et d'accroître les possibilités de relier un bien plus grand nombre de niveaux de référence locaux à un système unifié.

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In this complex world where numerous mapping, charting, geodetic, and digital products are defined in various local and/or regional geodetic datums, it becomes a straightforward requirement to simplify the complexity by referencing all the products to a common reference frame globally. With this need in mind, the Defense Mapping Agency (DMA) has been actively involved since 1960 in the development of a World Geodetic System (WGS). To date, four such systems, viz., WGS 60, WGS 66, WGS 72, and WGS 84, each successively more accurate, have been developed.

The latest, WGS 84, represents DMA's state-of-the-art modelling of the Earth from a geometric, geodetic, and gravitational standpoint using data, techniques, and technology available through early 1984.

### THE REFERENCE FRAME

The origin of the WGS 84 reference frame is the Earth's centre of mass and the Z- and X-axes are identical to the Conventional Terrestrial System (CTS) as defined by the Bureau international de l'heure (BIH) for the epoch 1984.0 (fig. I). This frame constitutes a mean or standard Earth, rotating at a constant rate ($\omega$) around an average astronomic pole fixed in time.

In turn, the WGS 84 reference frame is related to an Instantaneous Terrestrial System and a Conventional Inertial System:

$$\text{WGS 84 (CTS)} = [A]\,[B]\,[C]\,[D]\ \text{CIS} \qquad (1)$$

Origin: Earth's centre of mass

Z-axis = Parallel to the direction of the Conventional Terrestrial Pole for polar motion, as defined by the Bureau international de l'heure on the basis of the coordinates adopted for the Bureau international de l'heure stations

X-axis = Intersection of the WGS 84 Reference Meridian Plane and the plane of the Conventional Terrestrial Pole's equator, the Reference Meridian being parallel to the zero meridian defined by the Bureau international de l'heure on the basis of the coordinates adopted for the Bureau international de l'heure stations

Y-axis = Completes a right-handed, Earth-centred, earth-fixed orthogonal coordinate system, measured in the plane of the Conventional Terrestrial Pole equator, 90° east of the X-axis where the rotation matrices for polar motion [A], sidereal time [B], nutation [C], and precession [D] are from the FK 5 system referenced to Epoch J2000.0.

For practical realization, the WGS 84 reference frame or coordinate system was defined by suitably modifying the NSWC 9Z-2 coordinate system of the Navy Navigation Satellite System. This modification consisted of the removal of biases in the origin, scale, and longitude definition of the Doppler system and is defined as:

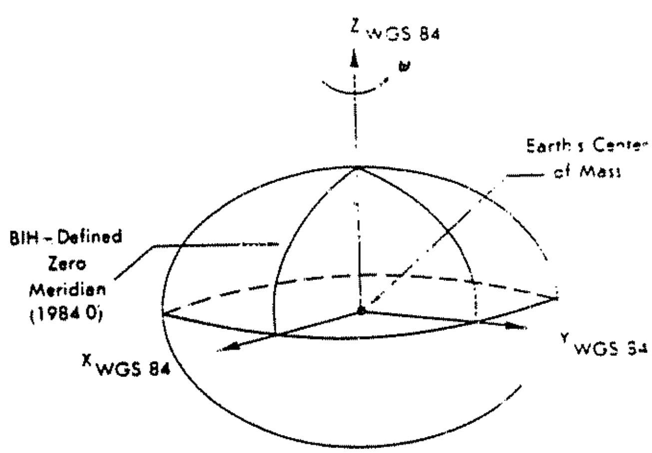
$$Z\ (\text{WGS 84}) = Z\ (\text{NSWC 9Z-2}) + 4.5\ \text{metres} \qquad (2)$$

$$S\ (\text{WGS 84}) = S\ (\text{NSWC 9Z-2}) - 0.6\ \text{ppm} \qquad (3)$$

$$\lambda\ (\text{WGS 84}) = \lambda\ (\text{NSWC 9Z-2}) + 0.814'' \qquad (4)$$

In the above relationships, equations 2 to 4 refer to the Z-axis bias, scale correction, and longitudinal bias in the definition of the prime meridian, respectively, and the WGS

**Figure I. World Geodetic System, 1984 reference frame**
*BIH-defined Conventional Terrestrial Pole (1984.0)*




*The original text of this paper, prepared by Muneendra Kumar, Defense Mapping Agency, appeared as document E/CONF.83/L.31

84, thus achieved, is coincident with the Bureau international de l'heure–defined CTS.[1]

## Defining parameters and associated constants

In geodetic considerations, three different surfaces or Earth figures are normally involved and used. In addition to the Earth's actual physical surface, the other two include a geometric (or mathematical) reference surface, the ellipsoid, and an equipotential surface, the geoid.

In determining the WGS 84 ellipsoid and its associated defining parameters, the WGS 84 Development Committee decided to adopt as its reference the Geodetic Reference System 1980 defined by the International Union of Geodesy and Geophysics.

The WGS 84 ellipsoid, as an integral component of the system for the Earth's geometric figure and theoretical gravity definition, is a geocentric, equipotential, ellipsoid of revolution. Table 1 lists the four defining parameters adopted from the Geodetic Reference System 80,[2] except for one minor exception. The WGS 84 defines $C_2$ instead of $J_2$ of Geodetic Reference System 80.

Other associated constants adopted and used in WGS 84 are given in table 2.

## The gravity formula

In many applications, such as the computation of gravity anomalies, theoretical (or normal) gravity ($\gamma$) is required as a reference value. Values of $\gamma_\phi$ in the WGS 84 (for any latitude $\phi$) can be computed using the closed formula:

$$\gamma_\phi = \gamma_e \frac{(1 + k \sin^2 \phi)}{(1 - e^2 \sin^2 \phi)^{1/2}} \quad (5)$$

where

$\gamma e$ = normal gravity at the Equator
= 978032.67714 mgal
$k$ = 0.00193185138639
$e^2$ = 0.00669437999013.

Table 1. WGS 84 ellipsoid: four defining parameters

| *Parameters* | *Notation* | *Magnitude* | *Accuracy (1 σ)* |
|---|---|---|---|
| Semi-major Axis | a | 6378137 m | ±2 m |
| Normalized second degree zonal harmonic coefficient of the gravitational potential | $\bar{C}_{2,0}$ | $-484.16685 \times 10^{-6}$ | $\pm 1.30 \times 10^{-9}$ |
| Angular velocity of the Earth | $\omega$ | $7292115 \times 10^{-11}$ rad $s^{-1}$ | $\pm 0.1500 \times 10^{-11}$ rad $s^{-1}$ |
| Earth's gravitational constant (mass of Earth's atmosphere included) | GM | $3986005 \times 10^8\ m^3\ s^{-2}$ | $\pm 0.6 \times 10^8\ m^3\ s^{-2}$ |
| *Parameter values for special applications* | | | |
| Earth's gravitational constant (mass of Earth's atmosphere not included) | GM′ | $3986001.5 \times 10^8\ m^3\ s^{-2}$ | $\pm 0.6 \times 10^8\ m^3\ s^{-2}$ |
| Angular velocity of the Earth (in a precessing reference frame) | $\omega^\dagger$ | $(7292115.8553 \times 10^{-11} + 4.3 \times 10^{-15}\ T_U)$ rad $s^{-1}$ | $\pm 0.1500 \times 10^{-11}$ rad $s^{-1}$ |

$T_U$ = Julian centuries from epoch J2000.0

Table 2. Relevant miscellaneous constants and conversion factors: World Geodetic System 1984

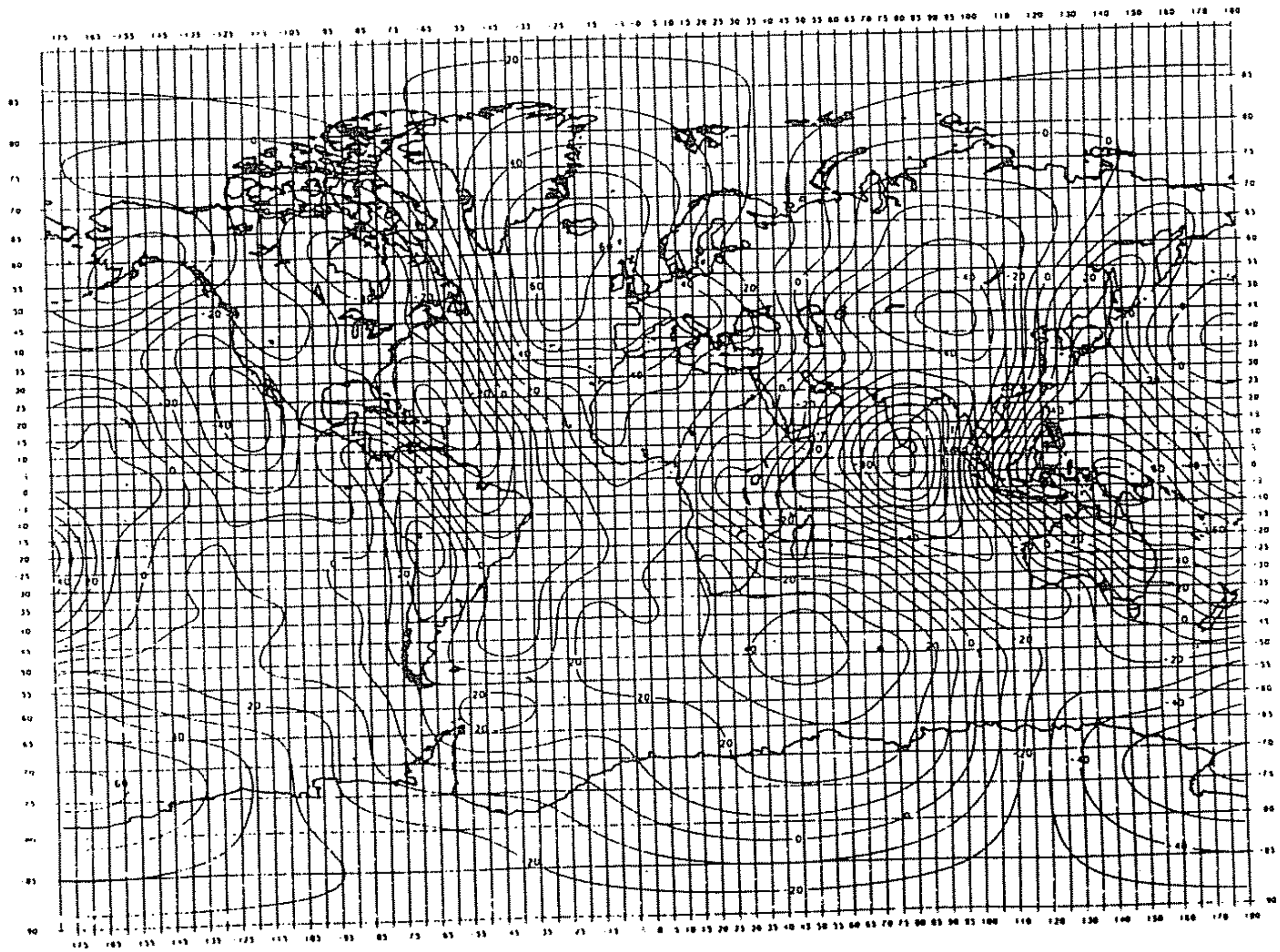
| *Constant* | *Symbol* | *Numerical Value* |
|---|---|---|
| Velocity of light (in a vacuum) | c | 299792458 m $s^{-1}$ |
| Dynamical ellipticity | H | 1/305.4413 |
| Earth's angular velocity | $\omega^*$ | $(7292115.8553 \times 10^{-11} + 4.3 \times 10^{-15}\ T_U)$ rad $s^{-1}$ |
| Universal constant of gravitation | G | $6.673 \times 10^{-11}\ m^3\ s^{-2}\ kg^{-1}$ |
| GM of the Earth's atmosphere | $GM_A$ | $3.5 \times 10^8\ m^3\ s^{-2}$ |
| Earth's gravitational constant (excluding the mass of the Earth's atmosphere) | GM′ | $3986001.5 \times 10^8\ m^3\ s^{-2}$ |
| Earth's principal moments of inertia (dynamic solution) | A | $8.0091029 \times 10^{37}$ kg $m^2$ |
| | B | $8.0092559 \times 10^{37}$ kg $m^2$ |
| | C | $8.0354872 \times 10^{37}$ kg $m^2$ |

*Conversion factors*

| | |
|---|---|
| 1 Metre | = 3.28083333333 US survey feet |
| 1 Metre | = 3.28083989501 international feet |
| 1 International foot | = 0.3048 metre (exact) |
| 1 US survey foot | = 1200/3937 metre (exact) |
| 1 US survey foot | = 0.30480060960 metre |
| 1 nautical mile | = 1852 metres (exact) |
| | = 6076.10333333 US survey feet |
| | = 6076.11548556 international feet |
| 1 statute mile | = 1609.344 metres (exact) |
| | = 5280 international feet (exact) |

$T_U$ = Julian centuries from epoch J2000.0

Figure II. WGS 84 Geoid (n = m = 18 truncation) Referenced to WGS 84 ellipsoid ($\overline{\delta C}_{4,0}$, $\overline{\delta C}_{6,0}$, $\overline{\delta C}_{8,0}$, and $\overline{\delta C}_{10,0} \neq 0$; Units = Metres).



### Earth gravitational model

The Earth gravitational model (EGM) of the WGS 84 is a spherical harmonic expansion of the Earth's gravitational potential and is defined complete through degree (n) and order (m) 180°, comprising 32,755 coefficients. However, only the coefficients through n = m = 18 are unclassified.[3]

Accuracy values are not available for all the WGS 84 EGM coefficients; however, an error covariance matrix is available only for coefficients through n = m = 41, which were determined from the weighted least squares solution.

### The geoid

In addition to the Earth's geometric surface or figure, the WGS 84 geoid, as the equipotential figure of the Earth (also approximated by mean sealevel over the oceans), is defined as so many metres above (+ N) or below (− N) the WGS 84 ellipsoid, where "N" is known as geoidal height or undulation.

The worldwide geoidal heights were calculated using the WGS 84 EGM through n = m = 180, and they can also be depicted as a contour chart (showing deviations from the WGS 84 ellipsoid) or as a grid of desired density. Figure II shows a worldwide WGS 84 geoid chart developed from a worldwide 1° × 1° grid using the unclassified EGM coefficients through n = m = 18.

The root mean square geoidal height for WGS 84, taken worldwide, is 30.5 metres and the error ranges from plus or minus 2 to plus or minus 6 metres (1 $\sigma$). The accuracy of the WGS 84 geoid is better than plus or minus 4 metres over approximately 93 per cent of the globe.

### Relationship with local geodetic datums

Counting islands and/or other "astro" datums, the number of local geodetic datums available for mapping, charting, and geodesy requirements and applications exceeds several hundred. If the inherent technical difficulties of dealing with these numerous local datums, each defined with its own specifications and basic limitations, are considered in daily usage, the picture is just too complex and almost chaotic.

Under this bleak scenario, one of the principal purposes of a World Geodetic System is to provide the means whereby these numerous local geodetic datums can be referenced to a common system (or to each other indirectly through extrapolation) and then, WGS can facilitate simplification of the global mapping, charting, and geodesy problem.

To achieve the referencing of a local datum to WGS 84, one major requirement is to have well-distributed control points common to both the systems. DMA maintains a worldwide database of Navy Navigation Satellite System, Doppler station. A search of this database produced 1,591 good quality Doppler stations, which also had coordinates defined in the local datum of the area.

These 1,591 Doppler stations cover 83 local geodetic datums spread out over all the six continents.[3] From a high of 405 Doppler stations common with the North American Datum 1927 in the contiguous United States, there are 29 datums with only one common station. This limitation of not having any check station thus affects about 35 per cent (29 of 83) of the datums.

As the local geodetic datums are generally defined only horizontally and provide mean sealevel (msl) heights from separately defined vertical datums the geodetic heights in the local datum ($H_{LD}$), required to compute datum transformation parameters, were generated using the following equation:

$$H_{LD} \approx h_{msl} + N_{LD}$$

In the above equation, the local datum geoidal heights (NLD) were obtained by appropriate transformation from the WGS 84 geoidal heights. These local geoids are absolute (contrary to the relative astro-geodetic that are available for a few of the local datums) and consistent in definition with each other and also with the WGS 84 geoid worldwide.

Table 3 provides a sample listing of the transformation parameters between the 83 local datums and the WGS 84; a full listing is available elsewhere.[4]

Table 3. Transformation parameters: local geodetic systems to WGS 84*

| *Local geodetic systems*[a] | *Reference ellipsoids and parameter differences*[b] | | | *Number of Doppler stations used to determine transformation parameters* | *Transformation parameters*[b] | | |
|---|---|---|---|---|---|---|---|
| | *Name* | *Δa(m)* | *Δf × 10*$^4$ | | ΔX(m) | ΔY(m) | ΔZ(m) |
| Provisional South American 1956 | International | −251 | −0.14192702 | | | | |
| Mean Value (Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, and Venezuela) | | | | 63 | −288 | 175 | −376 |
| Puerto Rico | Clarke 1866 | 69.4 | −0.37264639 | | | | |
| Puerto Rico and Virgin Islands | | | | 11 | 11 | 72 | −101 |
| Qatar National | International | −251 | −0.14192702 | | | | |
| Qatar | | | | 3 | −128 | −283 | 22 |
| QORNOQ | International | −251 | −0.14192702 | | | | |
| South Greenland | | | | 2 | 164 | 138 | −189 |
| Réunion | International | 251 | 0.14192702 | | | | |
| Mascarene Island | | | | 1 | 94 | −948 | −1 262 |
| Rome 1940 | International | 251 | 0.14192702 | | | | |
| Sardinia Island | | | | 1 | −225 | −65 | 9 |

*For complete table, see report referenced in note 4 at end of this paper.

[a]Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n = m = 180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

[b]WGS 84 minus local geodetic system.

TABLE 4 METHODS OF DETERMINING, AND ACCURACY OF WGS 84 COORDINATES

| *Method of determining WGS 84 coordinates* | *Achievable accuracies (1 σ)* |
|---|---|
| 1. Directly established in WGS 84 coordinate system via a satellite point positioning solution | Φ and ± 1 m<br>H ± 1 to 2 m |
| 2. By transformation from Doppler (NSWC 9Z-2) coordinates by bias removal | Φ and ± 2 m<br>H ± 2 to 3 m |
| 3. By transformation of WGS 72 coordinates: | |
| (a) At Doppler sites | Same as 2 above |
| (b) At non-Doppler sites where WGS 72 coordinates were obtained indirectly from local datums | Dependent on the originating local datum coordinates and transformation errors[a] |
| 4. By transformation of local datum coordinates | Same as 3(b) above |

[a]See DMA TR 8350.2-A, 1 December 1987.

In addition to the 83 local datums related to the WGS 84 through Doppler ties to the local control, transformation parameters (based on non-Doppler information) are also available for seven additional local datums.[4]

*Accuracy*

The accuracy of the WGS 84 coordinates of a site is significantly influenced by the method used to determine the coordinates. Table 4 lists the four methods generally available to establish the coordinate of a WGS 84 site and the associated accuracies achievable through each of the methods.

From table 4, it is noticed that method 1 (where a WGS 84 site is established through direct satellite observational data) gives the most accurate positional fix of 1-2 metres. Method 4 (the least accurate) is entirely dependent on the local/regional distortion of the local geodetic datum.

NOTES

[1]Bureau international de l'heure. "*Annual report for 1984*" (Paris, 1984).

[2]H. Moritz, "Geodetic reference system 1980", *Bulletin Géodésique*, 54(3), 1980.

[3]United States Department of Defense, "World Geodetic System 1984: its definition and relationships with local geodetic systems", Defense Mapping Agency technical report 8350.2 (Washington, D.C., 30 September 1987).

[4]Ibid., supplement; Part II, "Parameters, formulas, and graphics for the practical application of WGS 84", Defense Mapping Agency technical report (Washington, D.C., 1 December 1987).

## (b) *Acquisition of cartographic data from airborne and space platform*

### APPLICATIONS TOPOGRAPHIQUES DE SPOT À L'IGN-FRANCE*

*Document présenté par la France*


SUMMARY

SPOT features are used at IGN in order to produce topographic maps. The mapping process involves several phases: block space triangulation; photogrammetric stereo-plotting; photo-identification and completion; and map-editing.

Depending upon the purpose, the products can be line maps or image maps, regular maps or study maps. DTM can be generated from SPOT stereopairs in order to produce background ortho-images.


PROCESSUS DE RÉALISATION DE CARTES TOPOGRAPHIQUES SPOT

Nous décrivons ici l'ensemble des phases qui constituent la chaîne de production cartographique. Dans le cas de SPOT, suivant le type de produit final, certaines de ces phases peuvent être simplifiées ou négligées.

*Acquisition des données : prétraitement*

L'acquisition des données est en général plus délicate qu'en photographie aérienne, lorsqu'on veut couvrir de vastes zones en stéréoscopie, la programmation du satellite n'ayant pas été optimisée dans ce but. Il faut, en outre, pour les applications cartographiques, que les images respectent un certain nombre de contraintes :

*a*) Bonne qualité d'image;

*b*) Délais courts entre la saisie du segment gauche et du segment droit d'un couple;

*c*) Absence de nuages, de vents de sable, etc.

*Détermination du canevas d'appui*

Ce canevas d'appui est bien moins dense qu'en photographie aérienne. Les nombreuses mises en place de couples SPOT sur appareils de restitution analytique effectuées à l'IGN (si l'on inclut les travaux de la recette en vol de SPOT 1, environ 80 couples) permettent de dire que 6 points d'appui constituent le meilleur rapport qualité/coût (soit un point tous les 600 km$^2$). L'utilisation de la triangulation spatiale de bloc permet d'abaisser encore cette densité. La triangulation spatiale est l'extension à l'imagerie SPOT des méthodes d'aérotriangulation aérienne. Ici, l'unité de base est le couple stéréoscopique de segments. Le bloc SPOT est donc plus rigide que le couple aérien et peut être modélisé avec beaucoup moins de points d'appui. Nous donnerons

*The original text of this paper, prepared by P. Denis and A. Baudoin, Institut géographique national, appeared as document E/CONF.83/L.40.

comme exemple le résultat suivant obtenu sur un polygone test du sud de la France :

Nombre de segments de prise de vue : 4
Nombre de scènes : 16
Nombre de points connus : 197
Nombre de points d'appui : 16
Nombre de points de vérification : 181

Résidus moyens quadratiques :

| *Sur les points d'appui* | *Sur les points de vérification* |
|---|---|
| RMQ en $x$ = 10,95 m | RMQ en $x$ = 11,93 m |
| RMQ en $y$ = 9,19 m | RMQ en $y$ = 10,76 m |
| RMQ en $z$ = 6,63 m | RMQ en $z$ = 6,34 m |

N.-B. : 7 points d'appui au Nord du bloc, 7 au Sud et vers le Centre.

Exemple de résultats : triangulation spatiale

*Restitution photogrammétrique*

La géométrie non conventionnelle des images SPOT entraîne l'utilisation d'appareils de restitution analytiques avec des logiciels de modélisation spécifiques. Un logiciel de ce type a été développé sur les matériels TRASTER/MATRA de l'IGN en 1985 et a servi dès le lancement de SPOT à la fois aux travaux d'évaluation et aux travaux de production. Des zones appartenant à des pays aussi divers que la France, le Yémen, le Mali, la Guinée, l'Algérie ont été restituées (représentant en mars 1988 une surface d'environ 16 000 km², soit l'équivalent de 23 coupures au 1/50 000). Les films utilisés à l'IGN sont des "niveau 1A améliorés" :

*a*) On part des images numériques de niveau 1A;

*b*) Les dynamiques des deux images d'un couple sont étalées et rendues proches; le contraste local est amélioré;

*c*) Les films de précision sont générés sur un VIZIRCOLOR/SEP avec anamorphose le long des lignes (coefficient dépendant de l'inclinaison de l'axe de prise de vue), permettant ainsi d'éviter l'effet de fuite du terrain observé sur des couples disymétriques.

Différentes études ont permis de chiffrer la précision de restitution de couples SPOT sur points identifiables. La recette en vol "spécification du relief" effectuée en mars 1986 avait donné les résultats suivants (P. Denis *et al.*, 1986).

*a*) 31 scènes exploitées, donnant 60 couples stéréoscopiques;

*b*) 95 points connus utilisés;

*c*) 1 261 pointés stéréoscopiques, dont 653 sur points de vérification.

Les résidus moyens quadratiques sur points de vérification ont été :

| | *RMQ en x* | *RMQ en y* | *RMQ en z* |
|---|---|---|---|
| Résidus bruts | 8,0 m | 6,6 m | 7,1 m |
| Résidus filtrés | 4,7 m | 4,5 m | 5,3 m |

Le tableau suivant récapitule les résultats obtenus sur d'autres chantiers (A. Jaloux, 1987).

| *Nom du chantier* | *B/H* | *Nb. points de vérification* | *RMQ en x* | *RMQ en y* | *RMQ en z* |
|---|---|---|---|---|---|
| Ghardaïa (Algérie) | 1 | 275 | 7,1 | 7,2 | 4,4 |
| Peps n 89 | | | | | |
| Couple 1 | 0,4 | 148 | 11,8 | 8,7 | 9,5 |
| Couple 2 | 0,8 | 132 | 9,1 | 10,7 | 4,2 |
| Polygone Provence | | | | | |
| Couple 1 | 0,97 | 103 | 10,1 | 10,8 | 3,7 |
| Couple 2 | 0,57 | 121 | 9,9 | 11,6 | 4,1 |
| Couple 3 | 0,25 | 110 | 10,2 | 10,9 | 8,1 |

Sur le plan de la précision métrique, SPOT est donc adapté à une cartographie au 1/50 000 avec des courbes de niveau d'équidistance de 20 mètres.

*Photo-identification — complètement*

L'utilisation des images SPOT pour interpréter les thèmes topographiques est envisageable pour des cartographies à des échelles inférieures ou égales au 1/50 000.

Selon les régions, en particulier selon la densité de l'occupation humaine, l'échelle compatible avec les normes cartographiques en vigueur peut être le 1/50 000 ou le 1/100 000.

L'échelle du 1/50 000 peut être envisagée dans les régions à faible urbanisation et au parcellaire agricole assez grossier (les parcelles ne peuvent être identifiées que si elles contiennent au moins 10 à 20 pixels).

Dans le cas de la cartographie de la feuille de Ghardaïa au 1/50 000, l'interprétation visuelle, complétée par un passage sur le terrain, a permis de mettre en place les principaux détails topographiques et l'occupation du sol : réseau routier, réseau hydrographique, bâti dense et dispersé, végétation (A. Jaloux, 1987). L'échelle du 1/100 000 semble être optimale pour la cartographie issue de SPOT dans les pays industrialisés.

L'étude PEPS n° 89 sur la région de Marseille a permis d'obtenir les résultats suivants, par interprétation visuelle des images photographiques corrigées au niveau 3, à l'échelle du 1/100 000 en fausses couleurs, par observation stéréoscopique des couples panchromatiques et par interprétation assistée par ordinateur (classifications multispectrales) (P. Foin, 1987).

*Analyse du réseau routier*

Le tableau suivant montre que les images SPOT permettent d'identifier correctement les autoroutes et routes nationales et dans une moindre mesure les routes départementales.

| | *% d'identification correcte* | |
|---|---|---|
| | *Photo-interprétation sur images XS* | *Restitution images P* |
| Autoroutes | 100 | 100 |
| Routes nationales | 80 | 100 |
| Routes départementales | 40 | 90 |
| Autres routes | 35 | 70 |

*Analyse du réseau hydrographique*

Sur les images XS les surfaces d'eau libre sont très bien identifiables. Par contre, le suivi du réseau hydrographique linéaire est plus difficile. Même avec les images panchro, seulement 60 % environ du réseau principal est restitué.

*Cartographie du bâti*

La cartographie du bâti avec les seules images SPOT est difficile. L'utilisation de photographies aériennes au 1/30 000 permet d'améliorer la qualité de l'interprétation en distinguant différentes densités de bâti. Les limites des zones urbanisées, hors de l'habitat dispersé, apparaissent généralement avec netteté sauf lorsque la zone d'habitat est entourée de cultures à petit parcellaire pouvant comporter des serres ou des bâches en plastique.

*Cartographie des forêts*

Dans cette région méditerranéenne, il est possible de distinguer sur les images SPOT XS les massifs forestiers en distinguant les résineux plus foncés des feuillus plus rouges et plus clairs et de la garrigue rouge sombre. Cependant des confusions peuvent être possibles entre les résineux et des ombres portées sur certains versants

*Autres thèmes*

L'interprétation des différentes cultures reste délicate du fait du petit parcellaire, cependant la distinction entre zones agricoles et non agricoles est assez bonne, à part la difficulté de reconnaître directement sur les images SPOT les petits villages et les zones d'habitat dispersé. Par contre les carrières et les chantiers sont facilement identifiables comme dans le cas des tronçons autoroutiers.

*Utilisation de SPOT pour la révision*

Un essai de révision d'une carte au 1/100 000 a été réalisé sur la région d'Aix-en-Provence à l'aide d'une image SPOT en fausses couleurs prétraitée au niveau 3 à l'échelle du 1/100 000. Près de 85 % des changements à mettre en place sur la carte apparaissent sur l'image SPOT (les 15 % manquant correspondent aux éléments ponctuels ou linéaires de petite taille : pylônes, lignes électriques, réseau routier secondaire) Cependant parmi les changements visibles, seulement 25 % sont directement interprétables à partir de l'image SPOT sans l'aide d'autres informations. Il est donc indispensable d'utiliser une prise de vue aérienne, ou des documents cartographiques existants par ailleurs pour effectuer correctement les mises à jour. L'intérêt de SPOT dans le processus de révision est une mise en place plus facile et plus sûre des différents éléments modifiés.

*Recherche en cours sur l'automatisation de l'interprétation des images*

L'exploitation des images SPOT repose, même dans le cas de l'utilisation de systèmes de traitement d'image, sur l'expérience des photo-interprètes qui exploitent visuellement les données. Pour automatiser les processus d'interprétation afin de réduire les délais de production, l'IGN mène de nombreuses recherches faisant appel à la reconnaissance des formes et à l'intelligence artificielle. Parmi celles-ci, signalons la reconnaissance et le tracé automatique du réseau routier (I. Destival, 1987), et la segmentation d'images pour automatiser la révision de l'occupation du sol (H. LeMen, 1986).

### *Obtention du fond d'image*

Dans le cas d'un produit cartographique sur fond d'image, on utilise soit des fonds d'image de niveau 2, soit des fonds d'image de niveau 3, soit une combinaison des deux. Le choix résulte de plusieurs critères : échelle du produit final, relief du terrain, inclinaison de l'axe de prise de vues.

Le modèle numérique de terrain nécessaire au niveau 3 peut être obtenu de différentes façons:

*a*) Par numérisation des courbes de niveau sur les cartes existantes;

*b*) Par restitution photogrammétrique de couples d'images SPOT;

*c*) Par corrélation automatique (G. Masson d'Autume, 1984; P. Denis, 1986);

*d*) Par extraction d'une base de données altimétriques, lorsqu'elle existe.

La méthode de corrélation automatique de l'IGN utilise les courbes quasi épipolaires. Un essai effectué début 1988 sur la zone Aix-Marseille a donné les résultats suivants (la comparaison a été effectuée avec un modèle numérique de terrain issu de la base de données altimétriques de l'IGN):

Rapport base sur altitude
du couple SPOT : 0.43
Pas du MNT : 20 mètres
Nombre de noeuds du MNT : 276 × 301
Moyenne des écarts entre MNT : 6.7 mètres
Erreur moyenne quadratique : 9.5 mètres
Ecart type : 6.7 mètres

Ces résultats sont illustrés dans les figures I et II.

### *Rédaction — tirages*

Ces phases ne sont pas fondamentalement différentes de celles de la cartographie classique. La facture cartographique évolue avec le développement de l'automatisation. En particulier le mixage de fichiers image et de fichiers trait, dans le cas des produits sur fond d'image, doit permettre une simplification du processus et un abaissement des coûts.

## Les produits topographiques SPOT

SPOT permet la réalisation de toute une gamme de produits, du plus simple au plus sophistiqué, du moins cher au plus coûteux. Nous nous limiterons ici à ceux qui peuvent être qualifiés de topographiques :

*a*) Cartes régulières, obéissant à des critères très stricts (qualités métriques, qualités cartographiques) et adaptées à la cartographie de série (voir fig. III et VI);

*b*) Cartes d'études particulièrement adaptées aux avant-projets. Par exemple fond d'image rectifié + courbes de niveau, stéréominute monochrome... ;

*c*) Modèles numériques de terrain et leurs produits dérivés.

L'imagerie SPOT peut être également utilisée pour la constitution et la mise à jour de systèmes d'informations géographiques. Par exemple la Base de données cartographiques de l'IGN, en cours de constitution, tire une partie de ses informations de l'exploitation de SPOT (F. Salge *et al.*, 1987).

## Eléments de coûts : conséquences

Si nous voulons comparer, pour chaque phase du processus cartographique, les coûts de SPOT et de la prise de vue

**Figure I. Corrélation automatique : courbes de niveau issues de clichés aériens au 1/30 000**

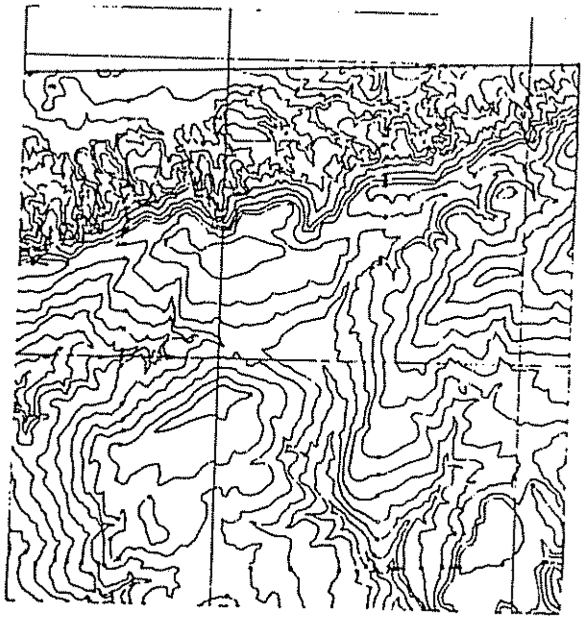
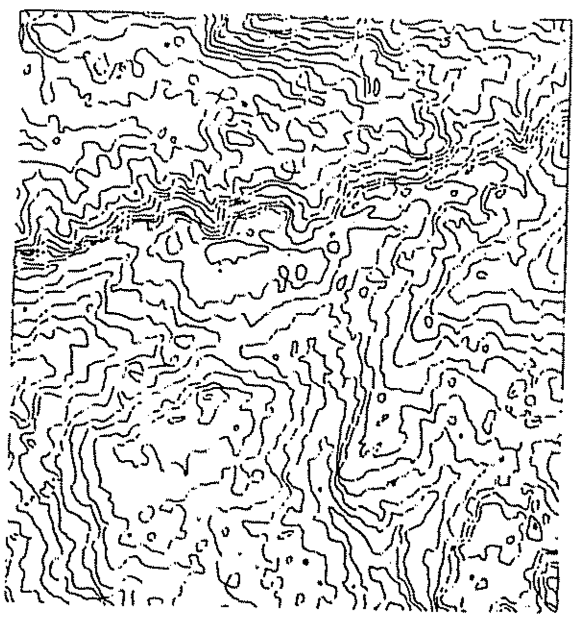


**Figure II. Corrélation automatique : courbes de niveau obtenues à partir d'un MNT calculé par corrélation automatique numérique d'un couple SPOT de B/H = 0,43**



Echelle des figures : 1/75 000
Equidistance : 20 mètres

Figure III. Cartographie de Ghardaïa (Algérie) : extrait du 1/100 000. Extrait d'image SPOT rectifiée au niveau 3
(SPOT © PRODUCT CNES-IGN © CNES 1986 © IGN PARIS 1987)

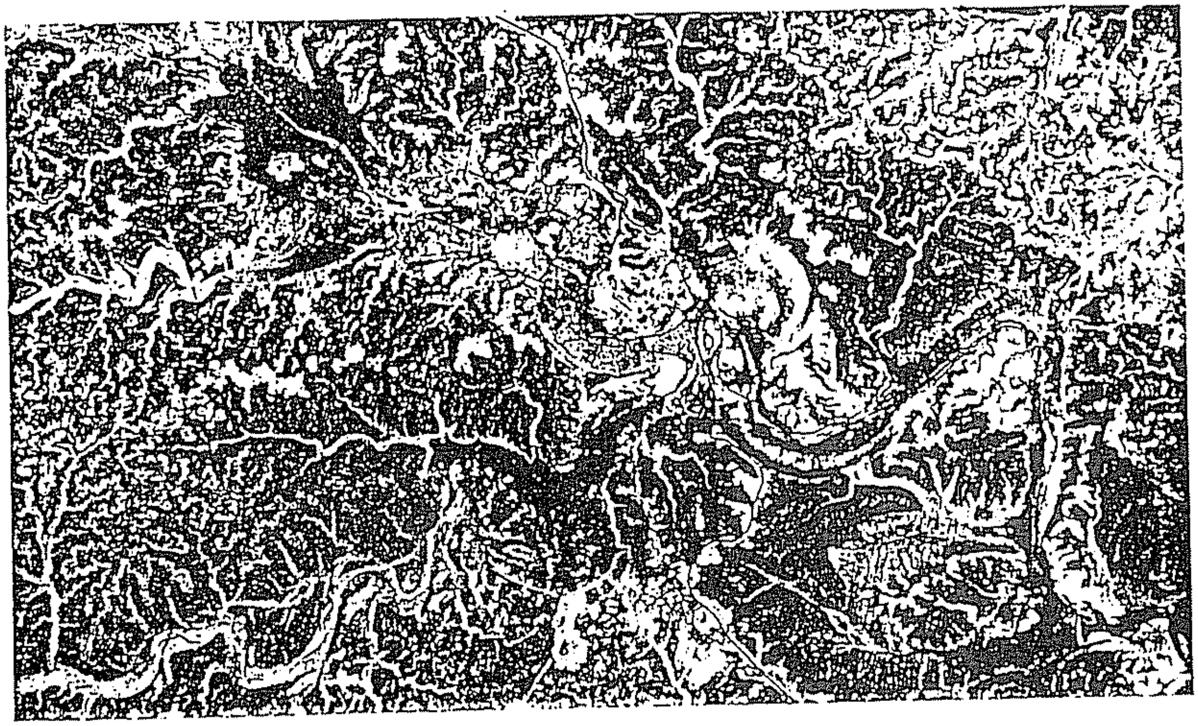


Figure IV. Cartographie de Ghardaïa (Algérie) : extrait du 1/100 000. Extrait de la planche de courbes de niveau
(© IGN PARIS 1987 © INC ALGER 1987)

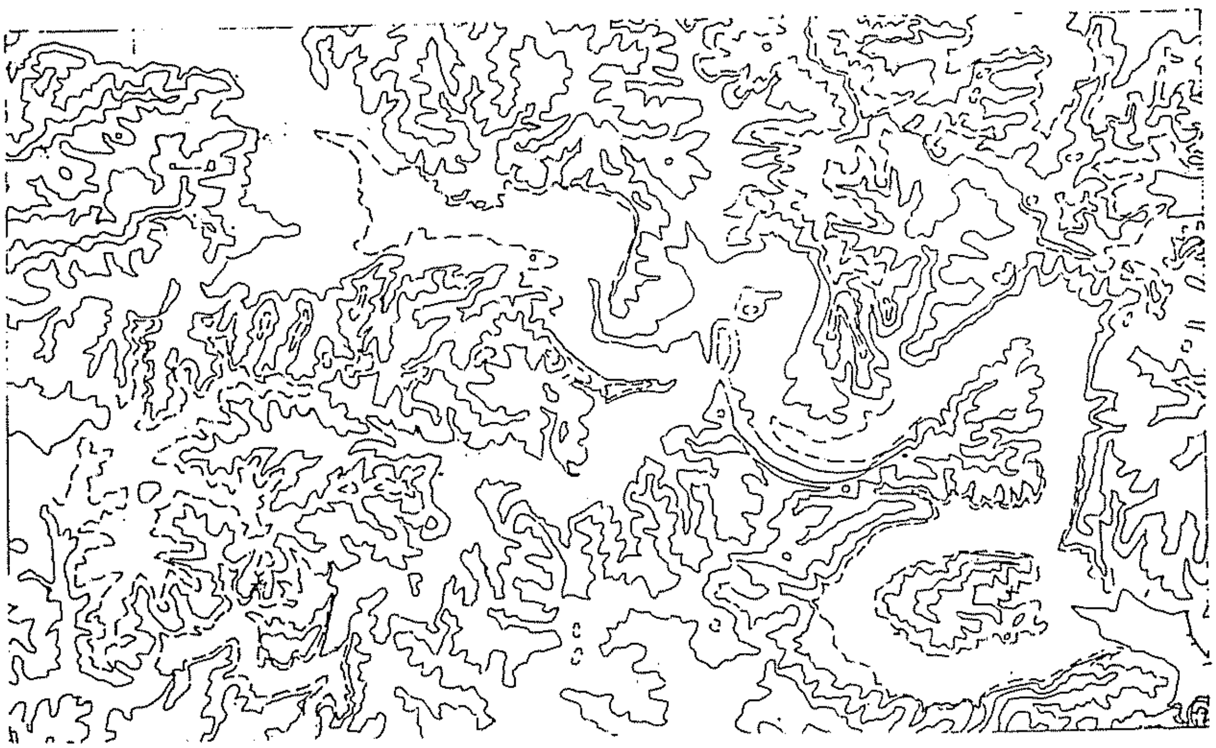


**Figure V. Cartographie de Ghardaïa (Algérie) : extrait du 1/100 000. Extrait de la planche de planimétrie après photo-identification**
(© IGN PARIS 1987 © INC ALGER 1987)

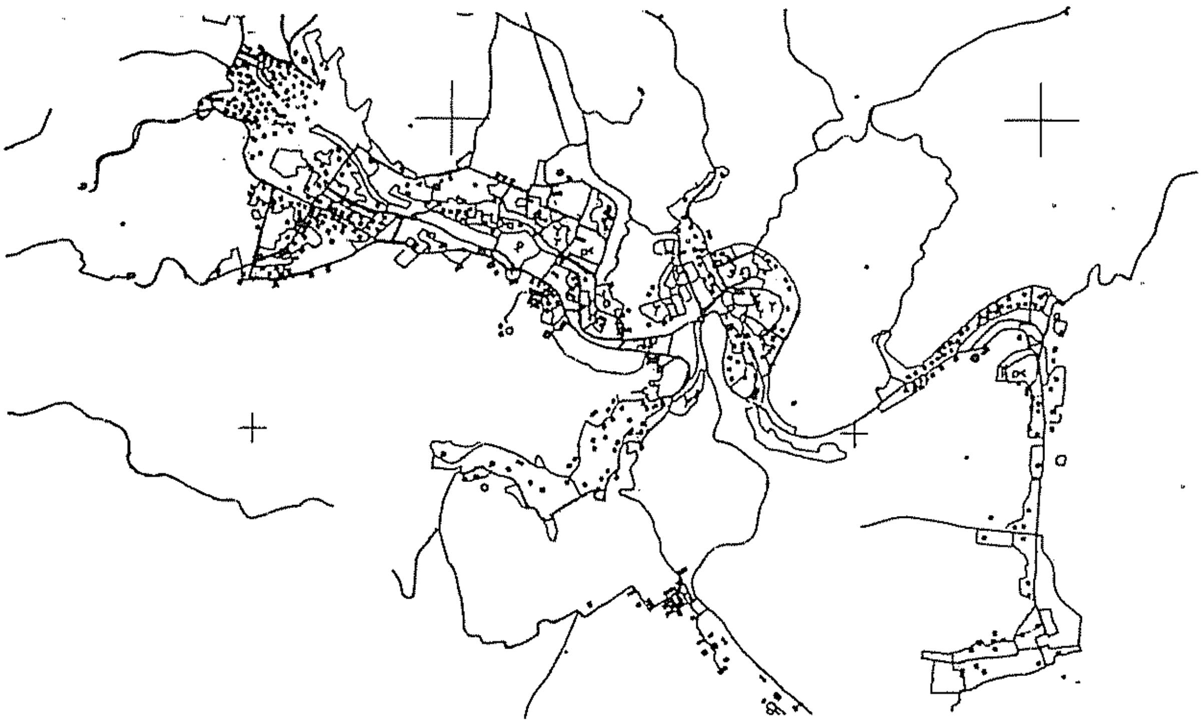


**Figure VI. Cartographie de Ghardaïa (Algérie) : extrait du 1/100 000. Extrait de la planche d'hydrographie**
(© IGN PARIS 1987 © INC ALGER 1987)

aérienne, nous obtenons le tableau suivant (K étant le rapport "coût prise de vue aérienne" sur "coût SPOT") :

| *Phases* | *Poids* | K | *Remarques* |
|---|---|---|---|
| Données | 3-5 % | $K=1$ à $K=4$ | |
| Canevas | 15-20 % | $K=2$ à $K=6$ | A – 50 % du processus |
| Restitution | 18-25 % | $K=3$ à $K=5$ | Kmoy ≃ 3 |
| Travaux topo | 20-30 % | $K \leq 1$ | |
| Rédaction | 15-25 % | $K \simeq 1$ | B – gains peu spectaculaires |
| Repro-tirages | 2-5 % | $K \simeq 1$ | ou pertes |

Nous constatons que les phases "acquisitions des données", "établissement du canevas" et "restitution photogrammétrique" sont très avantageuses lorsqu'on utilise SPOT, alors que les coûts des phases suivantes sont actuellement du même ordre de grandeur, et même plus élevés avec SPOT qu'avec des photographies aériennes. En particulier, à facture cartographique équivalente, la carte issue de SPOT nécessite un complétement sur le terrain plus lourd. En ce qui concerne la rédaction, les gains de productivité liés à l'automatisation des techniques devraient, dans les années qui viennent, rendre cette phase nettement moins coûteuse.

Quoi qu'il en soit, les cartes d'étude, pour lesquelles les phases "travaux topographiques" et "rédaction" sont très fortement réduites, semblent avoir l'avenir devant elles.

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## OPERATIONAL REMOTE SENSING CAPABILITIES IN GERMANY*

*Paper submitted by Germany*

### RÉSUMÉ


La télédétection peut être définie comme la collecte d'informations sur des objets, sans contact direct avec eux. Parmi les porteurs d'informations, le spectre des ondes électromagnétiques s'est révélé être d'une importance primordiale pour la télédétection à travers des milieux tels que l'air et l'espace (vide). A l'intérieur de ce spectre, la télédétection opérationnelle à travers l'air et l'espace se limite pour l'instant, en mode passif, aux ondes visuelles, à l'infrarouge proche et au rayonnement thermique. En mode actif, on utilise la télédétection dans les ondes d'hyperfréquence à partir des aéronefs. Il se peut que ce type de télédétection constitue bientôt un nouvel outil opérationnel.

Dans le rapport, on passe en revue les capteurs existant pour la photographie aérienne et la télédétection par satellite, on compare les capacités des divers capteurs pour la cartographie et on formule des propositions concernant les futurs capteurs de satellite destinés à cette activité.


### AVAILABLE SENSORS

#### *Aerial photography*

The primary remote sensing tool is still aerial photography. Its technology was developed starting in 1916 with the first aerial camera by Carl Zeiss, permitting systematic coverage of portions of the Earth's surface. With standard aerial survey cameras originally at formats 18 × 18 cm and later 23 × 23 cm, photographic resolutions of 20 to 40 lines/mm were reached for standard films and low contrast objects. With photogrammetric analog technology developed in parallel normal angle, wide angle and super-wide angle photography from flying heights between 1,000 and 12,000 m, aerial photogrammetric surveys permitted the basis for worldwide base mapping at scales ranging from 1:500 in urban areas to 1:50,000 (up to 1:250,000) for national surveys. Aerial surveys still continue to dominate data acquisition for topographic and thematic mapping in the 1990s, since these are the only tools providing recognition and geometric determination of objects on the Earth's surface with resolution and precision on the level of decimetre to metre.

Aerial photography and aerial photogrammetry, however, still have the drawback of costliness, which limits the extent of coverage, the scale of maps and the up-to-dateness of current mapping. In 1987 only 56.4 per cent of the land area of the Earth was covered at scale 1:50,000, and the rate of updating of current maps is only 2.3 per cent at that scale.

*The original text of this paper, prepared by G. Konecny, University of Hanover, Germany, appeared as document E/CONF 83/INF 15

Improvements to aerial survey technology have come about through new cameras with image motion compensation permitting resolutions of 50 to 70 lp/mm at low contrast as a result of reduced image motion combined with the use of high resolution films of lower sensitivity, paired with high resolution objectives.

The second improvement is about to take place with the introduction of GPS technology to fix the position of the exposure station during a photographic flight to the decimetre (dm) to m level, thus permitting a more systematic coverage and a vast saving of ground control, since the measured exposure station values, when introduced into the adjustment of aerial triangulation, can make the third-order-triangulation network more rigid. This will shortly lead to a reduction in cost of mapping operations. Assuming the same budget for mapping, a larger coverage and a better rate of update of mapping can be achieved.

### *Satellite remote sensing*

Through the introduction of satellite remote sensing (LANDSAT-MSS in 1972, MKF-6 in 1976) new tools have been added to complement the world mapping task.

The "review of latest technology in satellite mapping" contained in *World Cartography*, vol. XVII, classes the satellite remote sensing systems into three categories:

(*a*) Meteorological satellite systems (low spatial, high temporal resolution);

(*b*) Remote sensing satellite systems (intermediate spatial, spectral and temporal resolutions);

(*c*) Cartographic remote sensing satellite systems (high spatial, low temporal resolution, stereo-capability).

Of these, the general remote sensing satellite systems provide the multispectral capability for obtaining global thematic information. But only the cartographic remote sensing satellite systems have the capability to be marginally competitive with respect to the considerably more expensive, but more informative and more accurate, aerial photographic techniques.

The answer is obviously not to replace one technique by the other, but to combine standard aerial photographic technology with the new remote sensing technology in an optimization approach.

### *Satellite mapping capability*

The satellite mapping capability was reviewed by the International Society for Photogrammetry and Remote Sensing (ISPRS) Intercommission, Working Groups I/II and IV, at the Kyoto International Congress in 1988, as shown in the table.

| | *Planimetric accuracy* $\sigma_p$ *(m)* | *Planimetric suitability for scale* | *Altimetric accuracy* $\sigma_h$ *(m)* | *Possible contour interval (m)* | *b/h* | *Pixel equivalent* | *Mapping suitability (detectability)* |
|---|---|---|---|---|---|---|---|
| LANDSAT-MSS (USA) | ± 40 | 1:200 000 | nil | nil | nil | 79 | nil |
| LANDSAT-TM (USA) | ± 20 | 1:100 000 | (± 25 in parts) | 125 | 0.24 | 30 | nil |
| SPOT P (France) | ± 3 | 1:25 000 | ± 5 | 25 | 1 | 10 | 1:100 000 |
| KATE 200 (USSR) | ± 12 | 1:100 000 | ± 35 | 175 | 0.36 | 31 | nil |
| KFA 1000 (USSR) | ± 4 | 1:25 000 | ± 15 | 75 | 0.4 | 4 | 1:50 000 |

This summary of results must be compared with the following mapping requirements:

| *Scale* | *Planimetric accuracy (m)* | *Contour interval (m)* | *Detectability (m)* | *Remarks* |
|---|---|---|---|---|
| 1: 25 000 | ± 5 | 5 | 2 | Buildings, paths |
| 1: 50 000 | ± 10 | 20 | 5 | Minor roads |
| 1:100 000 | ± 20 | 50 | 10 | Building blocks, major roads |
| 1:200 000 | ± 40 | 100 | 20 | Major features |

Provided the current mapping standards are maintained, satellite imagery is therefore able to provide only marginal mapping capability, or to extract only part of the (thematic) information.

### *Commercialization of satellite image data provision*

While commercialization of satellite image data provision has taken place for remote sensing and cartographic satellite systems the price structure is constantly in flux. The following rough comparisons can be made:

| | *Full scene cost of CCT ($US)* | *Coverage* ($km^2$) | *Cost per* $km^2$ *($US)* | *Resolution in pixel equivalent (m)* |
|---|---|---|---|---|
| LANDSAT-TM | 6 000 | 33 000 | 0.18 | 30 |
| SPOT MX | 2 500 | 3 600 | 0.69 | 20 |
| SPOT P. | 2 500 | 3 600 | 0.69 | 10 |
| KFA 1000 | 1 500 | 7 000 | 0.21 | 4 |
| Aerial photography 1:120 000 | 7 000 | 700 | 10 | 1.2 |
| Aerial photography 1:3 300 | 500 | 0.23 | 2174 | 0.03 |

This gives rise to the consideration, that while aerial photography still cannot be reached in quality performance, it could be replaced in part by the less costly satellite data, provided minimum performance can be reached.

### *Future cartographic satellite sensors*

It must be realized that space agencies, the world over, have launched their remote sensing systems with other than cartographic interests in mind (e.g. LANDSAT-TM thematic data uses). Only the Soviet Union and France have launched systems of direct interest to the cartographic community, but the coverage of such systems in stereo has been far from reaching global goals. The cartographic community is therefore still in need of a satellite system that can provide global coverage with a high resolution performance and stereo capability.

In view of this, Germany is developing a sensor Stereo-MOMS 2, which will be flown experimentally on the D-2 Space Shuttle mission scheduled to be flown on a nine-day mission in 1992/93.

It is a triple electro-optical stereo-scanner with a swath of 40 km. The vertically oriented linear array detector will provide a 5-m ground pixel. The foreward and aft pointing linear arrays will provide 15-m ground pixel capability. For alternate multispectral uses vertical linear arrays at lower resolution will be added.

There are negotiations with the Soviet Union to fly the Stereo-MOMS for a three-year period in a more operational environment on the Priroda Module of the Soviet MIR-Space Station starting in 1994.

It is realized that tape recording of the data and the limited swath of the sensor will still not be able to provide global coverage.

Supplementing this, there are further negotiations, to include an improved photogrammetric camera, the MC, which was successfully flown as an experimental mission on Spacelab 1 in 1983. It would provide a near global coverage in stereo at a swath of 300 km up to latitudes −52° to +52° at resolutions better than 10 m.

At the same time preparations are under way to evaluate space images provided by the coherent radar system on the European Satellite ERS-1 to be launched in 1991 yielding the capability to generate 25-m pixel radar images.

The remote sensing-mapping community may thus be confronted with a large number of remote sensing images which may become of interest to the cartographic community, if the experimentation is successful.

## REMOTE SENSING DATA EVALUATION IN GERMANY

### *Aerial photogrammetry*

As in other countries, the photogrammetric community is well established in Germany. Companies, such as Hansa Luftbild (Münster), Kirchner & Wolf (Hildesheim), Maps (Munich), and others are part of the international facility providing worldwide services in aerial photography, mapping and photo interpretation.

Compilation and maintenance of the German 1:5,000 base map is the task of the state authorities for surveying and mapping in the 11 old and the 5 new states of Germany. While the in-house procedures for mapping and its updates are well established in the 11 old states, the reorganization of the new state survey offices is still under way. In general, the state survey offices receive aerial photography from the private companies under contract, and perform mapping operations. They also derive smaller-scale maps from the photogrammetric base map, as well as advanced digital vector products (ATKIS).

The private sector is engaged in special mapping (urban surveys, engineering projects).

### *Remote sensing*

The use of remote sensing based on photographic interpretation is also taken up by the private sector for different clients under contract.

The use of satellite imagery was introduced by a programme introduced with funds of the Ministry of Research and Technology under the wing of the German Aerospace Research Establishment (formerly DFVLR, now DLR) during the years 1973 to 1975. This programme permitted the establishment of satellite data processing centres in Frankfurt, Freiburg, Hanover and Munich during the 1970s.

In the meantime the number of processing centres has been increased. Those who are members of the European Association of Remote Sensing Laboratories (EARSL) are as follows:

*University Institutes*

Free University, Berlin
Institute for Geophysical Sciences

Free University, Berlin
Institute for Meteorology

Technical University, Berlin
Chair for Photogrammetry and Cartography

Rhine-Ruhr University, Bochum
Chair for Water Resources and Environment Technology

University of Freiburg
Division for Photogrammetry and Photointerpretation

University of Freiburg
Institute of Physical Geography

University of Hannover
Institute of Photogrammetry and Engineering Surveys

University of Munich
Chair for Geography and Remote Sensing in Geography

University of Munich
Geoscience Faculty, Remote Sensing Division

University of Munich
Chair for Landscape Technology

University of Saarbrücken
Department of Geography

University of Stuttgart
Institute for Navigation

University of Trier
Department of Remote Sensing

*Government laboratories*

Federal Institute for Regional Ecology (BFNL), Bonn

Institute for Applied Geodesy (IfAG), Frankfurt

Max Planck Institute for Meteorology (MPI), Hamburg

Federal Agency for Geosciences and Resources (BGR), Hannover

German Geodetic Research Institute (DGFI), Munich

German Aerospace Research Establishment (DLR), Oberpfaffenhofen

Central Institute for Physics of the Earth (ZIPE), Potsdam

*Space Industry*

Dornier Systems, Friedrichshafen

Messerschmitt-Bölkow-Blohm, Munich

*Value-Added Industry*

SpaceMap, Hildesheim

GAF, Munich

Hansa Luftbild, Münster

All procure their satellite data either directly from EOSAT, SPOT-Image or Sojuzkarta.

For data covering the territory of Germany a national point of contact was originally established at the DLR in Oberpfaffenhofen under the ESA-Earthnet programme. This programme maintains e.g. the LANDSAT receiving stations in Fucino (Italy), Kiruna (Sweden), and Maspalomas (Canary Islands). SPOT data are available through the stations at Toulouse and Kiruna.

The commercial data distribution has now been passed on from DLR to Dornier Systems, Friedrichshafen, which now serves as a data distribution centre for local data.

Most of the remote sensing laboratories are University Institutes with capabilities to process satellite data on computer compatible tape (CCT). They have installed conventional processing capabilities on VAX-computers, work stations or PCs, and they are able to perform the tasks of geometric and radiometric corrections; multispectral and multitemporal classification; special filtering operations; and remote sensing data outputs on paper and film.

Most laboratories perform research or project tasks for applications in remote sensing such as agriculture, forestry, land use, hydrology, geology, ecology, and cartography. Few still have the capability to process large amounts of data.

Another group of laboratories concerns applications conducted by government laboratories cooperating in national, European and international technical cooperation projects sponsored by the German Economic Cooperation Agency (GTZ), the European Economic Commission (EEC), the Food and Agriculture Organization of the United Nations

(FAO), the United Nations Development Programme (UNDP), the World Bank and others.

To these add principally the Federal Research Institute for Geosciences and Resources (BGR in Hanover) and the DLR. IfAG in Frankfurt uses satellite imagery for Antarctic mapping.

A third group of laboratories belong to the private sector. Among them are GAF (Munich) and SpaceMap (Hildesheim). This group is concerned with the capability of providing large-volume remote sensing data processing services for large projects.

OPERATIONAL PROCESSING CAPABILITIES

The current situation of operational capabilities in remote sensing can be characterized by the diagram.

As an example for the required capabilities of value-added industry the facilities of SpaceMap, Hildesheim are briefly described:

(*a*) SpaceMap is a company formed by partners of the aerial mapping and aerial system services industry (Hansa Luftbild, Kirchner & Wolf, GTP, Aerodata) affiliated with universities and their research and development potential;

(*b*) It orders satellite data through the usual channels;

(*c*) It provides a number of products with high volume data throughput capabilities such as:

- Raster scanning of existing maps and their vectorization
- Raster scanning of high resolution aerial photos
- Resampling and radiometric correction of satellite and scanned data into geocoded form
- Classification of multispectral, multitemporal and multisensoral imagery
- Output of combined raster-vector products
- Screening of such products for map printing
- Compilation of mosaics
- Digital orthophoto production
- Output of special filtered products (e.g. lineaments)
- Provision of digital terrain models
- Integration of such products into geographic information systems;

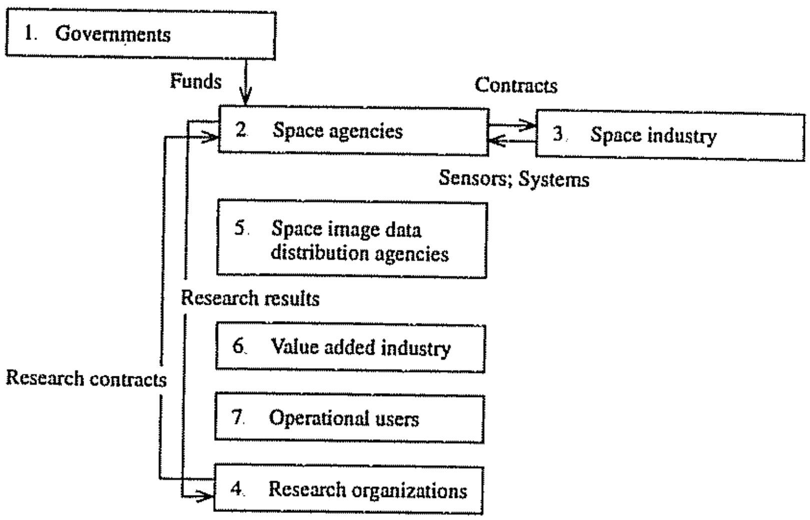
(*d*) To aid in the provision of additional data SpaceMap has the capabilities of

- GPS-controlled aerial photography and aerial triangulation
- GPS-controlled use of laser scanning for urban digital terrain model (DTM) landscapes and laser profiling (for height measurements in forests);

(*e*) In order to perform these tasks a high powered hardware and software system has been installed. It consists of

- MDA Meridian image processing system with strengths in geocoding based on a VAX 3800
- SUN 4/370-330 system for use with ARC/INFO and ERDAS
- MacIntosh-Canon colour printer system
- Intergraph InterPro 6280 for on-screen (and off-line) digitizing
- Intergraph InterServe 5200 with Optronics 5040 and Versatec 3444 for raster scanning and output of graphic products in dot or screened form
- Intergraph InterPro with VITEC board and photoscanner.

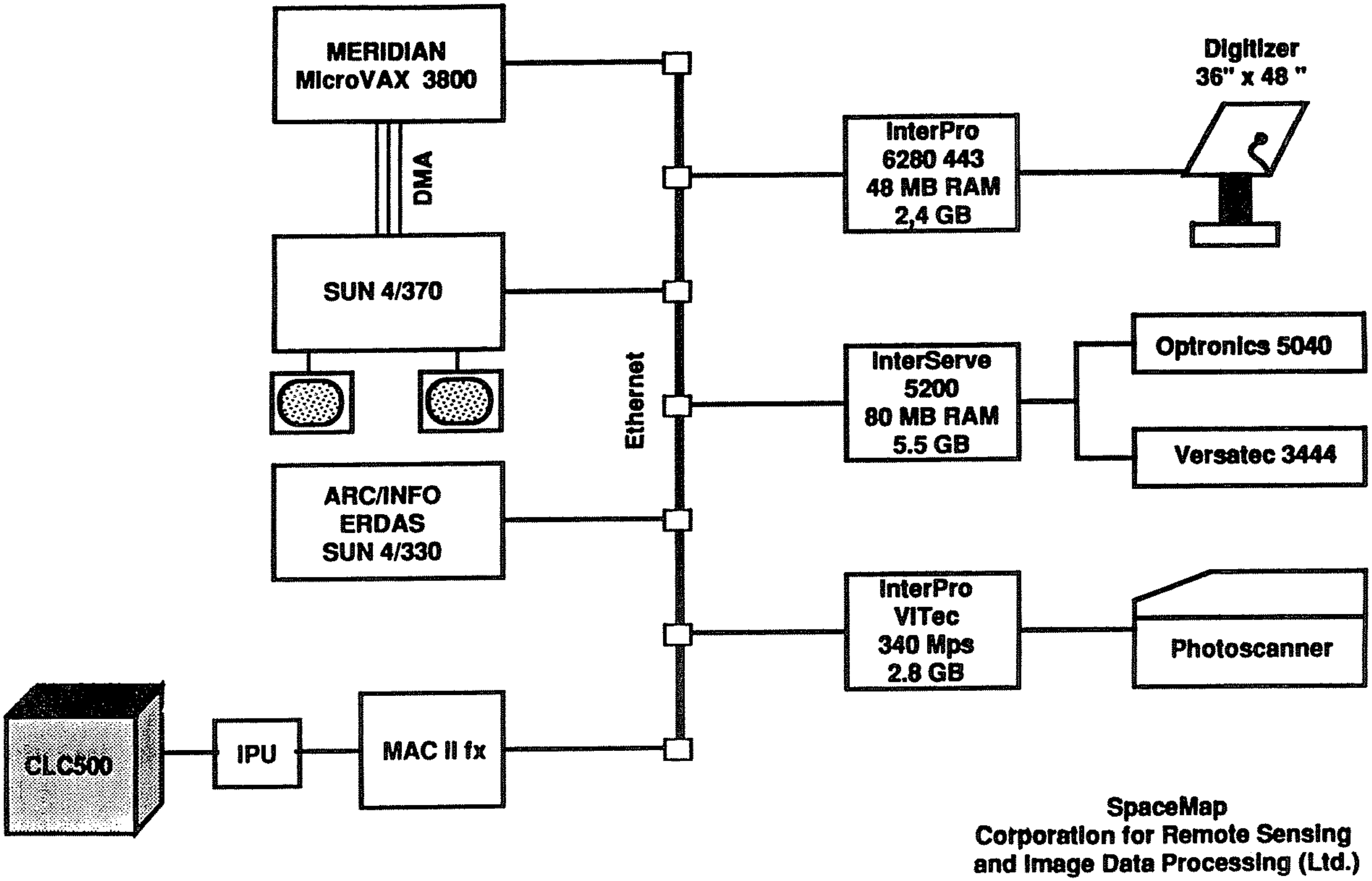
The described configuration provides integrated capabilities for the use of satellite remote sensing integration into national cartographic tasks. (Figure I.)




*Key*

1. Governments have traditionally initiated space programmes by appropriate funding
2. They have established space agencies.
3. These in turn have contracted space sensor and system construction to space industry
4. To validate needs for these space sensing systems they have generally used research organizations (e g universities) by space contracts to verify needs and sensor performance
5. Based on these research results, space image data distribution agencies were established. The marketing of space data has, however, been handicapped by the fact that neither research organizations nor space image data distribution agencies have in general had direct access to operational users.
6. This gap must now be filled by value-added industry which needs to bring current space products in line with operational needs
7. To the operational users belong the cartographic and thematic mapping agencies; they need to include budgets so that new remote sensing technology can be integrated into the mapping process

Figure I.  System overview



# TRENDS IN GPS PHOTOGRAMMETRY*

*Paper submitted by Germany*

## RÉSUMÉ

L'an dernier, on a réalisé en Europe de nouveaux essais de localisation cinématique par le GPS avec compensation par blocs. Le nombre grandissant de satellites disponibles a permis de diminuer les restrictions de temps de vol pour les photos et d'élargir les applications pratiques de cette méthode.

On note deux tendances contradictoires : pour la production, il faut limiter les activités supplémentaires de localisation par le GPS. C'est pourquoi on a également procédé à des essais sans station de référence au sol. En revanche, pour la recherche, on a combiné la localisation cinématique par le GPS avec des systèmes de navigation par inertie afin d'atténuer les problèmes d'interpolation entre les enregistrements du GPS.

Si les décalages et les dérives systématiques des centres de projection déterminés par la localisation GPS sont respectés dans le sens de la bande, même avec un positionnement absolu on peut obtenir des coordonnées d'une précision de ±20 cm. Le calcul des effets systématiques par compensation combinée doit reposer sur des points de contrôle. Avec des bandes photographiques croisées, on peut ramener à quatre le nombre de points de contrôle, même dans de larges blocs.

Même si l'on dispose de programmes de compensation combinée qui permettent de résoudre le problème de la photogrammétrie, il reste des difficultés concernant l'acquisition des données et le calcul des positions GPS. Il faudrait faire appel à de nouveaux récepteurs GPS permettant d'utiliser tous les signaux satellite disponibles; en parallèle, la chambre de prise de vues photogrammétrique devrait permettre un enregistrement de l'instant réel d'exposition.

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The connection between the photocoordinate system and the ground coordinates is based on control points. With block adjustment the number of necessary control points can be reduced drastically. But the effort for ground survey of the still remaining points is not negligible; it may equal the effort for the whole photogrammetric processing. A possibility for an additional reduction of the number of control points is to use projection centre coordinates determined by kinematic GPS positioning.

The NAVSTAR Global Positioning System (GPS) is becoming more and more complete, so restrictions to the operation time with at least four satellites within radio view are acceptable. Also, the connection between the photogrammetric camera and the GPS receiver has become commercially available. Expenditure of GPS receiver in the aircraft is limited. Only in case of relative positioning must additional measurements be done with a second receiver on the ground. For this reason also, tests have been made by absolute kinematic GPS positioning in connection with bundle block adjustment.

Point determination with GPS is based on the distances between the receiver and the satellites. The distances are determined by the interval of a signal from the satellite to the receiver; that means the measurements are time measurements. Three distances are sufficient for a three-dimensional intersection, but the receiver clock is not accurate enough to guarantee sufficient positioning so a fourth distance is necessary for the receiver time update. The time will not be measured directly; it is only possible to measure the phase of the waves. There are 2 carrier frequencies, the L1 frequency with 1,575 MHz, corresponding to a wave-length of 0.19 m and the L2 frequency with 1,227 MHz, corresponding to 0.24 m. In addition, there is a modulation of the signal with a frequency of 10 MHz—the P-code—corresponding to a wave-length of 29 m and a frequency of 1 MHz—the C/A-code with 293 m. Because of the noise the phase measurement is limited to − 1 per cent of the wave-length. That means, based on the carrier phase, a positioning is possible by theory with an accuracy of a few millimetres, but with the C/A-code only with some metres to a tenth of a metre. In addition to the phase the ambiguity has to be solved. This can only be done with additional information, which can be an integration over time and/or linear combinations of the wave-length.

The influence of the geometric constellation of the satellites to the positioning is described by different DOP-factors (dilution of precision). A PDOP $\leq 3$ is good, up to 6 sufficient, larger values poor.

The theoretical accuracy cannot be reached because of limited information about the satellite positions and the atmospheric conditions. The different, not well known parameters of the mathematical model limit the absolute positioning of a receiver in relation to the satellites to some tenths of a metre. The errors of the model are influencing not just the positioning of one receiver, but neighbouring receivers are influenced in the same way. So it is possible to determine the location of one receiver in relation to another within some millimetres or some centimetres if the distance between both does not exceed 50 km—the relative positioning.

### SYNOPSIS OF EUROPEAN TESTS UP TO 1990

A synopsis of European tests on GPS photogrammetry is available in Jacobsen (1990). This paper has not yet been published, so a summary will be made.

Tests have been made by the International Institute for Aerial Survey and Earth Sciences (ITC), Enschede, the Netherlands (Cortes and Heimes, 1988); the Institut géographique national (IGN), St. Mandé, France (Brossier and Million, 1990); the Rijkswaterstaat, Delft, the Nether-

*The original text of this paper, prepared by J. Jacobsen, University of Hannover, appeared as document E/CONF.83/INF.16.

lands (van der Vegt, Boswinkel and Witmer, 1988); the Continental Shelf and Petroleum Technology Research Institute, Norway (Andersen, 1989); the University for Armed Forces, Munich, together with Rheinbraun, Cologne, Germany (Hein, 1989); and the University of Hannover, Germany (Jacobsen, 1990; Jacobsen and Li, 1990).

The quality of kinematic GPS positioning has been checked against the locations of the projection centres determined by block adjustment. In any case systematic differences in size, of some to several metres, have been present. A drift of the GPS positions depending upon time has been in most of the data sets. After elimination of the systematic differences of the GPS positions the mean square differences have reached between ±4 cm in the case of a relative GPS positioning and ±60 cm in the case of absolute GPS positioning.

A special problem is the time recording of the photographic exposure. The coordinates of the projection centres are interpolated based on the time of the exposure between the GPS positions determined in a fixed time interval. Always 1ms difference in time will cause a coordinate error of 6 cm if the aircraft is operating with the slow speed of 200 km/h. The release signal of a camera with rotary shutter has a variable interval to the mid-time of exposure, so special sensors have to be added to the cameras (figure I).

The time recorded by the sensor has to be corrected to the effective instant of exposure. Without calibration this is only possible approximately. But constant errors in time will cause only constant shifts, which have to be compensated in any case. It is just important not to change the exposure time during photo flight.

Combined block adjustments with GPS positions have to respect the systematic errors of kinematic GPS data by additional parameters. Depending upon the quality of the used data a ground accuracy between ±10 cm and ±70 cm has been reached with just four control points. The Continental Shelf Institute has tried to use the independent model adjustment. This was only possible with a direct 7-parameter solution. The usual iterative procedure of 4/3-parameters (horizontal and vertical adjustment separately) cannot be used. In general the bundle method should be preferred.

## Latest European results

### *University of Stuttgart/Rijkswaterstaat*

The GPS test flight Flevoland of the Rijkswaterstaat includes 10 strips with approximately 18 photos/strip with a photo-scale of 1:3,800 (Friess, 1990a,b). A diode was attached to the used RC 10 to enable a sufficient time recording. The relative GPS positioning has been done with a Sercel TRSS-B in the aircraft and a Sercel NR52 in the test area. Usually five satellites could be used with a PDOP of 5. Only in two strips has the PDOP reached 30 and 57. With the exception of both poor strips, after individual strip elimination of shifts and drifts depending upon time, an accuracy of the projection centre coordinates of up to $S_{X_0}$ = ±8 cm, $S_{Y_0}$ = ±8 cm and $S_{Z_0}$ = ±4 cm has been reached. Where $S$ = accuracy considering the influence of shifts and drifts; $X$ = coordinate; O = point zero, or centre point, it was possible to calculate the drift over 4 strips and an interval of 15 minutes based on continuous positioning with five satellites. This common handling of the 4 strips resulted in $S_{X_0}$ = ±22 cm, $S_{Y_0}$ = ±28 cm and $S_{Z_0}$ = ±27 cm.

### *University for Armed Forces, Munich*

In 1988, the University FAF, Munich, performed, together with Rheinbraun, in the high precise test area Hambach several GPS flights with photo-scales between 1:4,200 and 1:6,600 (Dorrer and Schwiertz, 1990). Because of insufficient ambiguity solution, drifts of the GPS positions occurred. By iterative data handling based on controlled bundle adjustments the interval between the recorded time of a sensor and the effective instant of exposure was determined, together with the ambiguity. In addition, the differences between GPS positions and the projection centres determined by block adjustment were fitted by linear time variant similarity transformation. This yielded to mean square differences of $S_X$ = ± 9 cm, $S_Y$ = ± 8 cm and $S_Z$ = ± 4 cm. If there was no constraint to the exposure time, $S_X$ and $S_Y$ were reduced to ± 4 cm. This data handling is not possible for production but it demonstrates the high potential of kinematic GPS positioning.

Also in 1988 GPS photo flights have been made with a photo scale 1:25,000 in the control area for topographic

**Figure I. Instant of photographic exposure**

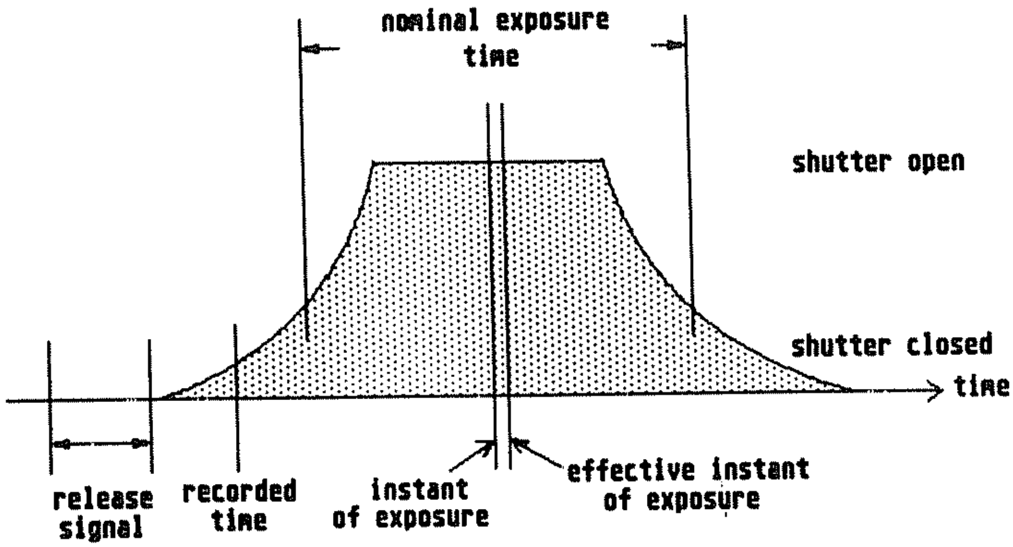
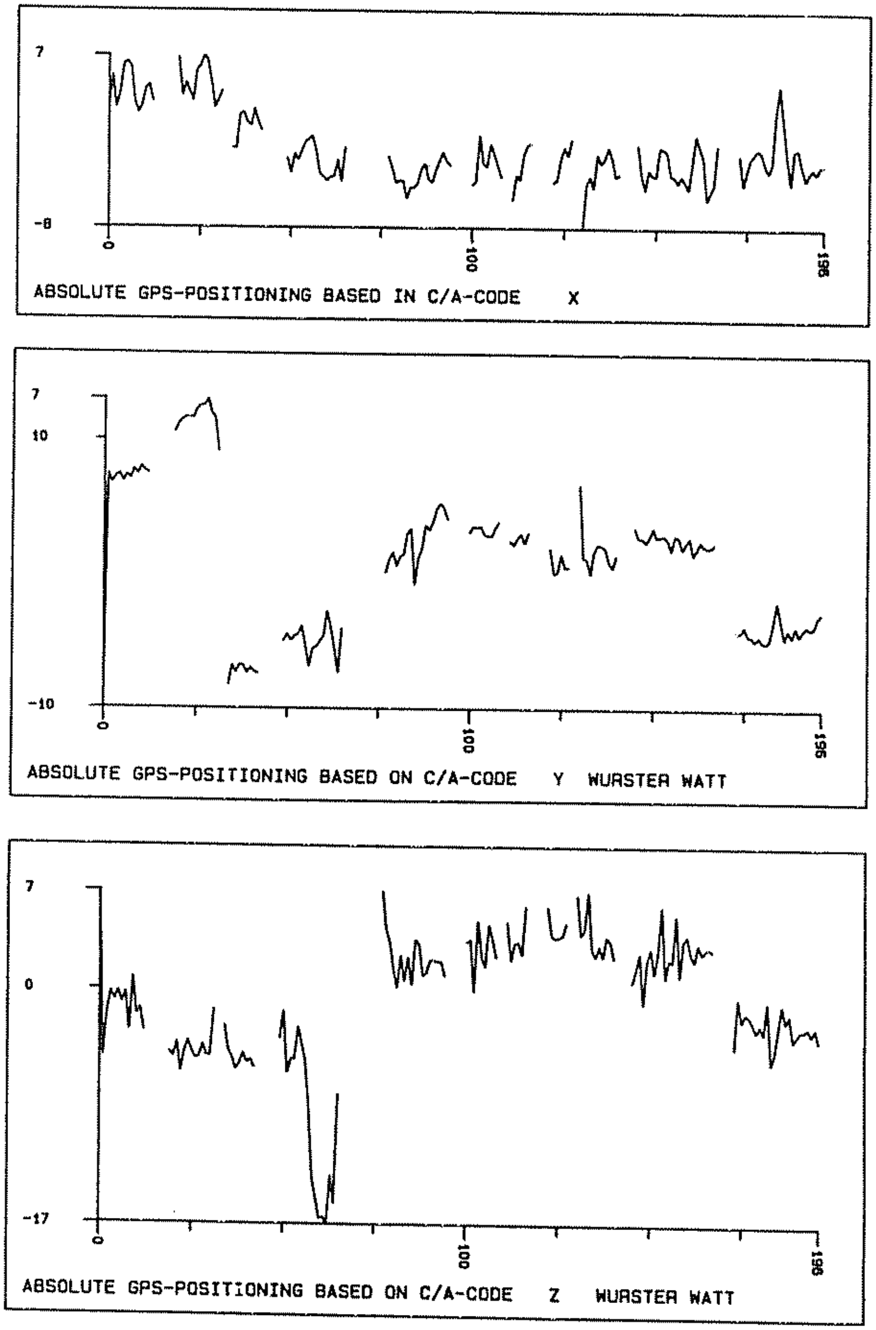


**Figure II. Differences in projection centres, bundle adjustment–GPS (Vertical scale in metres; horizontal: photo sequence)**



mapping, Schwabmünchen. Owing to the small satellite windows the photo flight of 5 strips with 40 photos each had to be made in 3 periods. In this case the ambiguity could be determined correctly prior to the flight by 10 minutes standby, so there have been no drifts of the GPS positions. The mean square differences between the GPS positions and the projection centres have been $S_{X_0} = \pm 37$ cm, $S_{Y_0} = \pm 47$ cm and $S_{Z_0} = \pm 29$ cm. This is in the range of the accuracy of the photogrammetrically determined projection centres, which has been $S_{X_0} = \pm 45$ cm, $S_{Y_0} = \pm 48$ cm and $S_{Z_0} = \pm 29$ cm. That means it is sufficient for this photo-scale, and the GPS positions can be better.

*University of Hanover, Test Wurster Watt*

In 1990, in the wetlands of the North Sea the company Gesellschaft für Technische Photogrammetrie made a photo flight. In this area navigation cannot be based on maps, so a Honeywell ELAC 8800 GPS receiver, based on the C/A-code, was used for flight navigation. In addition, the camera RMK 15/23 was attached with a photo-sensor to allow exact time recording of the photo exposure. Eleven photo strips with a sidelap of 30 per cent and 3 crossing strips with altogether 236 photos were flown at scale 1:4,200. The crossing strips were necessary for the solution of the bundle adjustment because only 6 triple complete and 1 vertical control point were available. The projection centres were determined by controlled bundle adjustment with the program system BLUH, with an accuracy in X and Y between ±8 cm and ±20 cm, and in Z between ±3 cm and ±15 cm (figure II).

From the beginning, absolute GPS positioning based on the C/A-code has not been expected to be very precise. Figure II shows the differences between the projection centre coordinates determined by bundle adjustment and by absolute GPS positioning after elimination of 100 m to 180 m shift. In three strips only three satellites could be received. The corresponding observations are not shown because they are not usable. Also within the observation of the fifth strip one satellite was lost. This caused a change of the z-coordinate of approximately 12 m.

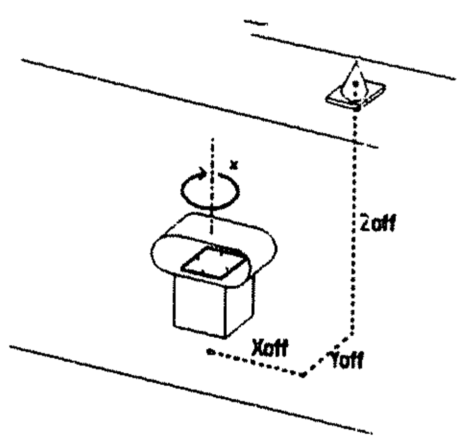
After stripwise elimination of the shifts, mean square differences between GPS and photogrammetrically determined projection centre coordinates reached $S_{X_0} = \pm 1.13$ m, $S_{Y_0} = \pm 1.13$ m and $S_{Z_0} = \pm 1.51$ m. Drift within strips was not significant. The relative accuracy to the next neighbouring photo-centre amounts to $S_{X_{rel}} = \pm 0.80$ m, $S_{Y_{rel}} = \pm 0.97$ m, and $S_{Z_{rel}}$ ±1.43 m. This means the dominating influence within a strip is the noise of the observation. The C/A-code has a wave-length of 293 m. In relation to this the achieved results are very good; but, finally, this type of GPS positioning should not be used for combined adjustment.

*University of Hanover, test Rheinkamp*

The coal mining company Ruhrkohle is checking photogrammetrically the subsidences caused by mining activities in any three years by bundle block adjustment with a photo-scale 1:4,000 and threefold photo coverage (p = q = 60 per cent, crossing flight with q = 20 per cent). The ground coordinates are required with standard deviations of ±3 cm in all components. Checks with independent check points have confirmed these requirements. Usually standard deviations of $S_X = S_Y = \pm 1.8$ cm and $S_Z = \pm 2.7$ cm are reached.

The ground points in the area of Rheinkamp determined by this method were used as check points for a kinematic GPS flight. In the aircraft 2 T14100, and also on a reference station in the test site 2 T14100 receivers were used, attached to the same antenna. The photo-flight was made with an RMK 30/23 of the German Space Agency, Oberpfaffenhofen, supplied with a sensor which records the instant of exposure based on the movement of the shutter. Also, the influence of changing object illumination to the registration of a diode mounted in the image plane was excluded.

**Figure III. Antenna offset**




The orientation of the camera against the aircraft was not changed during photo-flight, so it was possible to determine the antenna offset in relation to the camera. Such an offset can be respected depending upon the photo orientation as correction of the GPS antenna position in the bundle block adjustment program BLUH. A changing of the camera rotation will disturb the relation between the photo orientation and the offset. This is only possible if such drift angles can be recorded as in figure IV.

To reduce the problem of interpolation between the positions determined by kinematic GPS positioning in fixed time interval, the camera release signal was synchronized to the GPS receiver. The accuracy of kinematic positioning with the T14100 is better with a longer time for integration. For this reason an interval of three seconds has been used for the recording and photo exposure.

**Figure IV. Interpolation of projection centres between GPS points**

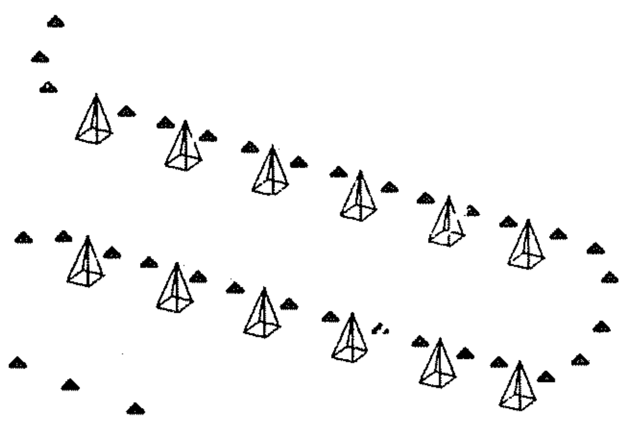
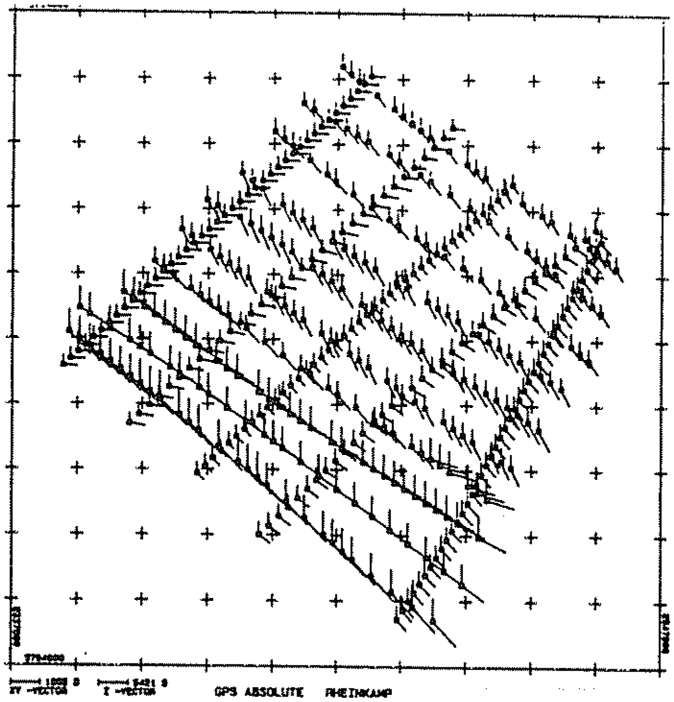


Figure V. **Differences between absolute GPS positioning and projection centres determined by BLUH**
*(Vector scale in centimetres)*




The photo-scale for the GPS flight was 1:4,000; 454 photos and 4,856 ground points are included. The block with 30 per cent sidelap was stabilized by 5 crossing strips. The bundle adjustment with program system BLUH determined the projection centres with an accuracy range of $S_{X_0}$ = ±4-7 cm, $S_{Y_0}$ = ±4-7 cm, and $S_{Z_0}$ = ±1-2 cm, based on $\sigma 0$ = ±4.8 μm. The large difference between the horizontal and vertical components is caused by the long focal length and correlation between $X_0$ and $Y_0$ to the altitude data.

By bad luck, 2 GPS receivers did not operate well; one of them was in the aircraft and one on the ground. In addition, these were not the receivers operating with the satellites. The quality of relative GPS positioning was reduced by this.

During a flight time of 1 hr, 36 min, usually five satellites were usable. In any turn to the next flight line, up to one or two satellites were lost. So cycle slips cannot be excluded.

Caused by loss of one satellite signal, 29 positions of the total amount of 454 images could be determined based on only four satellites. These positions do have a limited quality and are not used. The differences in projection centres shown in figure VI indicate changing shifts from flight line to flight line caused by cycle slips in the turn. Such erroneous ambiguity solution causes drifts depending upon the size of the shifts. For this reason also the drifts are different from strip to strip.

The shifts in the range between −16 m and +43 m do not affect the use of the data for combined block adjustment. But obviously the shifts and drifts have to be determined by additional parameters individual for any strip. The block configuration with crossing strips enables the bundle adjustment, with these unknown based on just four control points. (See table 1).

The accuracy of the absolute GPS positioning shown in the table is sufficient for most photogrammetric tasks. Be-

Figure VI. **Differences in projection centres, bundle adjustment–GPS**
*(Vertical scale in metres; horizontal photo sequence*
*Test Rheinkamp: absolute kinematic GPS positioning)*

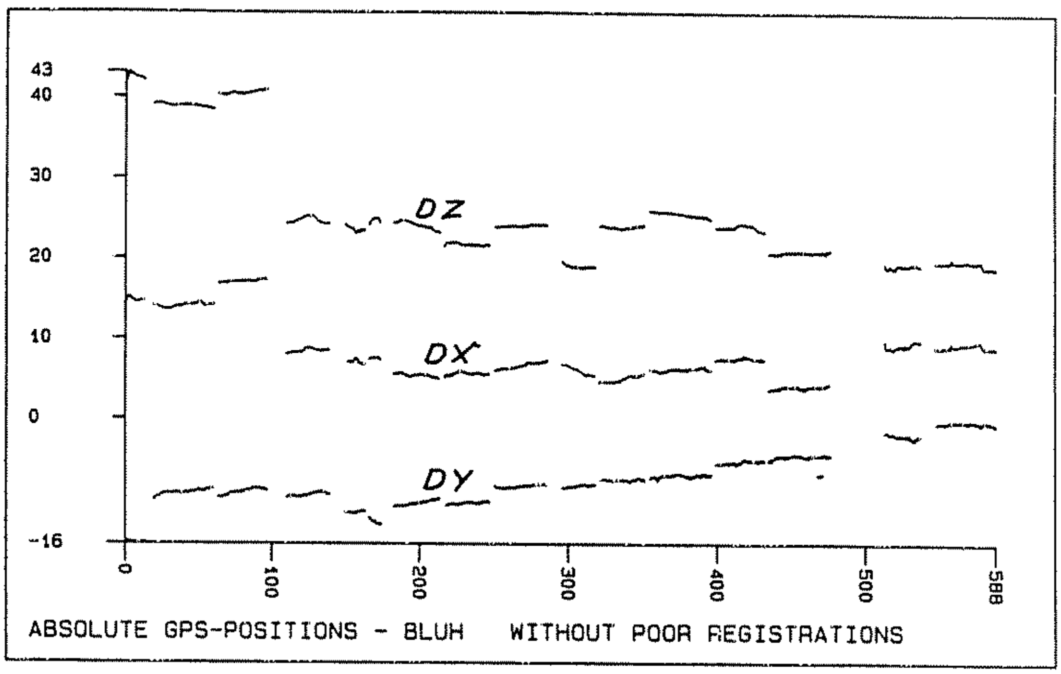


TABLE I GPS POSITIONS CORRECTED BY SHIFTS AND DRIFTS, WITH RELATIVE ACCURACY TO NEIGHBOURING PROJECTION CENTRE

| X | Y | Z |
|---|---|---|
| ±0 30 | ±0 23 | ±0 28 m |
| ±0.19 | ±0.13 | ±0.22 m |
| ±0 11 | ±0 09 | ±0 09 m |

*Note* RMS differences in projection centres determined by bundle adjustment and kinematic GPS after strip correction.

cause of receiver problems, relative GPS positioning was not better. The combined adjustment has not been finished so far because the data have been available for only 2 weeks.

## CONCLUSION

There is no further doubt about the importance of kinematic GPS positioning for photogrammetry. The different tests have demonstrated the power but also the still existing problems. It is necessary to use newer generation GPS receivers, which are able to receive all satellite signals in parallel. Dual frequency is important in the case of absolute positioning for compensation of atmospheric influences. The metric camera should have a link to the GPS receiver for the registration of the instant of exposure in the same time base. Such hardware is now available, for example, with the combination of the ASTEC XII receiver with the photogrammetric option and the RMK TOP, but there is still the problem of operational programs that can solve the GPS positioning in a short time.

Even if the projection centres can be determined accurately enough, it is necessary to have bundle block adjustment for the determination of shifts and drifts and the altitude data. The altitude data today cannot be determined accurately enough by other methods.

Further investigations are needed into the use of absolute kinematic GPS positioning. The effort to place a reference station within or close to the operation area is not negligible. It should be checked whether a reference station on the airbase is helpful.

No restrictions should be made on the photo-flight, otherwise the method will not be acceptable for practical application.

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# AERIAL PHOTOGRAPHY USING THE GLOBAL POSITIONING SYSTEM AND WILD RC-20 CAMERA*

*Paper submitted by Indonesia*

## RÉSUMÉ


L'Agence nationale indonésienne de coordination des activités de levé et de cartographie (BAKOSURTANAL) a procédé en 1990 à deux missions de photographie aérienne utilisant la technique de localisation différentielle du GPS, une caméra Wild RC-20 avec compensation de filé et un film aérien à haute résolution (Kodak Plus X 2402). Il s'agissait des premières missions de ce type réalisées en Indonésie.

Les deux missions ont été effectuées à bord de l'un des deux avions de levé aérophotogrammétrique *Tarus King Air 90* de BAKOSURTANAL. Toutes les opérations photographiques, y compris le traitement de l'émulsion, le tirage et l'indexation, ont été réalisées au laboratoire photographique de BAKOSURTANAL à Cibinong, dans l'ouest de Java. Le post-traitement en mode différentiel des données GPS a été réalisé sur le terrain et dans les locaux de BAKOSURTANAL à Jakarta et à Cibinong.

Dans le présent document, on donne un aperçu général des objectifs, des procédures et des résultats des deux missions, qui ont porté respectivement sur une zone proche de Wamena, dans l'Irian Jaya (projet Jayapura-Wamena), et sur une zone située autour de Jakarta (projet Jabotabek).


*The original text of this paper appeared as document E/CONF 83/INF.42

## Mission locations and objectives

Photographic missions using one of BAKOSURTANAL's Taurus King Air 90 aircraft, a Wild RC-20 FMC camera, two Trimble Navigation 4000 AX GPS Receivers, IBM PC compatible computer and Triable software were conducted in the remote Wamena-Jayapura area of Irian Jaya and in the densely populated area of greater Jakarta (JABOTABEK) on the island of Java.

A brief description of the objectives for each mission and general mission specifications are presented below.

### *Jayapura Wamena mission*

Aerial photography for the Jayapura-Wamena was obtained for a block of land between the village of Wamena, at the western limits of the block, and Indonesia's border with Papua New Guinea, on the eastern limit, as shown in figure I. The centre of the block was approximately 250 km southwest of Jayapura. This area in Irian Jaya is extremely remote, with very few roads and small scattered villages. Only small-scale mapping of questionable accuracy is available. In fact, a large part of this block had never been photographed from the air prior to the 1990 mission. Photography for Jayapura-Wamena area was flown at a nominal scale of 1:30,000 using black-and-white double X film (Kodak 2405).

The main objective of this mission was to obtain black-and-white vertical photography with GPS positions for each frame. This photography is to be used in the selection of a road corridor between the village of Wamena and the existing road near the village of Senggi, close to the Papua New Guinea border.

A second objective was to obtain photographs that would provide for more accurate mapping of the area, which will be used in the process of development planning for this remote area and its natural resources.

A third objective for the Jayapura-Wamena photography mission was to evaluate the potential of GPS positioning data for mapping control in remote areas of Indonesia. Use of GPS positioning in these areas is expected to reduce costs in both time and money

### *JABOTABEK mission*

Aerial photography obtained for the JABOTABEK mission was for an area around Jakarta centred on the towns and cities of Jakarta-Bogor-Tangerang-Bekasi, as shown in figure II. This area is the mostly densely populated and developed area in Indonesia, with an extensive system of ground survey control. Photography for the JABOTABEK area was flown at a scale of 1:15,000.

The main objective of the photographic mission was to obtain high-resolution black-and-white vertical photography (Kodak Plus X 2402 film) with GPS positioning of each frame. The primary user for the JABOTABEK will be environmental planners who are conducting an environment monitoring programme in the JABOTABEK planning area.

A secondary objective for the JABOTABEK mission is to provide high resolution photography for the updating of mapping in the area and also to provide up-to-date photography for urban planners and others concerned with the orderly development of the area

A third objective is to test and evaluate the accuracy of the GPS positioning data obtained for each photographic frame in an area with good ground survey control.

### *Wild RC-20 camera (FMC)*

A Wild RC-20 aerial camera with forward motion compensation (FMC) capability was used for both photographic missions. The camera used was equipped with a Universal AVIGON 15/4 UAGA-F lens with a focal length of 153 mm.

The camera's FMC system was used on the JABOTABEK mission only, owing to the low-flying heights above ground (±2,500 m) and the slow film speed of the Plus X high-resolution film.

The FMC system of the Wild RC-20 camera is capable of correcting up to 640 microns of image motion. Compensation for image motion is made automatically by the camera's systems, through the movement of both the camera's contact pressure plate and film during film exposure. The contact pressure plate can move at any speed between 1 mm/sec to 64 mm/sec. Image motion calculations are constantly made by the FMC system based on a ratio of aircraft ground speed, height above ground and the focal length of the lens.

An evaluation of the FMC's impact on the film quality for the JABOTABEK area will begin shortly.

### *Global Positioning System*

The two survey missions used two Trimble Navigation 4000 AX receivers, two IBM PC compatible computers and associated software. One of the 4000 AX receivers and a computer were mounted in the aircraft to act as the airborne receiver. The second 4000 AX receiver and computer were used as a static ground or reference station.

During each photographic flight both the airborne and ground receivers were programmed to track the same set of satellite or SVs. This was accomplished by producing a satellite visibility and geometry (PDOP) prediction prior to each flight and using the best selection of four SVs to create a sequence file of SVs to be tracked as a function of time. The sequence file was used by the computers controlling each receiver to force the receivers to track the same set of selected SVs.

The ground reference receiver recorded positional data on the selected SVs and also collected the systems almanac, health and ephemeris data on an hourly basis. The fifth channel of the ground receiver was used to sequentially track the four SVs being tracked in the receiver's first 4 channels. Data from the ground receiver fifth channel were used in post processing of data. The ground receiver was controlled by its computer using the program GPS GND. All data collected by the receiver were stored in the computer's hard disk.

The airborne GPS receiver and computer were interfaced to the RC-20 camera using a special RS 232 camera port. The airborne receiver, like the ground receiver, was controlled by its data acquisition computer using the program GPS-NAV. The aircraft computer contained a precise clock printed-circuit card, which was automatically synchronized to within 1 microsecond of UTC time.

This clock card contained hardware for time stamping to better than one millisecond the mid-exposure pulse of the Wild RC-20 camera. The time stamp data, exposure event number and GPS data were recorded together on Bernoulli 20 megadisks. The exposure event number and a rough position were also transmitted from the computer to the RC-20 camera. These data were encoded on the edge of each picture. These data were eventually used to correlate GPS post processing data with each photo frame.

Post-processing of GPS data was done in three steps. The first step used in the program "Correct" to estimate and reduce bias for each of the four channels. This process was done separately for each receiver. The second step uses the Trimble navigation program "Post-Nav" to differentially process the GPS data. This step corrects the airborne receivers databased on the ground reference receivers data.

The third stage uses the program "Pinpoint" to read the file of event numbers, GPS time stamps and GPS position versus time produced by the "Post Nav" in step 2. "Pinpoint" then creates an output listing of the corrected GPS aircraft positions, interpolated to the time stamp of the RC-20 shutter mid-exposure signal. A list correlating the time and position data to the exposure event numbers recorded on the film is also produced. The output listing of position and event number were than matched to the flight index maps by film roll and flight-line numbers.

The final listing for GPS position data and photography was organized by film roll number and flight-line number. Horizontal position data were recorded to 1/10,000 of a second. Vertical position data were recorded to 1/10 of a metre.

### RESULTS AND CONCLUSIONS

The primary results and conclusions for the first GPS positioning aerial photography survey made in Indonesia were shown below.

*Jayapura-Wamena*

Approximately 4,000 line kilometres of photography were flown for this photo-block between 14 September 1990 and 14 November 1990. A total of about 2,100 photo frames were exposed for the mission. GPS for this block of photography is expected to be highly variable owing to the short periods of four SV GPS window availability and difficult photographic weather conditions.

*JABOTABEK*

Photography for the JABOTABEK area was flown between 15 November 1990 and 28 November 1990. A total of about 3,600 line-kilometres of photography was obtained during this period. The number of photographic frames exposed was 3,300. GPS data for this photo-block are expected to be much less variable than data for the Irian Jaya mission. Good GPS coverage and good photographic weather were available during the survey.

*Global Positioning System*

Position data collected during both photography missions were collected using three different satellite configurations. These configurations include:

3 SV Stand alone (airborne data only)

4 SV Stand alone (airborne data only)

4 SV Differential

Photography was obtained using these three different satellite configurations to ensure that photographic coverage was obtained for each block during good photographic weather conditions. Reflights were attempted in areas with weak GPS coverage during periods of less than suitable weather conditions and strong GPS coverages to infill the GPS data.

The highest accuracies for GPS positioning data will occur with four SV differential coverage. Accuracies of +3 m in horizontal positions and +4 m in vertical positions are estimated for four SV differential coverage. Accuracies for stand-alone coverage of both three and four SV will be much lower.

Studies are presently being made to evaluate fully the potential of airborne GPS positioning data for mapping purposes in Indonesia. Results for these studies should be available within the next year.

## REMOTE SENSING IN INDONESIA*

*Paper submitted by Indonesia*

### RÉSUMÉ

Ce rapport décrit le rôle joué par BAKOSURTANAL dans les levés aérophotogrammétriques et l'emploi de la télédétection pour la cartographie en Indonésie.

Remote sensing, including aerial photography, has been used in two different fields: (*a*) for topographic information by photogrammetric compilation; and (*b*) for thematic information by image interpretation process.

The oldest form of airborne remote sensing is the use of aerial photography for the production of topographic base maps. With the availability of aerial photos, visual interpretation is conducted for assessment of information of natural resources and environmental conditions, such as forestry, geology, vegetation, landscape analysis, engineering and urban planning etc. Both activities are carried out by different organizations without any common programme. Since the same data source is used for both applications, it would be more efficient to integrate base mapping with resources inventory.

Later, when satellite remote sensing becomes operational, the utilization of satellite imagery will be incorporated in the operational system to augment the up-to-dateness of information through multi-stage and multi-sensor approaches.

However, since optical remote sensing, such as aerial photography and the present satellite remote sensing, cannot penetrate cloud, which is the prevailing situation in most tropical countries, airborne synthetic aperture radar (SAR) is used to overcome the gaps of information in those areas of persistent cloud cover.

### THE ROLE OF BAKOSURTANAL

BAKOSURTANAL, since its creation as part of the first five-year national development plan in 1969, and within the framework of its coordinating tasks for basic surveys and national mapping activities, has a leading role in the National Resources Inventory Programme. This has resulted in

*The original text of this paper appeared as document E/CONF.83/INF 43.


South China Sea
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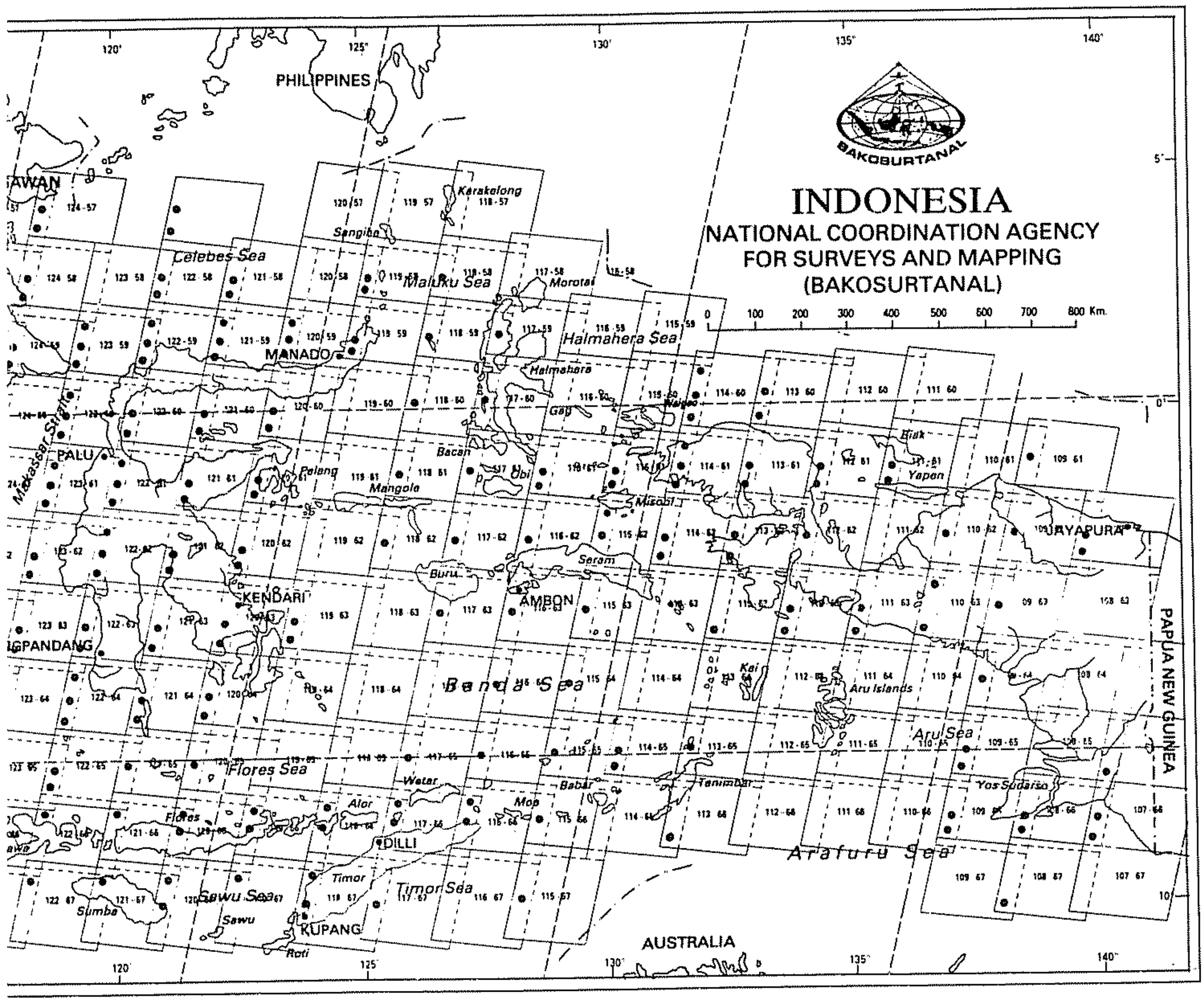
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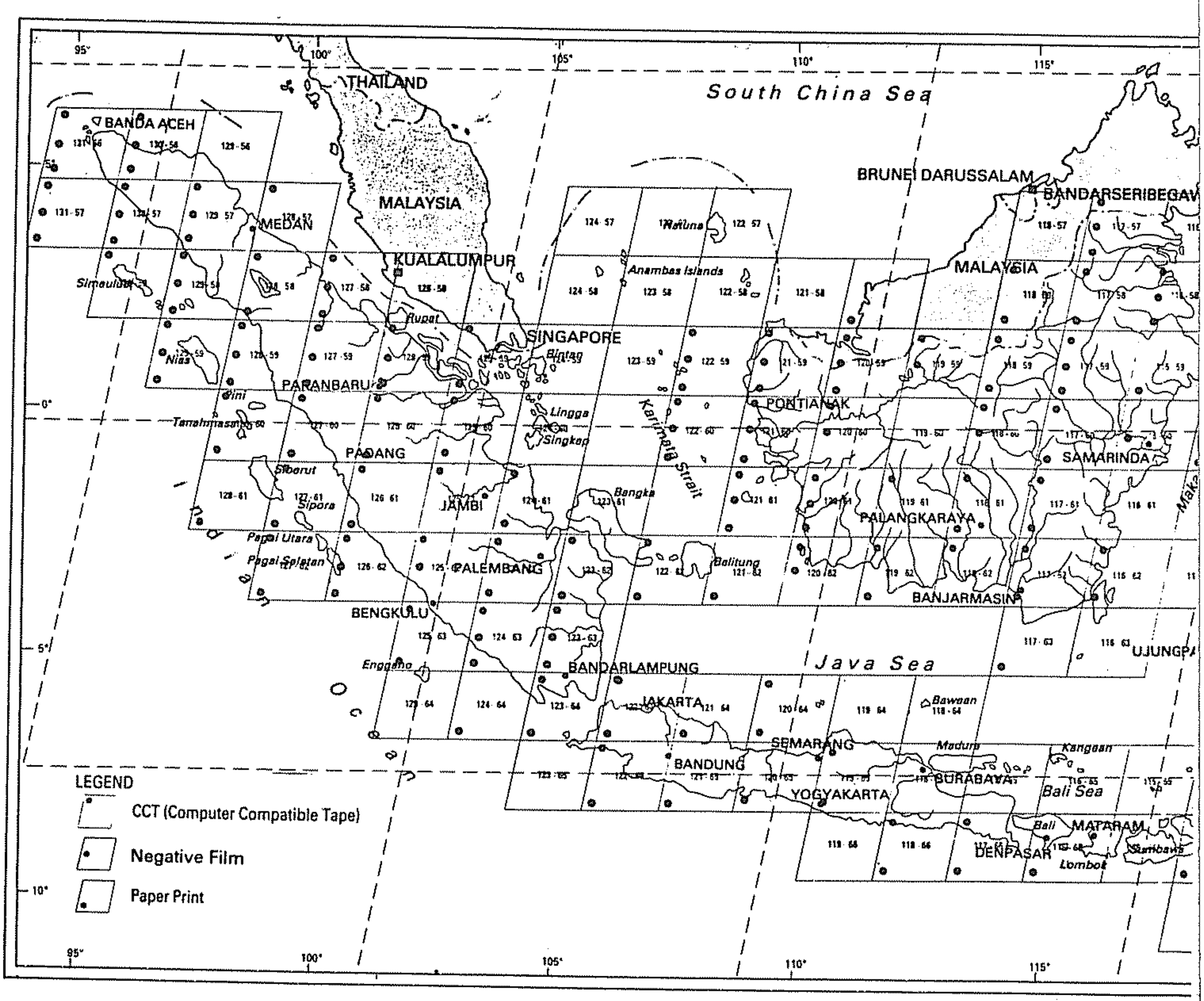
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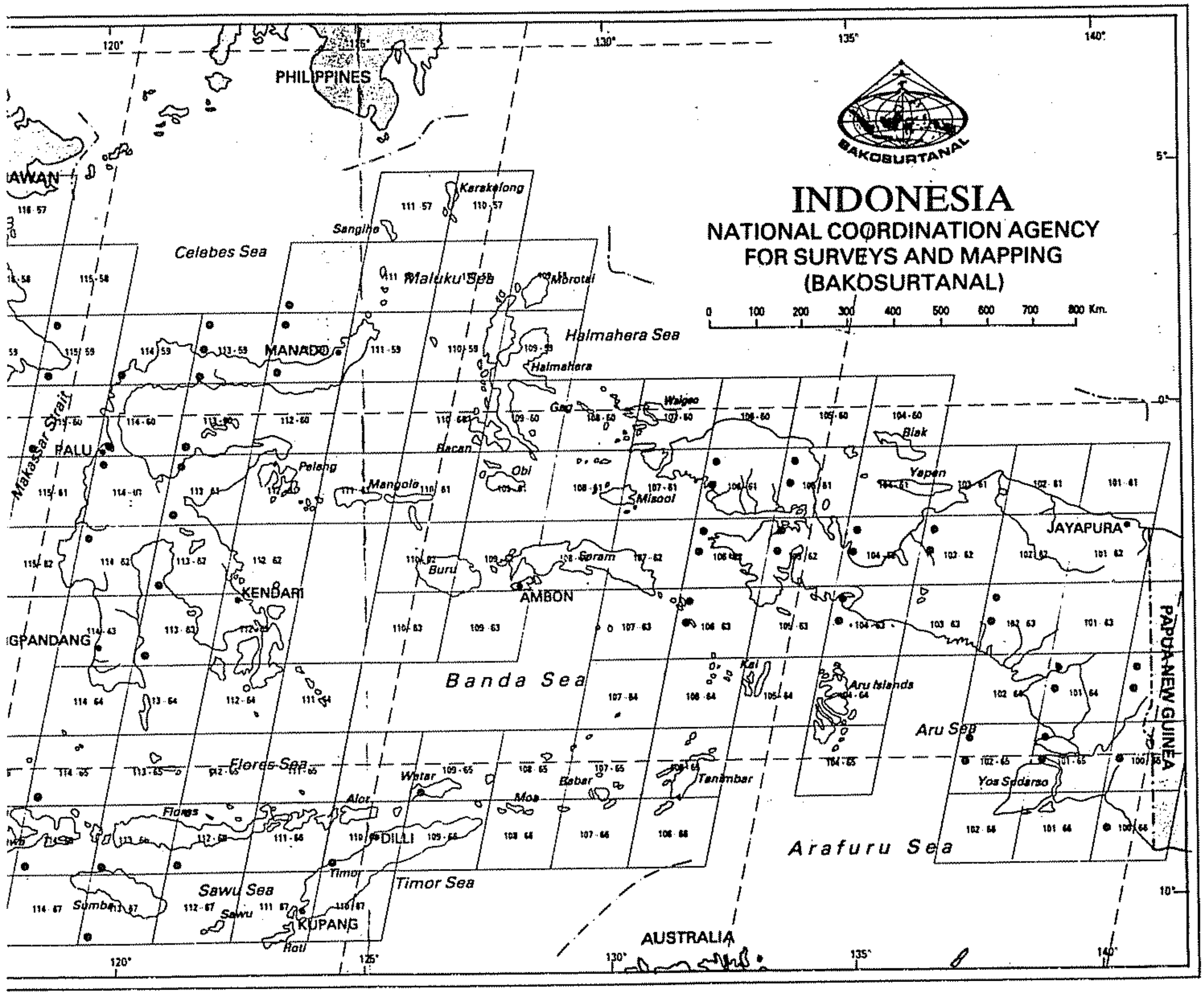
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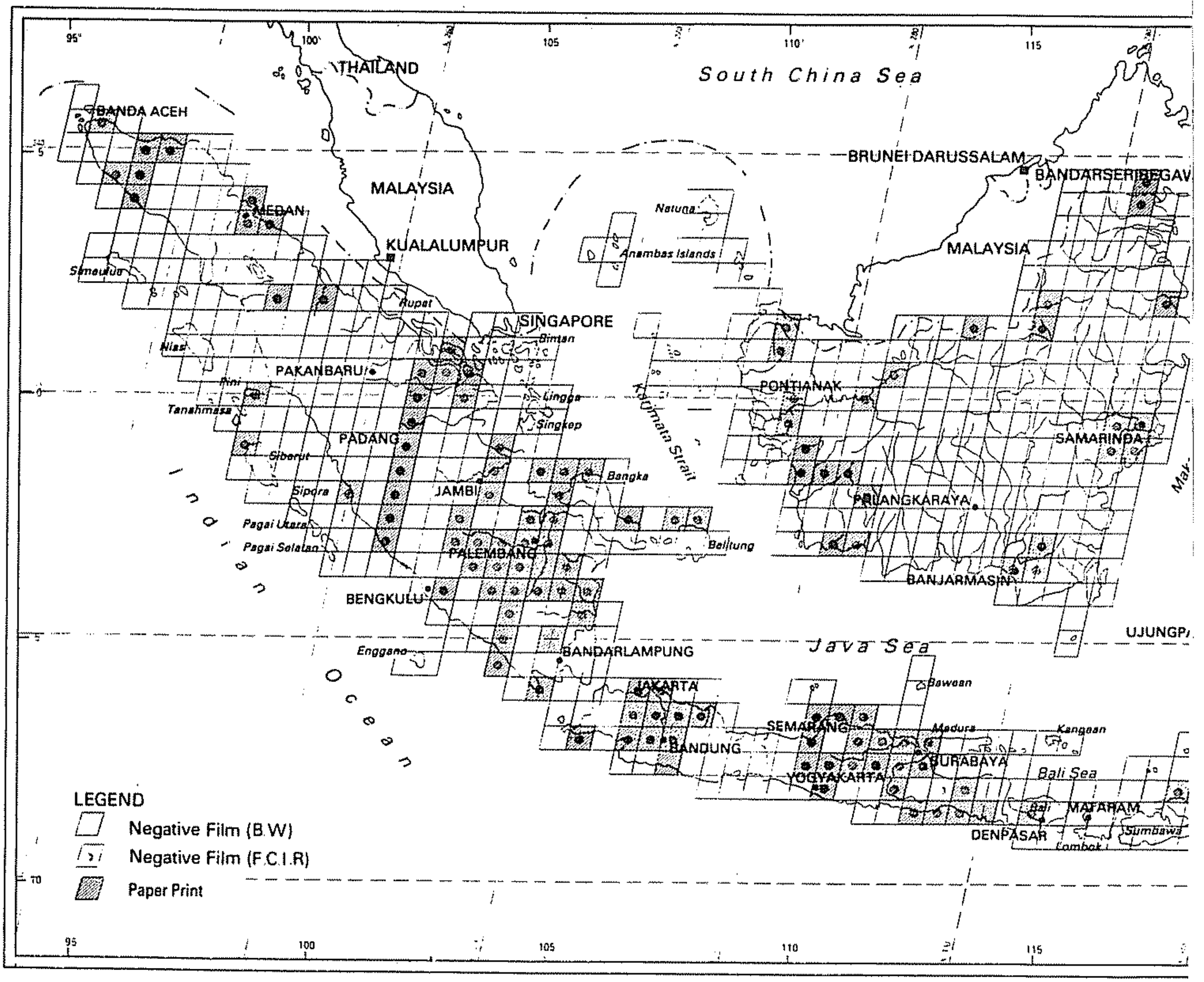
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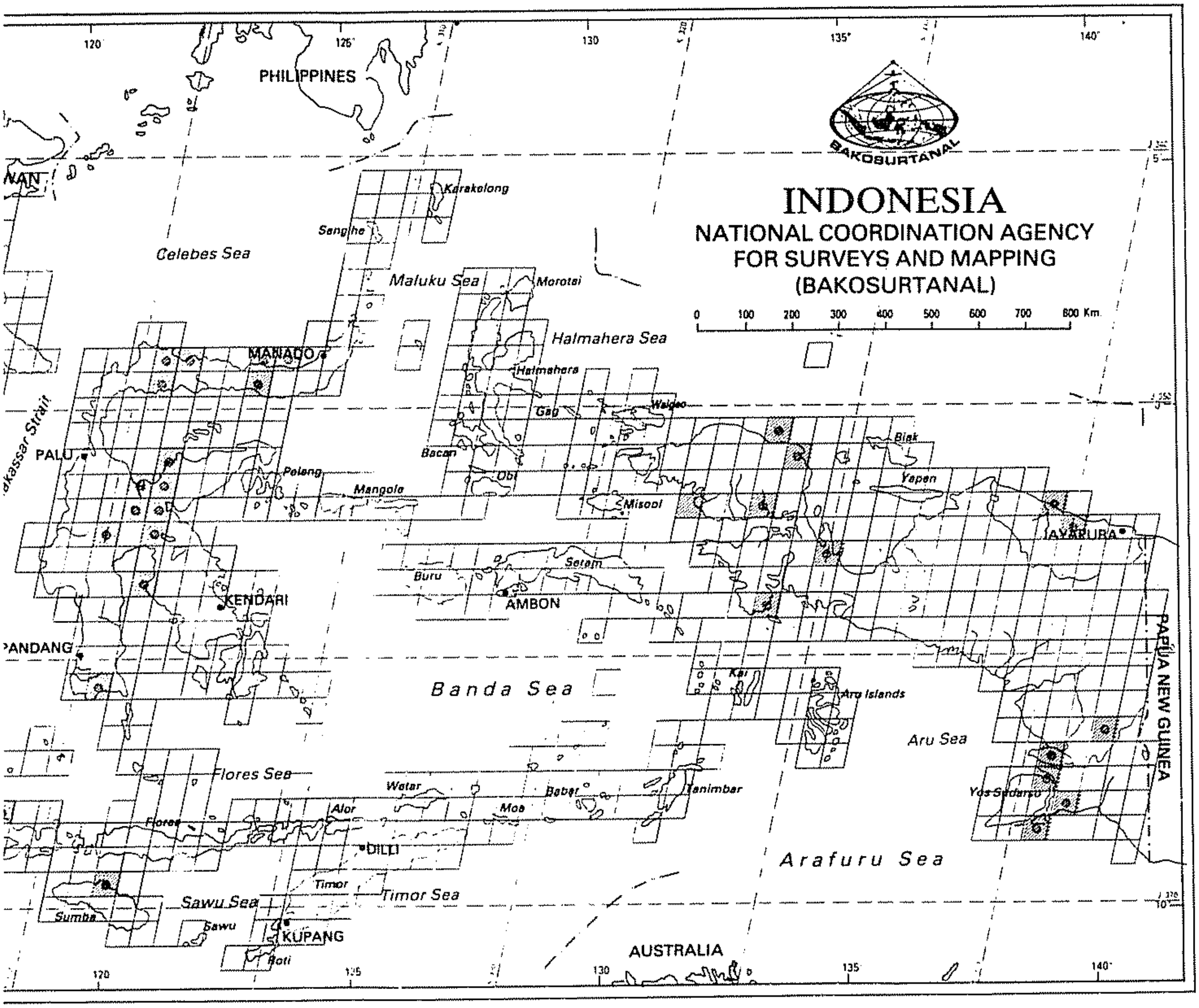
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a greater awareness at BAKOSURTANAL of being in the information field (including mapping), and not only the mapping field.

This awareness in turn has led to the expansion of its mission from conventional topo-map production to the setting up of a geographic information network for land resource evaluation and physical planning, linking together other geo-information producing and using agencies (provincial planning agencies, etc).

In order to achieve this goal, BAKOSURTANAL had directed its activities to provide, among other things, image coverage of the entire territory, ranging from high altitude aerial photography and satellite imageries for the purpose of inventory of natural resources up to detailed surveys for topographic mapping.

## Review of data acquisition

During the last 20 years high altitude aerial photography, at 1:100,000 scale in black-and-white, covered the islands of Sumatera, Irian Jaya (partly), Maluku, Kalimantan (partly) and Sulawesi. The latter was covered with dual camera system with additional false colour infra-red photography at 1:60,000 scale. The islands of Java, Bali, the Lesser Sunda Isles (Nusa Tenggara Barat and Nusa Tenggara Timur) were covered with dual camera aerial photography at 1:60,000 black-and-white and 1:30,000 false colour infra-red, respectively.

For gap areas due to cloud, airborne SAR was taken, especially in the northern part of eastern Kalimantan and the central part of Irian Jaya. In addition to the existing aerial photo coverage of Sumatera, this island was also covered with SAR imagery for updating the information.

Aerial photography will still be the best source of information, especially at larger scales. For this reason, a new programme for aerial photography will be at 1:25,000 scale and larger to support a land management and cadastral database.

Kinematic GPS in aerial photography has been experimented with in 1990 in the area between Senggi and Wamena to support the road design between Jayapura and Wamena to break the isolation of this mountainous district (Kabupaten). Kinematic GPS was also used in the new aerial photography of Jakarta-Bogor-Tangerang-Bekasi (JABOTABEK) at 1:25,000 scale, for planning and monitoring the heavily developed region surrounding the Greater Metropolitan of Jakarta. This new technology has proven adequate to provide geometric control for the aerial photos taken, so that the provision of ground control will be minimal.

With the availability of LANDSAT imagery since 1972, Indonesia has made use of this technology to support resources inventory. Data were purchased from the EROS Data Center or through LANDSAT receiving stations in Bangkok or Alice Springs.

Since 1984, the National Institute of Space and Aeronautics (LAPAN) has operated a LANDSAT ground receiving station for multispectral scanner systems (MSS) data. However, owing to the limited size of the antenna, the area covered is limited to Sulawesi, while data for the eastern part of Indonesia are still dependent upon the Australian receiving station. There is a programme to upgrade the LAPAN station to receive thermatic mapping as well as SPOT data and move its location to a more central part of Indonesia, such as Pare-pare in Sulawesi.

The problem of cloud remains the constraint in utilizing the satellite data to best advantage. Statistics in the last ten years of sensing show the following:

| *Cloud Cover* | *Area Coverage* |
|---|---|
| *(percentage)* | |
| 0-10 | 3.18 |
| 0-30 | 10.87 |
| 0-60 | 21.06 |

With the availability of SPOT data, BAKOSURTANAL started to purchase them for national use, especially for forest inventory. A purchase contract was signed in 1988 with the Swedish Space Corporation to deliver 1,000 frames, either hard-copy or computer-compatible tape upon request. By the end of the contract in December 1990, only 645 frames have been accepted with cloud content less than 10 per cent.

With the launching of ERS-1 satellite which has radar capability, there is much higher hope that tropical areas such as Indonesia could be fully covered. Training in the application of radar image interpretation should be a pré-condition to optimizing the use of these data.

Maps 1 and 2 show the coverage of LANDSAT and SPOT data as at 1 January 1991.

## Remote-sensing applications in Indonesia

The short-term applications of remote-sensing data in Indonesia are towards increased knowledge and collection of information on the national territory. The results of those applications are meant to acquire accurate databases of resources usable for input to the geographical information system (GIS) in order to permit and accelerate development projects. The long-term applications are towards monitoring the environment and boosting the sustainable development of the country.

It is anticipated that the field of applications of remote sensing technology will be oriented towards the following fields:

| | |
|---|---|
| Agricultural sector | 15% |
| Land use planning | 10% |
| Forestry | 25% |
| Mapping | 20% |
| Water resources | 5% |
| Urban and civil works | 5% |
| Energy–geology–mining | 10% |
| Military | 10% |

A few examples of thematic uses of remote sensing imagery:

*Forestry*

National projects:
- National forest inventory
- Timber plantation development
- Reforestation
- Environmental impact assessment

Private companies:
- Obligation of mapping for concession holders

*Mapping/Cartography*

Topographic base mapping
Regular updating
Thematic mapping (land cover)

*Planning*
National projects:
Land use inventory and mapping
Integrated rural development

Transmigration second stage development
Environmental management
Regional
Needs of the provincial planning agencies (BAPPEDAs) for planning and monitoring

## (d) *Hydrologic surveying and nautical charting*

### INTEGRATED TOPOGRAPHIC SURVEY OF SHELF AREAS*

*Paper submitted by the Union of Soviet Socialist Republics*


### RÉSUMÉ

Les problèmes liés à l'étude et à l'exploration des fonds marins font l'objet d'une attention grandissante, notamment en ce qui concerne les zones de plateau continental à faible profondeur. Pour développer les études sur ce sujet, il faut faire des levés topographiques des fonds marins.

L'Entreprise aérogéodésique de Moscou partage l'expérience qu'elle a acquise dans les levés effectués au moyen de méthodes combinées (sondages et méthodes planimétriques, gravimétriques et magnétiques) afin de répondre aux divers besoins de la clientèle.


The tasks connected with the study and exploration of the sea bottom are gaining more and more attention; at present, specifically, those connected with small-depth shelf areas. Increase in shelf studies requires topographic survey of the sea bottom.

As a result of the shelf survey, topographic maps that will be a continuation of land maps can be produced. Such topographic maps will show bathymetric data, bottom vegetation, sea fauna and soils. Salinity and water temperature are also measured. These topographic maps are used for generation of navigational maps, study of specific water areas, geologic survey and design works, fisheries, building of various engineering structures etc. Thus the results of the on-shelf works can be used by geodesists, geologists prospecting mineral resources, navigators, designers of various hydrotechnical facilities, and mineral exploration, fishing and underwater cultivating companies.

Execution of sea geodetic works consists of the following:

(*a*) Correct on-sea positioning of points and sections previously marked in the projects (geological and geophysical observations, designed positioning of the vessel);

(*b*) Acquisition of navigational and geodetic data required for management of technological processes;

(*c*) Navigation of vessels and ships on the pre-set programme;

(*d*) Calculation of vessels coordinates during sea-works performance;

(*e*) Bathymetric measurements (points and profiles).

The following are required for topographic survey of shelf:

(*a*) Equipment carrier: a vessel;

(*b*) Measuring equipment: echo-sounder, water sound speed meter, thermometers, .

(*c*) Navigational equipment: systems of near- and far-range action;

(*d*) Qualified staff.

Technology of the work consists in regular coverage of the explored water area by sounding tacks. The distance between tacks, depending on the scale of survey and distance between the contour lines, may be from 50 to 1,500 metres.

The requirements of different branches of the national economy for topographic maps are very wide. In order to meet these requirements within the minimum period and with minimum expense there must be a reliable approach to the composition and merging of diversified types of survey work. The cost of vessels carrying equipment is a major kind of expense in shelf mapping.

The Main Administration of Geodesy and Cartography (GUGK) of the USSR has carried out multiple experimental and industrial projects on shelf survey, which allows conclusions to be made on techniques for integration of the survey. The following issues are common in shelf mapping:

(*a*) Development of coast and sea altimetric and planimetric networks;

(*b*) Determination of planimetric position of the points, depth sounding and obtaining of specific information for thematic maps;

(*c*) Level measurements.

Specific information for thematic maps includes the following types of surveys: gravimetric, magnetic, hydrometric, soils specific, bentos, hydro-biological, using divers, ecological investigations etc

An important stage of shelf topographic survey is the use of topographic scanning sonars, giving the possibility of surveying inter-tack intervals in laboratories located near to the worksite areas and avoiding extra tacks. Such survey can add geomorphological data to the topographic map.

The soil survey includes mapping of bottom sediments, bathymetric and hydrosonar survey. Detailed geomorphological survey of the sea bottom is carried out.

However, the experience proves that in integrated mapping it is feasible to carry out echo-sounding together with sonar survey. Also, analyses of sonar data, soils survey,

*The original text of this paper appeared as document E/CONF 83/L 18

photo and TV survey data must be done simultaneously with biological survey. That process of survey integration must include bentos survey, whose aim is fauna classification of the sea-bottom. Cartographic interpretation of bentos survey unites the bentos data collected from observation points, on which the specialist will draw countour lines closing specific fauna societies living on the bottom ground or inside it. Mapping of bottom life on the hydro-map has the same value as presentation of vegetation on land maps. That point unites the content of land and sea maps, and therein lies the main difference from navigational maps.

Thus, the various types of surveys, recorded on a common topographic base, give a practically complete image of the surveyed area.

As to the mapping of geophysical fields—gravitational and geomagnetic—these kinds of surveys make it possible to carry out, together with topographical survey and solution of the above-mentioned main geodetic mapping, an important economic task, which is to locate mineral deposits, first of all of oil and gas, by field anomalies.

The Moscow Geodetic Enterprise of the USSR has carried out such work in eastern Siberian, Okhotsky, the Caspian Sea and other sea-shelf surveys with very encouraging results. In this respect, recently remarkable progress has been made in preparing and organizing reliable analysis of performed surveys. The USSR is now covered completely by precise gravimetric survey. The combined models prepared in the USSR, owing to international gravimetric survey, are correct and reliable.

As a result of work performed, the following should be mentioned:

(*a*) The USSR has a national basic gravimetric network (NBGN), which determines the gravimetric system of the USSR independently of foreign systems and is reliably connected with the international gravimetric system. The USSR gravimetric system determines the level, scale and metralogical base for all types of gravimetrical works carried out in the USSR for economic (deposits prospecting) and scientific (geodynamics studies and modifications of the gravimetric field of the Earth) purposes;

(*b*) Gravimetrical national network of first order was created in the USSR: this unique geodetic formation has no analogy in the world comparable in measurement accuracy, surface coverage and signalization of the points. The first-order network permits development of total gravimetrical survey of the country;

(*c*) Gravimetrical survey of Far East seas and separate water areas of the Pacific Ocean was carried out; also gravimetric survey of the Arctic. This allowed accurate calculation of altitudes of geoid, and plumb deviation on vast territories of the USSR and in intermediate coastal waters and ocean-bottom areas.

An important stage of gravimetric survey in the Arctic is the integration of gravimetric and magnetic surveys carried out by the Moscow Airgeodetic Enterprise on the Navosibirsky Islands. That survey yielded the necessary data for independent aircraft navigation and indicated the correlation of anomalies of gravimetric and geomagnetic fields. The high quality of gravimetric and magnetic surveys on the Novosibirsky Islands, as judged by experts from the Ministry of Geology of the USSR, is a sound basis for beginning prospecting work on the islands, as well as for continuing this kind of survey there.

Development of gravimetric work for the exact calculation of the Earth's gravimetric field and pre-calculation of satellite tracks has a bearing on a number of geodetic tasks, such as:

(*a*) Reduction of angle changes of the astronomic and geodetic networks of the USSR (similar works abroad have been done only in the United States), preparation of gravimetric maps which, jointly with topographic maps, allows calculation of FAI anomalies (sheets $5' \times 7'.5$) and deviation of plumb (0.5″-1.0″ for plane areas and 2″ for mountains)

(*b*) Calculation of the altitudes of quasi geoid by astronomic and gravimetric levelling for the whole USSR territory and determination of elements of orientation of Krassovsky ellipsoid relative to the general Earth ellipsoid.

Data from different kinds of gravimetrical survey are used for geological investigations. Small-scale surveys detect the areas for detailed studies. The results of detailed surveys by maps of 0.05-0,5 mgal distance can be used for study of oil and gas prospective areas, detection of possible deposits of ferrous, non-ferrous and rare-earth metals, and exploration of huge deposits of minerals. Determination of points of higher density allow coordination and unification of all national surveys.

As the temporal changes of gravimetric force on the shelf are very small, gravimetric survey data can be considered as the basic data to be used by customers at any time. For this reason, it is feasible to perform these works constantly; also it is connected to the fact that determination of gravimetric Earth field parameters must be carried out every 7-8 years. So the importance of tasks that can be solved by gravimetric data is evident.

The Moscow Airgeodetic Enterprise has powerful facilities and large amount of different gravimetric and navigational equipment. The Enterprise can carry out all kinds of gravimetric work and shelf survey. The work is done by qualified staff and the data are processed in a gravimetric laboratory with highly experienced personnel.

The Enterprise can assist anybody interested in integrated studies of shelf and the Earth's gravitational field.

## APPLICATION OF REMOTE SENSING DATA IN STUDIES OF NATURAL RESOURCES AND MAPPING*

*Paper submitted by the Union of Soviet Socialist Republics*


### RÉSUMÉ

L'URSS a acquis une vaste expérience en ce qui concerne l'application des techniques de télédétection à la surveillance des ressources naturelles et de l'environnement ainsi qu'à des fins cartographiques. Les images satellite soviétiques sont reconnues par la communauté internationale comme étant les meilleures du monde sur le plan de la résolution (5 mètres). Le rapport porte sur l'utilisation intègre des images spatiales; les services et activités d'exportation de SOYUAZKARTA, le seul distributeur de données de télédétection soviétiques; les différents types de matériel exportés par SOYUZKARTA; et les activités de cartographie menées à l'étranger.


The problems of food supply, energy and ecology are increasingly important among the issues that arise in the constantly developing world of today. The growth of population, and the consequent need for food supplies, increased power consumption and atmospheric and hydrospheric pollution worry scientists and Governments of many countries, and indeed, the ordinary people of the world, as they see a growing danger of ecological crisis. These problems can be solved by effective application of the results of scientific and technical progress. Natural resources studies and human environment control through remote sensing can be considered as among the most important directions of scientific progress.

When compared with traditional land and air survey methods of study, remote sensing enables programming in advance of image specifications of areas with regard to scales and spectral bands; reduction of expense in obtaining and processing initial data; and guarantee of a combination of large-area coverage and identification of final data bulks.

The Soviet experience shows that remote-sensing data can be successfully used in 300 different scientific and economic fields. The Soviet space system supplies satellite data for more than 1,000 organizations and ministries. Yearly customers receive up to 1 million images, which can be applied in planning of economic development and nature management of great territories; environment control; hydrometeorological forecasts; minerals and under-soil deposits prospection; assessment of agricultural resources, land and forest cadastre; estimation of water reserves and hydraulic resources; evaluation and determination of areas classified by mudflows, avalanches and seismic hazard; design of huge construction and hydrotechnical projects, railways and roads, oil and gas pipelines; off-shore investigations, sea and ocean studies; location of biologically productive areas, and places promising for fishery; and map compilation and updating, specifically for areas of difficult access (for example, Antarctica, high mountains, Amazonia, etc.).

The Soviet Union has considerable experience in application of remote-sensing data in all the above-mentioned activities. Some brief examples are specified below.

Geological interpretation of spectrozonal space images over the eastern coast of the Caspian Sea identified 66 structures promising for oil and gas deposits, including 10 structures on the sea bottom up to 15 m depth. At the same time, more than 30 big fractures with polymetallic deposits were found.

The best results in hydrogeological interpretation give application of non-direct features.

In the semi-desert areas of Central Asia, significant reserves of sweet water covered by moving sands were found. Drilling confirmed the availability of water which can be used for pasture purposes.

The early space location of forest fires, specifically in underpopulated Siberia, makes it possible to protect timber resources, reduce air pollution, provide for ecological balance etc. Space data can be practically applied for forest mapping, elaboration of projects of forest exploration and reproduction and early identification of diseases and insects.

Space images allow the study of sea-bottom relief, its geological structure, vegetation areas, currents, water pollution etc. In favourable illumination conditions and water transparency, images of the bottom up to 30 m depth can be obtained.

Space images are widely used for design of large hydrotechnical facilities, high dams in the Caucasus and Pamir and construction of oil and gas pipelines in hardly accessible and swampy regions of western Siberia.

Nowadays the mapping of the whole territory of the country has been concluded at scales 1:25,000, 1:50,000 and smaller. The compilation of maps for the eastern regions, the high mountains of Pamir and Tiang Shiang was made with application of remote-sensing images. The updating of topographic maps is done now through application of well-tried technology by survey data of cameras KFA-1000 and MK-4 which have high resolution. Space surveys are considerably more efficient compared to air survey (three or four times more so, depending on the area). One image of the MK-4 camera simultaneously covers an area of 330 sq km, equal to 110 sheets of map at scale 1:50,000. One image of the KFA-1000 camera covers 500 sq km, corresponding to 20 sheets of map at scale 1:50,000. The scope of field-work is considerably reduced as the images of similar objects are identically illuminated and have equal optical density, which makes it easily possible after interpretation of the first object to find analogous objects over the total image area.

It is possible, in these conditions, to computerize space image interpretation and mapping processes.

Soviet cartography promptly and reliably contributes to exploration of the western Siberian industrial complex, oil and gas prospecting in the west and the north and construc-

*The original text of this paper, prepared by M. V. Piskulin. SOJUZKARTA, Moscow, appeared as document E/CONF 83/L 19 tion of long pipelines and hydropower stations, thus overcoming the problems of the Caspian and Aral seas and others.

Attention may be drawn to the following figures. By United Nations estimations, African and South American countries are only 30 per cent covered by topographic survey at scale 1:50,000. A quarter of a century will be needed for mapping at this scale by traditional methods. The annual portion of available maps updated amounts to only 2-3 per cent.

The case of maps at scale 1:25,000 is even worse—1.5 per cent in Africa and 6.7 per cent in South America. United Nations experts think that compilation of these maps will take 135 years.

Taking into account that most natural resources investigations in any field require that the results be presented on a map, cartographic issues are of prime significance to any country. High-resolution space images with stereoscopic processing possibilities can speed up mapping by simultaneous natural resources studies.

The Soviet foreign economic association SOJUZKARTA is the sole exporter of remote-sensing data.

For the most efficient application of remote-sensing data we offer relevant consultations and vocational training to customer specialists on the different trends of space information usage.

SOJUZKARTA in its activities firmly follows the principles relating to remote sensing of the Earth from outer space adopted by the General Assembly in its resolution 41/65 of 3 December 1986. Strict observance of these principles is agreed upon by SOJUZKARTA and its customers when they purchase the data.

SOJUZKARTA represents on the foreign market the Soviet geodetic services, General Administration for Geodesy and Cartography (GUGK). This Administration consists of 3 research institutes, 25 topographic and geodetic regional services, 3 geodetic and photogrammetric tools-producing plants and 10 cartographic factories. Soviet geodesists and cartographers have made and compensated an enormous astronomic-geodetic and levelling network of high accuracy and have mapped the whole country at scale 1:25,000.

Hundreds of specialists from GUGK are working in Asian, African and Latin American countries, rendering technical assistance in developing national geodetic services, carrying out topographic, geodetic and air survey and cartographic works.

In the last years important works were finalized in Angola, Afghanistan, the Islamic Republic of Iran, Cuba, Nicaragua, Mozambique, Mongolia, Viet Nam, Yemen, the Libyan Arab Jamahiriya, Ethiopia and other countries.

The work is done by large missions, up to 100 men each, equipped with modern air survey craft, helicopters, powerful transport facilities, and necessary geodetic instruments and equipment.

In addition, SOJUZKARTA performs geodetic works for construction and prospection operations and geodetic and mining support of geological and mineral extraction works; it carries out topographic survey of off-shore areas, lakes and seas and surveys underwater communication lines; renders know-how and engineering services and sells technology and software for geodesy and cartography.

The Association can export for remote-sensing data-processing the following instruments, which are not available from any other company:

| | |
|---|---|
| CONTACT-1 | Contact printing and composite device |
| CPM-1 | Multiband composite projector |
| PC-1 | Composite device for compositing multispectral images with fivefold enlargement |

SOJUZKARTA offers a large variety of geodetic tools: technical theodolites, medium and high accuracy theodolites, astronomic universal tools, distance meters, electronic tacheometers, all kinds of levels, pipefinders, geodetic tools, photogrammetric equipment, gravimeters.

SOJUZKARTA yearly exports many different cartographic products: maps, atlases, globes, relief maps, including special, educational and tourist maps, made with application of remote-sensing data. Maps and atlases are edited in Russian, English, German, French and Spanish. Upon desire of the customer, several maps can be published in the language of the customer's country.

The world knows the highly informative content of Soviet maps and atlases (for example the Large World Atlas). In the near fiture a detailed plan of Moscow (scales 1:38,900 and 1:15,000 of the central part) will be published in English, German and French.

SOJUZKARTA, based on scientific and industrial potentialities of the Soviet geodetic services, is ready to perform the above-mentioned work anywhere in the world, at high quality and in good time.

For implementation of large-scale projects, SOJUZKARTA cooperates with scientists and experts from the Soviet Ministry of Geology, the Water Management Ministry, the National Hydrometeorology Committee, the General Space Organization, the Academy of Science, and other bodies.

Nowadays, SOJUZKARTA has agency agreements with companies from the United States, Australia, Japan, China, Peru, Argentina, Brazil etc.; and is dealing on this matter with Belgium and Great Britain. Scientific and business people from Great Britain and Europe can widely use our space images, specifically for implementation of large joint projects in developing countries.

It is hoped that the present meeting will result in a widening of dialogue between eastern countries and the USSR and that relations in the field of science and technology, particularly, in the practical application of remote-sensing data, will play an important part in developing cooperation between the Soviet Union and Thailand.

# STATUS OF HYDROGRAPHIC SURVEYING AND NAUTICAL CHARTING IN ASIA AND THE PACIFIC*

*Paper submitted by the International Hydrographic Bureau*


## RÉSUMÉ

Pour l'Organisation des NatiorsUnies, l'Organisation hydrographique internationale (OHI) fait office de centre de liaison et fait autorité en ce qui concerne les travaux hydrographiques sur les plans international et mondial. L'ONU a demandé à l'OHI d'établir et de tenir à jour un rapport sur l'état de l'hydrographie dans le monde. La présente communication résume les conclusions de ce rapport en ce qui concerne la région de l'Asie et du Pacifique.

Il ressort clairement de l'étude la plus récente sur la question que l'état de l'hydrographie dans le monde n'a que très peu progressé au cours de la décennie écoulée. La très grande majorité des pays en développement ne disposent guère, voire nullement, de moyens techniques adéquats; or, le manque de levés et de cartes marines est considéré comme une entrave sérieuse au commerce maritime et aux activités connexes telles que la pêche et l'exploitation de ressources non renouvelables.

Dans la région de l'Asie et du Pacifique, l'état des levés hydrographiques est sensiblement le même que dans le reste du monde. Des 52 pays côtiers de la région, 17 (soit 22 %) ne disposent pas de moyens techniques propres; 19 autres (soit 16 %) disposent de quelques moyens; seuls les 16 restants (31 %) disposent de capacités techniques suffisantes ou importantes. L'on a dressé la liste des 17 pays côtiers qui sont les plus démunis en ce domaine, suivis de 13 autres dont les moyens sont quelque peu moins déficients. C'est à ces Etats qu'il faudra en priorité accorder une aide extérieure. C'est en Asie que se trouvent 3 des 8 zones maritimes pour lesquelles les cartes marines sont jugées des plus insuffisantes. De même, c'est dans la région de l'Asie et du Pacifique que se situent 7 des 10 zones qui ont été signalées au Bureau hydrographique international (BHI) par les organisations maritimes non gouvernementales comme nécessitant l'établissement de cartes à plus grande échelle ou de levés plus détaillés.


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The United Nations recognizes the International Hydrographic Organization (IHO) as the one focal point and source of authority on matters associated with international and world hydrography. The IHO was solicited as a consultant and advisor when the first comprehensive report on the status of hydrography worldwide was made and presented to the Sixth United Nations Regional Cartographic Conference for Asia and the Far East, in Teheran in 1970. Since that time, the IHO has been asked on several occasions to prepare similar reports, of which the most recent one has been under preparation during the last two years, to be printed and distributed in early 1991 as IHO publication SP-55. A preliminary version of the report was presented to the fourth United Nations Regional Cartographic Conference for the Americas, held in 1989.

The most obvious conclusion to stem from this recent study is that, despite earlier recommendations made in the previous reports, there has been little significant improvement in the status of the developing coastal States, where the lack of adequate surveys and nautical charts is seen as seriously retarding their socio-economic progress, as is described in the report of IHO activities under agenda item 4.

The following is a summary of conclusions in publication SP-55, with special regard to the findings concerning Asia and the Pacific. It should be underlined that some of the figures are based on a limited sampling.

### FINDINGS IN IHO REPORT SP-55

In general, the status of hydrographic surveying and nautical charting in Asia and the Pacific differs not significantly from the situation worldwide. The overall status is probably somewhere in the range of from "poor" to "fair". Major maritime nations are in the "satisfactory" range level of hydrographic adequacy, but it is the developing nations that are being adversely handicapped by the lack of adequate data and charts. Hydrographic capability is poor or totally lacking in a large majority of developing countries: this is a clear statement of the problem that confronts international hydrography and the United Nations

The ability of developing coastal states to improve their economy is highly dependent upon marine commerce. Adequate hydrographic surveys and nautical charts that permit the safe transit of ships to and from ports are among the basic requirements for economic development. While no significant increases in the overall size or draught of world shipping are envisaged, developing countries, particularly, may need to prepare to cater for deeper draught vessels than previously handled if port facilities are improved.

The International Maritime Organization (IMO) accepts responsibility for the regulation of maritime shipping routes in order to improve safety of navigation. The IMO recommends the adoption of national traffic separation schemes (TSS) and deep water routes (DWR), requiring that these waters be adequately surveyed and charted before they are brought into force. World maritime States without a hydrographic capability are therefore prevented from submitting TSS and DWR, in order to protect their coasts from possible

*The original text of this paper appeared as document E/CONF 83/L 4.

marine pollution, unless they can provide evidence of their waters having been adequately surveyed. Economic pressures have forced shipping companies to accept much lower underkeel clearances in recent years, and underkeel clearances of less than five metres are not uncommonly accepted.

Hydrographic data and charts are also pre-requisites for the exploitation and management of maritime resources and for the exercise of the exclusive rights to vast sea areas which coastal States are granted through a series of United Nations Law of the Sea conferences. A great number of States have still to delineate the extent of their exclusive economic zone and their continental shelf. The present definition of the juridical continental shelf is highly complex and will require detailed bathymetric and geophysical surveys in order to delineate its outer limits, when these extend beyond 200 nautical miles from the baselines.

### *Surveying and charting capability assessment*

Approximately 32 per cent of the world maritime States have no national hydrographic capability. Approximately 40 per cent have some, but only about 28 per cent fall into the category of having adequate to fully developed capabilities. The corresponding figures for the 52 coastal States of Asia and the Pacific show that 17 States (33 per cent) have no national capabilities, 19 States (36 per cent) are in the group of having some capabilities, while 16 States (31 per cent) have reasonably adequate to fully developed capabilities. The study identifies that the 35 coastal States of the Asian region, in all, dispose of 124 ships and 106 boats designated for hydrographic surveys, with only 9 ships and 16 boats shared between the 17 maritime nations in the Pacific region.

A total of 50 coastal nations worldwide were (in December 1988) assigned the lowest surveying and charting capability. Seven of these are in the Asian region:

- Brunei
- Iraq
- Jordan
- Maldives
- Qatar (small survey unit now operational)
- United Arab Emirates
- Yemen

Nine States are in the Pacific region:

- Kiribati
- Marshall Islands
- Micronesia
- Northern Mariana Islands
- Palau
- Papua New Guinea (relies on cooperative plan with Australia)
- Samoa
- Tonga (action now started to form a capability)
- Tuvalu

These nations should be given priority when international organizations and other countries are considering development programmes or other kind of assistance.

In addition to these, there are 11 States in Asia and two States in the Pacific which were assigned the next lowest rating. These States should also be considered as prime candidates for hydrographic support:

In the Asian region:

- Bahrain (survey unit now operational)
- Bangladesh
- Democratic Kampuchea
- Islamic Republic of Iran (some work completed by contract)
- Kuwait
- Lebanon
- Oman (survey unit now being formed)
- Saudi Arabia (contract surveys completed)
- Sri Lanka
- Syrian Arab Republic
- Viet Nam

In the Pacific region:

- Solomon Islands (survey unit now operational)
- Vanuatu (survey unit being formed)

### *Surveying and charting assessment*

Of an area of 97 million sq km* worldwide studied by the report, only 29 per cent is considered adequately surveyed, 22 per cent requires resurveying and 49 per cent is classified as inadequately or not surveyed. The corresponding figures for the Asian region indicate that 30 per cent is adequately surveyed, 34 per cent needs resurveys, and 36 per cent is considered inadequately or not surveyed. For the Pacific region, only 17 per cent is considered adequately surveyed, while 11 per cent needs to be resurveyed, and as much as 72 per cent is considered inadequately or not surveyed.

While the figures above indicate a regional status for Asia much in line with those for the overall status worldwide, it should be noted that the south-central/western Pacific is listed as one of three large major regions of hydrographic deficiency. Three of the eight world maritime areas assessed as having the most inadequate nautical charts are found in the Asian region:

- Jordan
- Paracel Islands
- Spratly Islands

Furthermore, seven of a total of the specific areas worldwide identified to the IHB by non-governmental maritime organizations as requiring larger-scale charts or more detailed surveys than are currently available belong to the Asia and Pacific region:

- Gulf of Oman
- Northern Arabian Gulf (excluding Kuwait and Kharg Island)
- Strait of Bab el Mandeb
- South China Sea
- Gulf of Papua
- One Fathom Bank (Malacca Strait)
- Java Sea (selected areas)

*Area estimates were available for only 81 per cent, approximately, of the world's maritime exclusive economic zones.

# OCEAN MAPPING ACTIVITIES OF THE INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION*

*Paper submitted by the Intergovernmental Oceanographic Commission*


## RÉSUMÉ

La grande majorité des données bathymétriques existantes et encore utilisées actuellement sont de qualité médiocre au regard des normes modernes. Lorsque la position d'un navire n'est pas déterminée avec certitude, la précision des isobathes s'en ressent.

La COI s'occupe de cartographie marine depuis que l'Assemblée générale des Nations Unies a approuvé, dans sa résolution 2560 (XXIV) de décembre 1969, le Programme élargi et à long terme d'exploration et de recherche océaniques.

La COI, qui travaille en étroite collaboration avec l'Organisation hydrographique internationale, coordonne les actions menées au plan international supplémentaires dans certaines régions, et prépare et imprime des cartes bathymétriques destinées à tous les utilisateurs.

Les spécifications et les légendes de toutes les cartes bathymétriques préparées sous l'égide de la COI répondent à une norme commune. Ces cartes sont toutes conçues de manière à répondre aux critères suivants :

*a*) Etre claires, simples et faciles à lire;

*b*) Donner des renseignements exacts et complets sur la topographie des fonds;

*c*) Donner les valeurs les plus détaillées et les plus précises possible sur la profondeur en un point quelconque de la feuille.


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The bottom of the world's oceans covers more than two thirds of the surface of the globe, and its relief is more complicated than that of the land because it is less subject to changes wrought by erosion. Besides this, the oceanic crust is much younger than continental blocks and is not so thick. For these reasons the roughness of the ocean bottom is more strongly expressed.

The latest technological achievements in cartography on land, particularly the use of remote sensing, cannot be applied to the development of marine cartography because of the impenetrability of ocean water masses by light beams. This is why at the present time the topography of the seafloor is not as well known as the topography of the far side of the moon.

But the need for exploitation of ocean resources increases each year, and requires careful regulation, based upon a detailed knowledge of the marine environment.

One of the first and most important steps in the exploration of the oceans is the preparation of bathymetric charts showing the topography of the ocean bottom in as much detail as possible. For this reason, ocean mapping has made considerable progress in recent years and has become one of the major activities of the Intergovernmental Oceanographic Commission (IOC).

For compilation of bathymetric charts a knowledge of the measured depth alone is not enough. Knowledge of the geomorphology, geology and sedimentology of the seafloor is also essential; for this reason the involvement of the IOC scientific community is extremely important. On the other hand, the production of bathymetric charts can also be a stimulus to the research of many marine scientists because the topography of the seafloor strongly influences physical, chemical and biological processes, especially in the near bottom layers.

The great majority of existing bathymetric data still in use today is of low quality by modern standards. Uncertainties in the determination of a ship's position limit the accuracy of the isobaths.

The IOC, working in close collaboration with the International Hydrographic Organization (IHO), coordinates international efforts to archive all existing available data, to undertake additional investigations in some regions, and to compile and print bathymetric charts to meet the needs of all types of ocean users.

All bathymetric charts compiled under the aegis of the IOC are prepared to a common standard in regard to cartographic specifications and legends. They are all designed to meet the following requirements:

(*a*) Simple, easy to read, clear;

(*b*) Provision of correct and comprehensive information on the bottom topography;

(*c*) Provision of the most detailed and accurate value available for the depth at any point on the sheet.

In recent years, many national and international organizations have taken on the task of compiling charts for various ocean regions. In certain cases this has been undertaken principally to facilitate the exploitation of particular ocean resources. The IOC's aim is to ensure a planned approach to the long-term mapping of the world seabed, not only to meet current needs but in the perspective of the long-term development of ocean sciences and services.

In general, for any given ocean region a bathymetric chart is first compiled which serves as a base chart; following this, geological and geophysical maps (overprinted on the base chart) are prepared. The same base chart can also be used for the compilation of charts showing the distribution and circulation of water masses and of living and non-living resources.

The IOC has been active in ocean mapping since the United Nations General Assembly endorsed, by its resolution 2560 (XXIV) of December 1969, the Long-term and Expanded Programme of Oceanic Exploration and Research (LEPOR). In 1970 compilation of the *Geological/Geophysical Atlas of the Indian Ocean* was started (pub-

*The original text of this paper appeared as document E/CONF 83/L 33

lished in 1975) in order to compile in map form the findings of the International Indian Ocean Expedition (IIOE). In 1972 the IOC and IHO agreed to co-sponsor the production of a new edition of the *General Bathymetric Chart of the Oceans* (GEBCO). The GEBCO (5th edition), published in 1982 by the Canadian Hydrographic Service (on behalf of IOC and IHO), consists of 19 sheets depicting the bathymetry and morphology of the world's oceans. This series takes advantage for the first time of the development of new concepts of global tectonics and modern navigational systems.

In 1973, following IOC resolution VIII-11, a group of experts was set up to prepare a large-scale bathymetric base chart of the Mediterranean and Black seas. With the cooperation of the IHO, national hydrographic services and individual scientists, the first edition of the *International Bathymetric Chart of the Mediterranean* (IBCM) was printed and published by the Head Department of Navigation and Oceanography, Leningrad, on behalf of the IOC, in 1982. IBCM geological-geophysical series are in the course of preparation.

The IOC has now set up an effective structure of subsidiary groups and editorial boards for its ocean mapping programme. The activities of the various groups are described in the remaining sections of this paper.

## The Consultative Group on Ocean Mapping

At its seventeenth session, in January-February 1984, the IOC Executive Council established the Consultative Group on Ocean Mapping (CGOM), as it had become apparent that there was a need to have within the structure of the IOC an appropriate advisory body, formed of highly qualified scientists in the field of ocean mapping and related activities, to act as an overall technical mechanism linking together the diverse ocean mapping projects with which the Commission is involved.

The CGOM is composed of the chairmen of all the supervisory groups and editorial boards of the Ocean Mapping projects sponsored or co-sponsored by the Commission. It meets to discuss current developments and reports biennially to the IOC Assembly.

## General Bathymetric Chart of the Oceans

The General Bathymetric Chart of the Oceans (GEBCO) was initiated at the beginning of the century by Prince Albert I of Monaco. The first edition was published in 1903. The success of the chart inspired scientists to continue preparations for further editions. By 1972, four editions had been either completely or partially published, but then, following a strong recommendation from the Scientific Committee on Oceanic Research (SCOR) on content and general requirements, the IOC and the IHO agreed to co-sponsor an entirely new (fifth) edition, to be compiled by marine scientists, incorporating the best available bathymetric data and employing the latest geological and geophysical knowledge of the structure of the seafloor.

A Joint IOC-IHO Guiding Committee for GEBCO was established, consisting of 10 members, 5 nominated by IOC and 5 by IHO. The IOC experts are nominated after consultation with the Scientific Committee on Oceanic Research (SCOR), the International Association for the Physical Sciences of the ocean (IAPSO) and the Commission for Marine Geology (CMG). The IHO experts are selected from volunteering hydrographic offices (VHOs).

With such close collaboration between scientists and hydrographers, the fifth edition of GEBCO was completed by 1982; it consists of 16 sheets on Mercator projection at a scale of 1:10 million (at the equator); 2 sheets on polar stereographic projection at a scale of 1:6 million (at 75° latitude); and, published in 1984, the World's Oceans in one sheet, on Mercator projection at a scale of 1:35 million (at the equator) with the polar regions at a scale of 1:25 million (at 75° latitude).

A GEBCO Sub-Committee on Geographical Names and Nomenclature of Ocean Bottom Features was set up at the same time as the Guiding Committee to oversee the standardization of nomenclature used for ocean bottom features, together with their geographical names. In late 1988 a *Gazetteer of Geographical Names of Undersea Features,* as shown (or which might be added) on the GEBCO and on the IHO small-scale International Chart Series, was published in English and French. This incorporates the English/French version of a publication *Standardization of Undersea Feature Names;* English/Russian and English/Spanish versions have been published separately. English/Chinese, English/German, English/Japanese and English/Portuguese versions are in preparation.

The Guiding Committee has concluded that the future of the GEBCO lies with the development of a continuously updated digital bathymetric contour database, together with appropriate subfiles. Products from the database are marketed using current technology, and a new edition of the traditional GEBCO printed map series will be published from time to time as appropriate, and when funds permit.

This database, which will be easily accessible and user friendly, has now been named the *GEBCO Digital Atlas.* Initially it will consist of a collection of digitized bathymetric contour maps of the world's oceans, with sub-files for track control, and a gazetteer of undersea feature names. Later, it is planned to add a digital terrain model and/or a gridded data set, and to create a CD-ROM for use on personal computers (PCs).

Magnetic tapes of digitized bathymetric contours of certain regions are already available, and the *GEBCO Digital Atlas* is expected to be fully operational by mid-1991 (see annex I). A new 6th edition of the GEBCO traditional printed paper chart is now scheduled for publication in 1995.

## International geological/geophysical atlases of the Atlantic and Pacific Oceans

The *Geological/Geophysical Atlas of the Indian Ocean* (GAPA) was published in 1975, under the overall supervision of the IOC, to bring together all data collected during the International Indian Ocean Expedition (1959-1965).

Further atlases in this series consist of an Atlantic Ocean atlas (published in 1990) and a Pacific Ocean atlas (in preparation and scheduled for publication by the end of 1993). The numerous maps therein of various parameters are being compiled by eminent marine geologists and geophysicists working in leading scientific institutions throughout the world. (See annex II (*a*)-(*c*).)

## International Bathymetric Chart of the Mediterranean and its geological/geophysical series

The International Bathymetric Chart of the Mediterranean (IBCM) was the first IOC regional mapping project. It was initiated in the early 1970s by scientists participating in the joint IOC/ICSEM/FAO Cooperative Investigations in the

Mediterranean (CIM), and it can be said that at the present time the Mediterranean has become one of the best explored regional seas in the world, from the point of view of cartography of the sea bottom.

Several bathymetric charts of limited areas already existed at that time, some on scales as large as 1:200,000. However, development of high precision echo-sounding and positioning techniques made it possible to collect a large amount of new data in a relatively short space of time. This became an essential premise for the preparation of high quality bathymetric charts of the Mediterranean on a scale of 1:1 million (at 38° north). The chart, consisting of 10 sheets on Mercator projection, was printed and published by the Head Department of Navigation and Oceanography, Leningrad, on behalf of IOC, in 1982.

Specifications prepared for compilation of the IBCM have been revised from time to time and in 1986 they were adopted by the Consultative Group on Ocean Mapping as "Specifications for international bathymetric charts produced under IOC regional mapping projects".

The IBCM contours have been digitized and are now available on magnetic tape to the scientific community at "symbolic" royalty and reproduction costs.

After the publication of the IBCM, the 1:250,000 plotting sheets were, at the request of the IOC, transferred to the World Data Centre for Bathymetry (IHO). Subsequently, they were distributed to a number of IHO's volunteering hydrographic offices (VHOS) for updating and continued maintenance, with a view to publication of a second edition of the bathymetric chart later.

Results of the first surveys in the Mediterranean using swath sounding systems, i.e. SEABEAM, SeaMARC, Hollming ECHOS etc., have recently been received by the World Data Centre for Bathymetry, e.g. a survey south of Cyprus carried out by the Soviet R/V *Akademik Nikolai Strakhov*. It is expected that in due course a large area of the Mediterranean will be covered by such surveys and that the data will be used by the VHOs for updating the bathymetric database.

Following publication of the IBCM, it was decided to publish five separate geological/geophysical map series (of 10 sheets each on the same scale), using the IBCM bathymetry as a base, on the following subjects:

Bouguer Gravity anomalies
Seismicity
Plio-Quaternary/Messinian structure
Unconsolidated sea-bed sedimentation
Magnetic anomalies

The first series (Gravity) has recently been published. The second series (Seismicity) is in press and is scheduled for publication by mid-1991. The other three series are expected to appear thereafter at the rate of one further series a year.

### International Bathymetric Chart of the Caribbean Sea and Gulf of Mexico

Preparation of the bathymetric chart covering the Caribbean Sea, the Gulf of Mexico and adjacent regions (IBCCA) was initiated in 1986. The approved assembly diagram provides for 17 sheets at scale 1:1 million (at 15° north). Compilation of a number of sheets has already started and it is expected that the northern 10 sheets will be completed by 1992. A colour proof copy of the first of those sheets was printed in 1991.

The IBCCA region has been divided into regions of responsibility for each of the participating countries. The leading role, and responsibility for the final scribing, editing and printing of the chart series, has been assumed by the Instituto Nacional de Estadística, Geografía e Informática, Mexico.

### International Bathymetric Chart of the Western Indian Ocean

An editorial board for the International Bathymetric Chart of the Western Indian Ocean has been established with members from countries of the region and other interested countries. Its first session was held in April 1989 in Antananarivo, Madagascar. At this session decisions were reached on the overall limits of the region to be charted, the assembly diagram showing sheet limits, availability of data, and responsibilities of participating countries.

During the second session (July 1990, Mauritius), the first results of the collection and plotting of data were discussed. Plotting sheets of two large areas of the IBCWIO region were displayed for consideration.

The leading role, including provision of the chief editor in editing, printing and publication of this series, has been assumed by the Bundesamt für Seeschiffahrt und Hydrographie (BSH), Hamburg, Germany.

### International Bathymetric Chart of the Central Eastern Atlantic

An editorial board for the International Bathymetric Chart of the Central Eastern Atlantic (IBCEA) was established by the IOC Assembly at its fourteenth session in March/April 1987.

During its first session (February 1990, in Nigeria) the editorial board adopted an assembly diagram consisting of 12 sheets, to be published by the Hydrographic Services of France and Portugal on behalf of IOC. It was also decided that a digital version of each sheet would be published at the same time as the printed version.

The project will consist of four successive stages:

(*a*) Data collection—this stage is now operational;
(*b*) Data quality control;
(*c*) Geomorphological interpretation;
(*d*) Printing and publication of the chart.

### International Bathymetric Chart of the Western Pacific

A meeting of an IOC Ad Hoc Group of Experts on Ocean Mapping in the WESTPAC Area was held in June 1990 in Tianjin, China.

The Group adopted a recommendation to the IOC Assembly, proposing the creation of this project and the establishment of an editorial board for this purpose.

The Group drafted "Specifications for the International Bathymetric Chart of the Western Pacific (IBCWP)" to be adopted by the Editorial Board. (See document E/CONF.83/INF.26, annex VII.)

In view of the large area covered by the WESTPAC region, the western (marginal) part was divided into six subregions (see annex II). The compilation, printing and publishing of sheets from these subregions will need to be implemented in different ways, and further negotiations will be needed before the overall mechanisms of implementation can be finalized.

## Other possible regional ocean mapping projects

Plans for the preparation of an International Bathymetric Chart of the Red Sea and Gulf of Aden have been drawn up, with the Institute of Oceanographic Sciences Deacon Laboratory, United Kingdom, acting as the lead agency. The project is in abeyance at the present time awaiting identification of the necessary funding source.

The project consists of the base bathymetric series in 11 sheets at a scale of 1:500,000 (at 20° north) and three separate geological/geophysical map series (of 11 sheets each on the same scale), showing respectively: gravity anomalies; magnetic anomalies (showing seismicity and isochrons on the observe); and isopachs (sediment thickness).

At meetings of relevant IOC Regional Committees, proposals have been put forward for international bathymetric charts of the Central Indian Ocean and the Antarctic (southern oceans). No firm plans yet exist for these areas.

## Conclusion

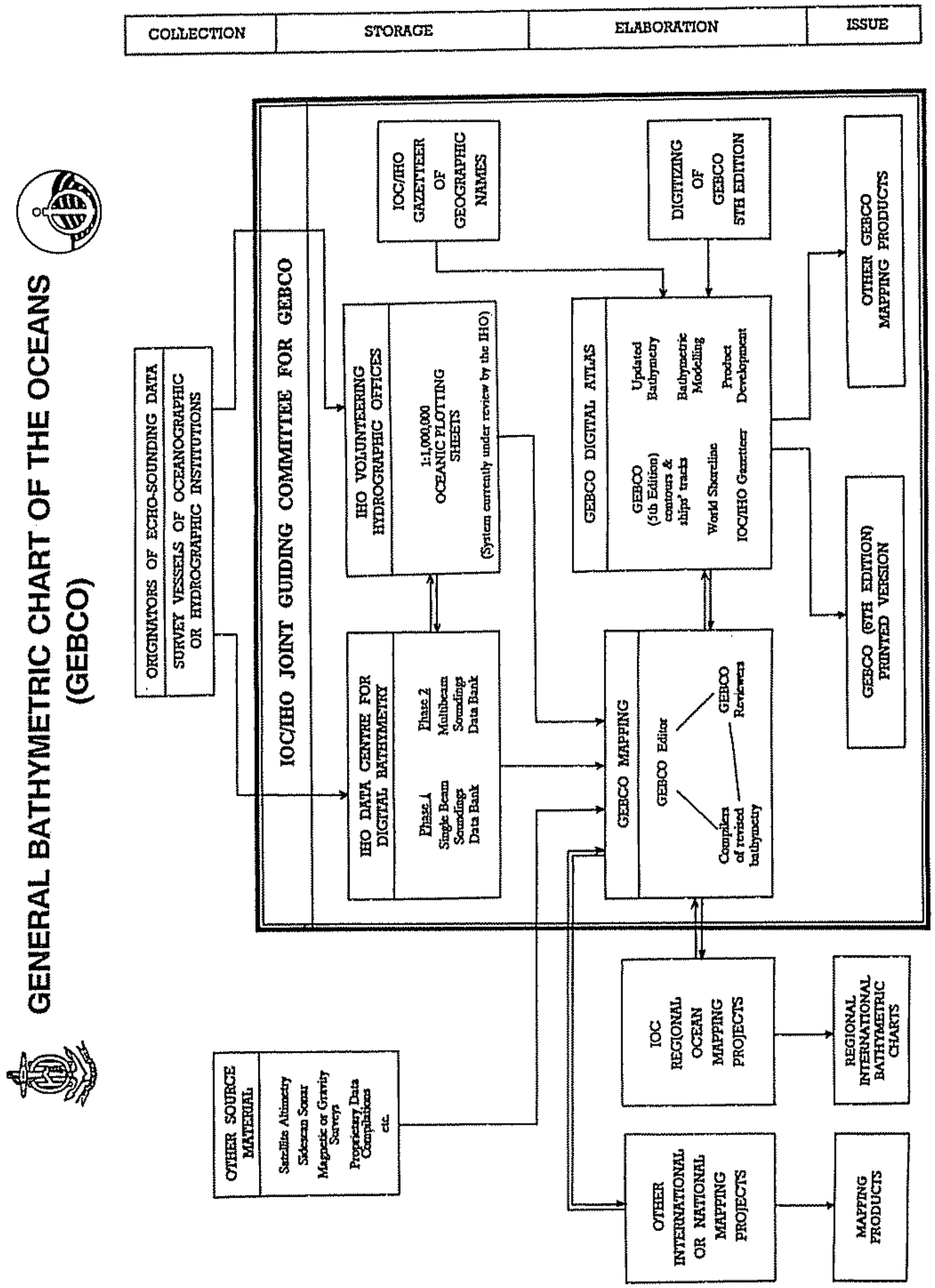
As each large-scale regional bathymetric project is completed, it is intended to digitize the contours and other ancillary material. These will then be incorporated into the *GEBCO Digital Atlas* to replace contours digitized from the smaller scale GEBCO sheets.

The *GEBCO Digital Atlas*, together with the recent establishment of an IHO International Data Centre for Digital Bathymetry, will also facilitate the preparation of digital terrain models (DTMs) of the seafloor.

Overall, these activities constitute a significant contribution to the exploration and exploitation of the world's oceans.

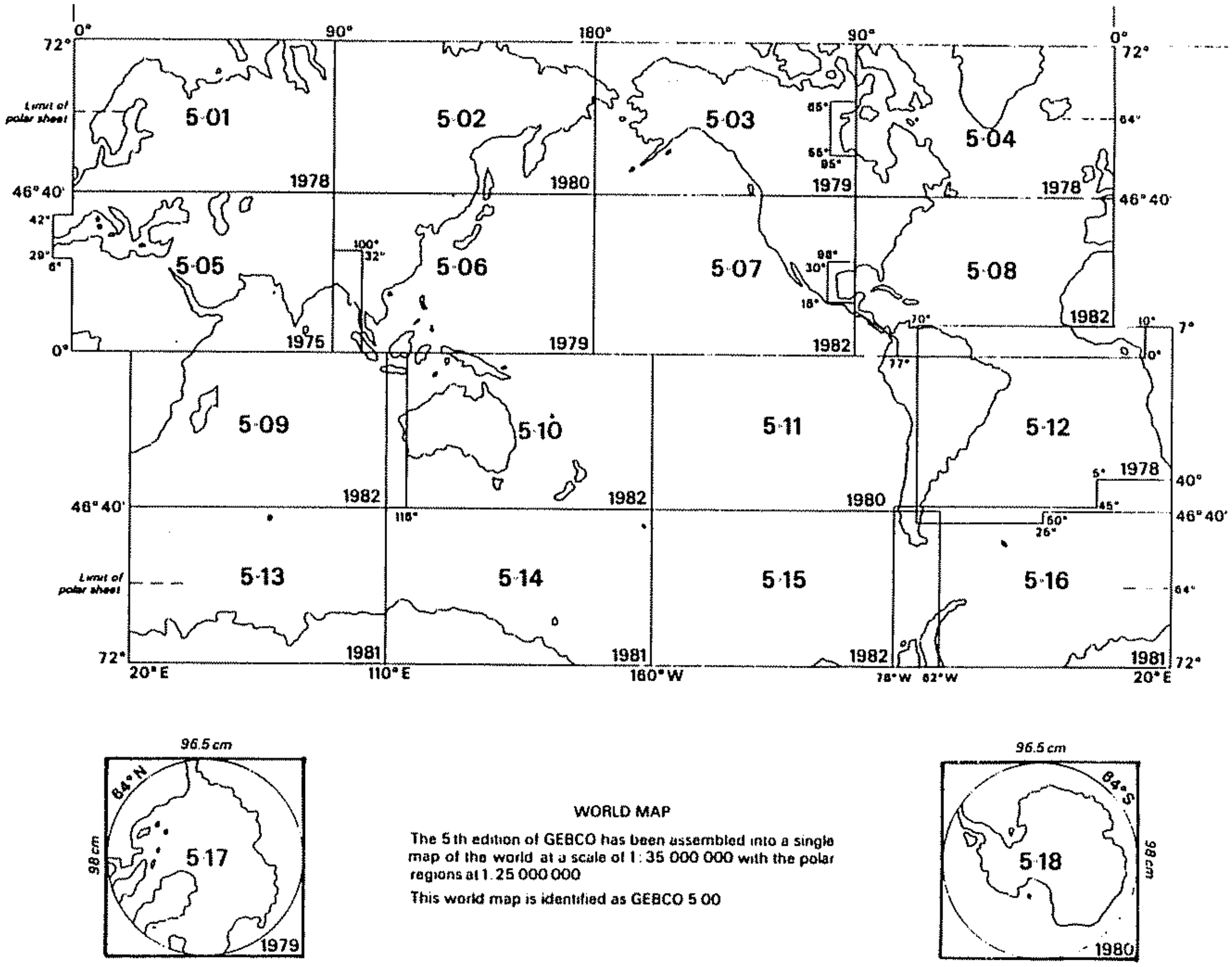
## ANNEX I

### GEBCO Structural Diagram



ANNEX II (*a*)

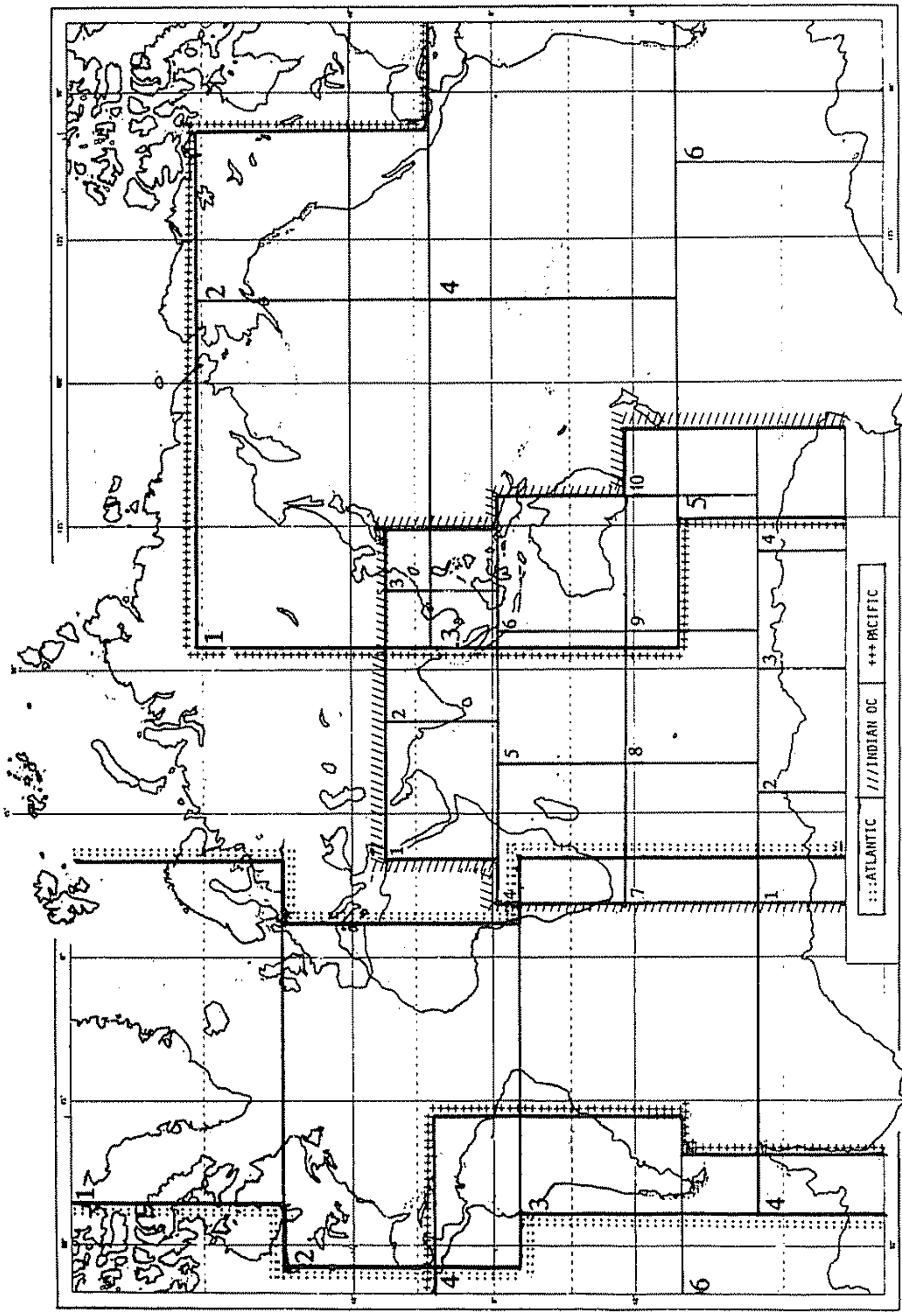
**General Bathymetric Chart of the Oceans**




Scale 1:10 million at the Equator

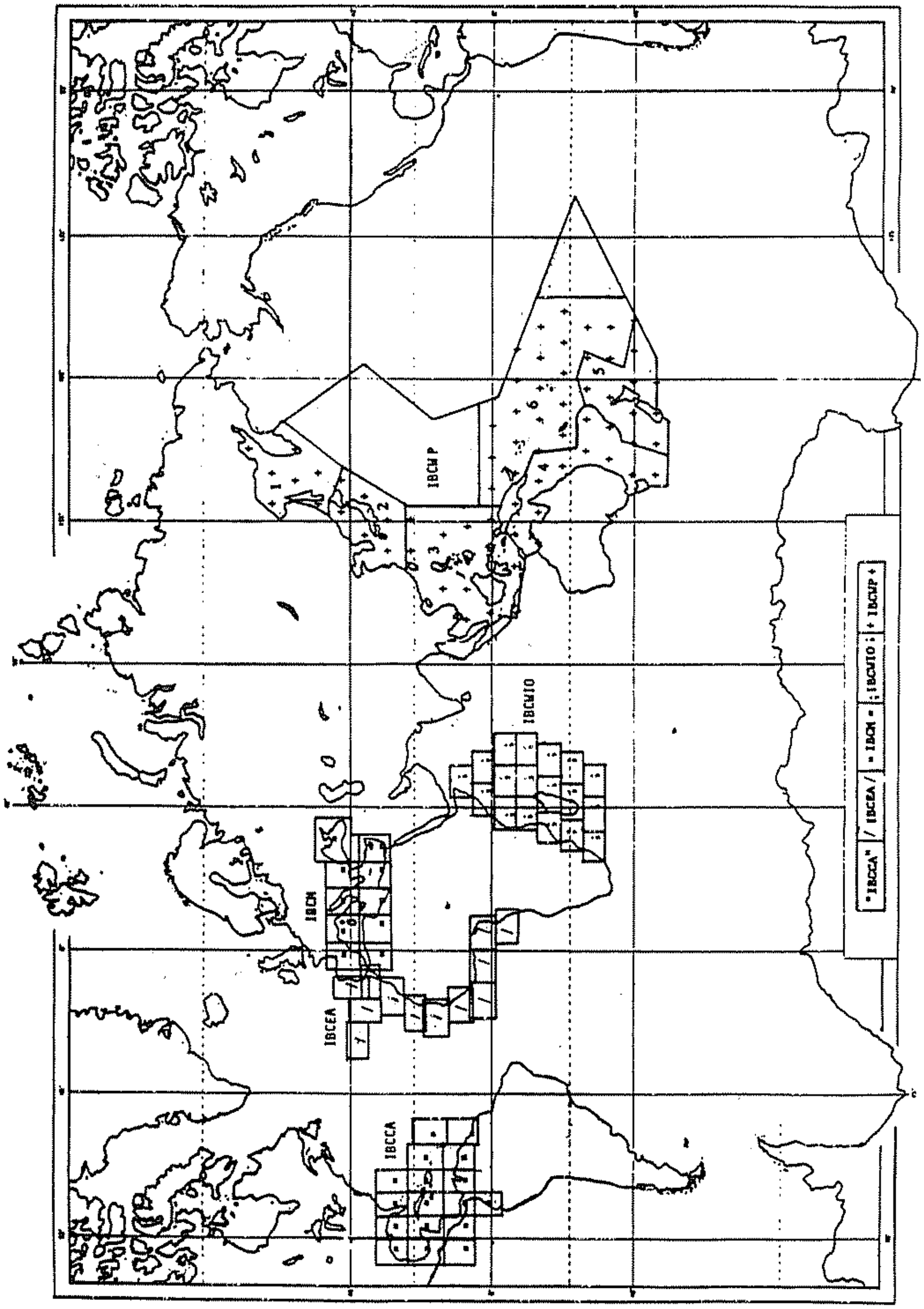
## ANNEX II (*b*)

**The Geological/Geophysical Atlases**



## ANNEX II (*c*)

**The regional IOC ocean mapping projects**



# REPORT OF THE IOC AD HOC GROUP OF EXPERTS ON OCEAN MAPPING IN THE WESTPAC AREA*

*Paper submitted by the Intergovernmental Oceanographic Commission*

The Intergovernmental Oceanographic Commission (IOC), in association with the International Hydrographic Organization (IHO) and other international bodies, is closely concerned with the mapping of the ocean bottom. Through its sponsorship a series of regional bathymetric, geological and geophysical charts is being compiled as a continuation and enlargement of the General Bathymetric Chart of the Oceans (GEBCO). In June 1990, at Tianjin, People's Republic of China, a meeting was held of the IOC ad hoc Group of Experts on Ocean Mapping in the WESTPAC Area, during which the bathymetric mapping of the marginal seas of the western Pacific region was planned. These vast waters were divided into six subregions, and the appropriate coastal countries were invited to compile the charts. At the same meeting, an Editorial Board was established to coordinate the prepared sheets.

The paper contains excerpts from the report of the meeting: annex IV sets out the work done so far in the GEBCO series and the need for and feasibility of compilation of a 1:1M bathymetric chart of the western Pacific marginal seas and the recommendations of the Group of Experts for international cooperation in the project; annex VI shows the approximate limits of the proposed subregions; annex VII gives the specifications for the international bathymetric chart.

La Commission océanographique intergouvernementale (COI), en association avec l'Organisation hydrographique internationale (OHI) et d'autres organes internationaux, s'intéresse vivement à la cartographie du fond des océans. Grâce à son appui financier, une série de cartes bathymétriques, géologiques et géophysiques régionales qui complète la Carte générale bathymétrique des océans (GEBCO) et étendra la zone couverte est en cours d'élaboration. En juin 1990, le Groupe spécial d'experts de la COI sur la cartographie des océans dans la région de WESTPAC, réuni à Tianjin (République populaire de Chine), a planifié la cartographie bathymétrique des mers marginales du Pacifique occidental. Ces vastes plans d'eau ont été divisés en six sous-régions, et les Etats côtiers concernés ont été invités à dresser les cartes. Au cours de cette réunion, un Comité de rédaction a été établi pour coordonner les feuilles qui ont été élaborées.

Le document contient des extraits du rapport de la réunion : l'annexe IV fait le point des travaux déjà effectués en ce qui concerne la série GEBCO, montre la nécessité et la faisabilité d'une carte bathymétrique (à l'échelle de 1/1M) des mers marginales situées dans le Pacifique occidental, et présente les recommandations formulées par le Groupe d'experts au sujet de la coopération internationale dans le cadre du projet; l'annexe VI indique les limites approximatives des sous-régions proposées; l'annexe VII donne les caractéristiques techniques de la carte bathymétrique internationale.

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## PROPOSAL FOR THE COMPILATION OF THE 1:1M BATHYMETRIC CHART OF THE WESTERN PACIFIC MARGINAL SEAS THROUGH INTERNATIONAL CO-OPERATION

*Report of the ad hoc Group of Experts: annex IV*

### 1. *Background*

Seawater covers over two-thirds of the earth's surface, so it is difficult to directly observe the seafloor features. The technology of remote sensing used in mapping on land cannot be ideally applied to the development of ocean mapping because of the impenetrability of the huge ocean water masses by wave beams. Although, for half a century, trenches with depth over 10,000 metres, rift zones running several thousand kilometres and a large number of seamounts have been discovered in the oceans, little has yet been understood of the seafloor topography so far.

One of the first and most important steps in the growing development of the oceans is the preparation of bathymetric charts showing the topography of the ocean bottom in as much detail as possible on the basis of the collection and analysis of the increasing bathymetric data. In recent years, many coastal nations and international organizations have compiled and published bathymetric charts for various oceanic regions.

Since the United Nations General Assembly endorsed the Long-term and Expanded Programme of Oceanic Exploration and Research in 1969, IOC has been active in promotion of the international ocean mapping. In 1970 the compilation of a Geological/Geophysical Atlas of the Indian Ocean was started (published in 1975 by the Academy of Sciences and the Main Administration of Geodesy and Cartography, USSR) using the findings of the International Indian Ocean Expedition. And two further atlases in this series covering the Atlantic and Pacific Oceans are now in preparation. In 1972, the IHO and the IOC set up the Joint IOC/IHO Guiding Committee to compile the 5th Edition of the General Bathymetric Chart of the Oceans (GEBCO), which was published in 1982 by the Canadian Hydrographic Service. This series of 16 1:10M and 2 polar GEBCO sheets is based on a large amount of valuable sounding data and incorporates the latest research findings on modern marine geological structures and geophysics. In 1973, a group of experts was set up to prepare the 1:1M Bathymetric Chart for the Mediterranean Sea and the Black Sea. It was the first IOC regional mapping project and this region is at present one of the best explored regional seas in the world from the point of view of cartography of the sea bottom. The first edition of this chart series was printed and published by the Head Department of Navigation and Oceanography, USSR, on behalf of the IOC, in 1982. The editorial boards for ocean mapping set up so far by the IOC include: the 1:1M Bathymetric Chart Editorial Board for the Caribbean Sea and the Gulf of Mexico and their adjacent regions, initiated in 1986; the Bathymetric Chart Editorial Board for the Western Indian Ocean with members from countries of the region and

*The original text of this paper appeared as document E/CONF 83/INF 26. The complete report of the meeting of the Group of Experts may be obtained from the Intergovernmental Oceanographic Commission. UNESCO. 7 Place de Fontenoy, Paris.

other interested countries, which was set up in 1989; and the Editorial Board for the Central Eastern Atlantic established by the IOC Assembly at its Fourteenth Session in April 1987. At meetings of relevant IOC Regional Committees, plans for a 1:500,000 Bathymetric Chart for the Red Sea and the Gulf of Aden have been drawn up and proposals put forward for International Bathymetric Charts for the Central Indian Ocean, the Southern Atlantic and the Western Pacific.

At the meeting of the IOC WESTPAC Sub-Commission held in Hangzhou, China, in February 1990, the Chairman appointed a group of experts to analyse the situation and discuss the proposal for the bathymetric chart of the Western Pacific Ocean. Today, the successful convening of a meeting of the IOC Group of Experts on Ocean Mapping in the Western Pacific Region in Tianjin, China, will surely greatly contribute to this project.

## 2. *User's requirements*

The 5th Edition GEBCO Sheets and their plotting sheet system illustrate the outstanding progress and achievement in ocean mapping of the world today. However, display of the bottom features of the marginal seas is limited due to their large scale. On the other hand, the 1:1M World Map which has been in use for over 70 years only covers the land. The bathymetric chart for the Western Pacific Ocean may be regarded as an appropriate expansion and extension of the two above-mentioned series of maps of the marginal seas. With definite purposes for application, it provides the users of sea bottom topography with a common and most effective interpretation.

Ocean bottom topography provides the support for all marine activities, and the bathymetric chart offers a useful tool for drawing up plans and programmes as well as various marine laws and regulations in ocean management.

Development of maritime transportation and trade is a prerequisite for improving the economies of the coastal countries, and the provision of sufficient hydrographic data according to the modern standards is the basic requirement for guaranteeing the sailing safety of ships and ocean engineering constructions.

The Exclusive Economic Zone (EEZ) may extend to a range of 200 nautical miles from the accepted baseline. On the one hand, the coastal countries are responsible for the hydrographic surveys in the EEZ. In order to support the increasingly growing fishing activities and mariculture, the users in the field of fishery will undoubtedly need marine environmental information, including bathymetric charts.

The control of nonrenewable marine resources will be extended to the outer limits of the continental shelf and the coastal states will urgently need to know the scope of their continental shelves, which requires the provision of the latest ocean measurements so as to identify the location of the outer limits of the continental shelf and verify the potential reserves of nonrenewable resources. The National Ocean Service (NOS) of the United States used the multi-beam sounding system to provide full-coverage measurement of the ocean bottom, acquiring the bathymetric chart for the continental shelf and slope in such detail and precision as has never been achieved before. The bathymetric chart thus obtained is used to define the regional features and resource conditions of the surveyed area. Comprehensive work on hydrography and geophysics is required for the exploration and industrial exploitation of marine oil and gas. An adequate sounding and topographic information service is necessary for the prospect of reserves, detailed exploration, well site determination, platform development, and oil and gas pipeline planning.

The rugged sea bottom, especially near-bottom topography, affects the physical, chemical and biological processes of the ocean and therefore it is a factor which warrants special attention in marine scientific research. The bathymetric chart contributes to the interpretation of seafloor geology and it is also the basic map for compiling sailing charts, marine special-subject (gravity, magnetics, sedimentation, geological structure and resources) maps and for plotting various statistical data.

The bathymetric chart, like other maps, is a form of expression in written language, a special way of processing, storing and transferring bathymetric information, and may establish digital topographic models. It thus has a variety of potential benefits. Its scientific content and successful artistic expression can enlighten the users on the applications of the chart and broaden their thinking. With the development of science and technology and the uninterrupted introduction of new concepts, in addition to satisfying the needs of the users in the fields of ocean shipping, fishing, oil and gas exploitation, marine laws and regulations, and environmental protection, the bathymetric chart may be valuable to marine scientists as well as to decision makers.

## 3. *Conditions available for the compilation of the bathymetric chart*

Since the 1970s, the Hydrographic Department of the Maritime Safety Agency, Japan, has been carrying out surveys for nautical charts, and has compiled and published over 100 sheets of a Continental Shelf Topography Chart on a scale of 1:200,000 and 5 sheets of a Bathymetric Chart on a scale of 1:1M covering the whole of Japan including the continental shelf and slope, thus providing valuable experience for the co-operative compilation of the bathymetric chart for the Western Pacific. The Hydrographic Department has set up the nautical chart digital database and developed automatic plotting of its current nautical and bathymetric charts. As a result, the ratio of nautical charts being compiled automatically has been increasing.

The Soviet Union published the Marine Atlas in the early 1950s and in the 1970s compiled the Oceanic Atlas, which has new and scientific contents. Moreover she has conducted a survey of the national continental shelf, and compiled and published bathymetric charts of the continental shelf.

Starting the continental shelf survey in 1969, Australia plans to compile over 280 sheets of the 1:250,000 Continental Shelf Bathymetric Chart and establish a Hydrographic Information System on the Hewlett Packard 9000/840 Computer.

China began to conduct a bathymetric survey in the sea area 100-150km offshore in the early 1950s. Up till now, over 30 large-scale comprehensive marine surveys and international co-operative investigations, including ocean sounding, have been undertaken in the adjacent waters of China, acquiring large amounts of sounding data, some of which have been published as bathymetric charts according the needs of the users.

The China National Marine Data and Information Service, which is concurrently the WDC-D (Oceanography), is a comprehensive department for marine information technology and public-benefit service, maintaining business contact with the surveying and mapping agencies of a dozen ministries, commissions and administrations at home and carrying out various forms of co-operation and exchange in technology and data. For example, the National Laboratory of Resources and Environment Information System of the Chinese Academy of Sciences is a research centre under the guidance of international experts. With the VAXII 785 Computer at its core, the centre owns an information acquisition, processing and analysis system consisting of the IIS Image Processing System, Plaincomp C-120, Orthocomp Z2 Rectifier and SEG-6C Colour Rectifier as well as the ARC/INFO Geography Information Software and several microcomputers.

The Research Institute of Surveying and Mapping of the National Bureau of Surveying and Mapping is carrying out the programme of acquiring, compiling and processing the data, including marine information, and of establishing databases on the basis of the VAXII/750, 780, 785, and MICRO VAXII Computer, CALCOMP9100, ALTEK Graph Digitizer, TEKTRONIX 4991 Scan Digitized Workstation as well as the Log-E and DIPIX Digitized Graph Processing System. The Department of Cartography of the Wuhan Technical University of Surveying and Mapping has developed the Map Database Management System, the General-Purpose Map Projection Transformation Software Package and the Microcomputer Geography Information System. The National Marine Data and Information Service started early research on computer-aided ocean mapping. In 1987, it imported from the United States the Intergraph system, whose major equipment includes the MICRO VAXII Computer, Interpro 32 Colour Graph Workstation, TISO 12 Digitizer and Gerber 3278 Plotter. In combination with the IBM4341 Oceanographic Data Processing System and aided by a microcomputer laser filmset and a whole set of printing equipment, the Intergraph System has acquired satisfactory results of cartography in the compilation of marine special-subject maps, acquisition, editing and output of bathymetric data and application programming. It may be believed that China's capability as mentioned above alone constitutes the support for the compilation of the bathymetric chart of the Western Pacific Ocean. The National Marine Data and Information Service is under the State Oceanic Administration which is in charge of the national marine work. In response to the ocean mapping programme for the Western Pacific, the Administration will provide technological and budgetary support and guarantee. To sum up, we believe that at present conditions are basically ripe for the implementation of a bathymetric chart programme for the Western Pacific region. This is mainly manifested in the fact that the coastal countries of the Western Pacific have conducted widespread sounding surveys, and own marine scientific talents in various disciplines, the softwares and hardwares for establishing sounding and topographic databases, automatic mapping systems and satellite image and data processing. At the same time they are provided with the data and technical conditions necessary for the compilation and publication of the bathymetric chart as well as the financial support for the publication of this chart series.

### 4. *Recommendations for cooperation*

The statistics from the seven coastal regions of the world oceans show that only 30% of the waters has been surveyed in sufficient detail, 27% needs to be surveyed again and 42% lacks survey or has not been surveyed. It is obvious, therefore, that the compilation of the 1:1M bathymetric chart for the Western Pacific requires extensive international co-operation among the coastal countries in this region and other interested participating nations. We hope that more countries and organizations will join in this significant international ocean mapping activity.

In this connection, we make the following recommendations:

(i) *Area of coverage*

The focal coverage of the bathymetric chart of the Western Pacific is 65°N-45°S, 100°E-165°W, including a series of Western Pacific marginal seas, straits, bays and adjacent waters. Large as it is, this region boasts many coastal nations, which have conducted widespread hydrographic surveys. While preparing the valuable sounding data of this region, we will first consider the data in the possession of the WDCs and the WODCs. We will also take into consideration the data owned by other well-known mapping projects in this region such as GEBCO, GAPA, CCOP, etc., whose sounding and topographic data may also be quite useful. Of course, it may be a good idea to divide as appropriate this region into sub-regions on the basis of the coverage of the data, but perhaps that will affect the integrity and the joining of the plotting sheets. In view of this, China intends to undertake the task of plotting, printing and publishing all the sheets for this region, while seeking support and co-operation from the Soviet Union, Japan, Australia, etc. We think that the prospects are promising.

The selection of the chart scale for this region is also very important. Mr. Scott said in a record letter: "As I mentioned above, on what scale should the printed chart series be published? i.e. do sufficient data exist in the region from which to prepare a series on a scale of 1:1 million?" We feel that the final chart scale of the bathymetric charts in relation to the GEBCO, GAPA and CCOP programmes is generally too small, affecting the display of ocean bottom topography. In view of their general-purpose applications, they cannot replace the unified and systematic compilation of 1:1M bathymetric charts and their functions. Moreover, the chart scale of other regional mapping projects sponsored by IOC is 1:1M, so for consistency, in this region the same scale should be used. Furthermore, it is also necessary to keep the scale of the bathymetric chart of this region in line with that of the 1:1 M land mapping programmes. Therefore, for this region, we intend to use the 1:1 M scale, although for the areas that lack sufficient data, a smaller scale may be necessary.

(ii) *Institutional arrangements*

(*a*) In the name of the IOC Sub-Commission for WESTPAC, the coastal countries in the Western Pacific and other interested participating countries are invited to recommend expert candidates to form, through consultation, the Editorial Board for the International Bathymetric Chart of the Western Pacific. China is willing to be the Chief Editor of this Board and set up the administrative body (headquarters) in Tianjin, China. The responsibilities of the administrative body are to acquire, analyse, manage and exchange the various valuable sounding and topographic data of this region, undertake to report to the IOC Consultative Group on Ocean Mapping the detailed plan, recommendations and annual reports on the project and activities to be implemented, keep abreast of the progress of the mapping project, coordinate the mapping tasks, carry out scientific and technological consultations related to the mapping project, analyse the problems and guarantee quality, and keep the IOC Sub-Commission for WESTPAC informed of progress with the mapping project.

(*b*) In the name of IOC, the International Hydrographic Organization is invited to participate in this mapping activity, and to co-operate with the Editorial Board for the International Bathymetric Chart of the Western Pacific region in the fields of sounding and topographic data acquisition, and the editing of the bathymetric chart.

(*c*) Countries outside the region, and international programmes and bodies (GEBCO, GAPA, CCOP, SOPAC, EAHC) are invited to participate in the co-operative mapping and provide technological and data support.

(iii) *Technical programme*

(*a*) Referring to the available regional cartographic literature, the Editorial Board for the International Bathymetric Chart of the Western Pacific region will formulate technical specifications and legends and report to the IOC Consultative Group on Ocean Mapping.

Unified provisions must be made for the intervals of contours for the region as a whole, but for different sea areas appropriate adjustments and changes may be made according to topographic characteristics.

(*b*) Based on the available sounding and topographic data catalogue provided to the Editorial Board for the International Bathymetric Chart of the Western Pacific region by the participating countries, a data collection and exchange mechanism will need to be established.

(*c*) A Data Quality Control Group could be established if the Chief Editor deems it necessary.

(*d*) To facilitate the management, use and renewal of the sounding and topographic data, the sounding and contour data are predigitized and databases are established. Unified design is made of the function, content, data structure, input data types, digitized patterns and encoding system as well as the precision of the input/output data.

(*e*) Backed by the sounding and topographic databases, the bathymetric fair chart is compiled and plotted, mainly depending on computer-aided plotting technology, combined with conventional plotting technology.

(*f*) After defining priority sea areas for mapping, a specimen map should be compiled as a basis for modification and addition of specifications by the Editorial Board.

(*g*) Before the fair chart goes to press, the chart editors and scientific and technological co-ordinators should undertake to make a scientific evaluation and explanation, in combination with regional oceanographic research findings, on the ocean bottom features plotted by using the contour lines, and report to the Editorial Board.

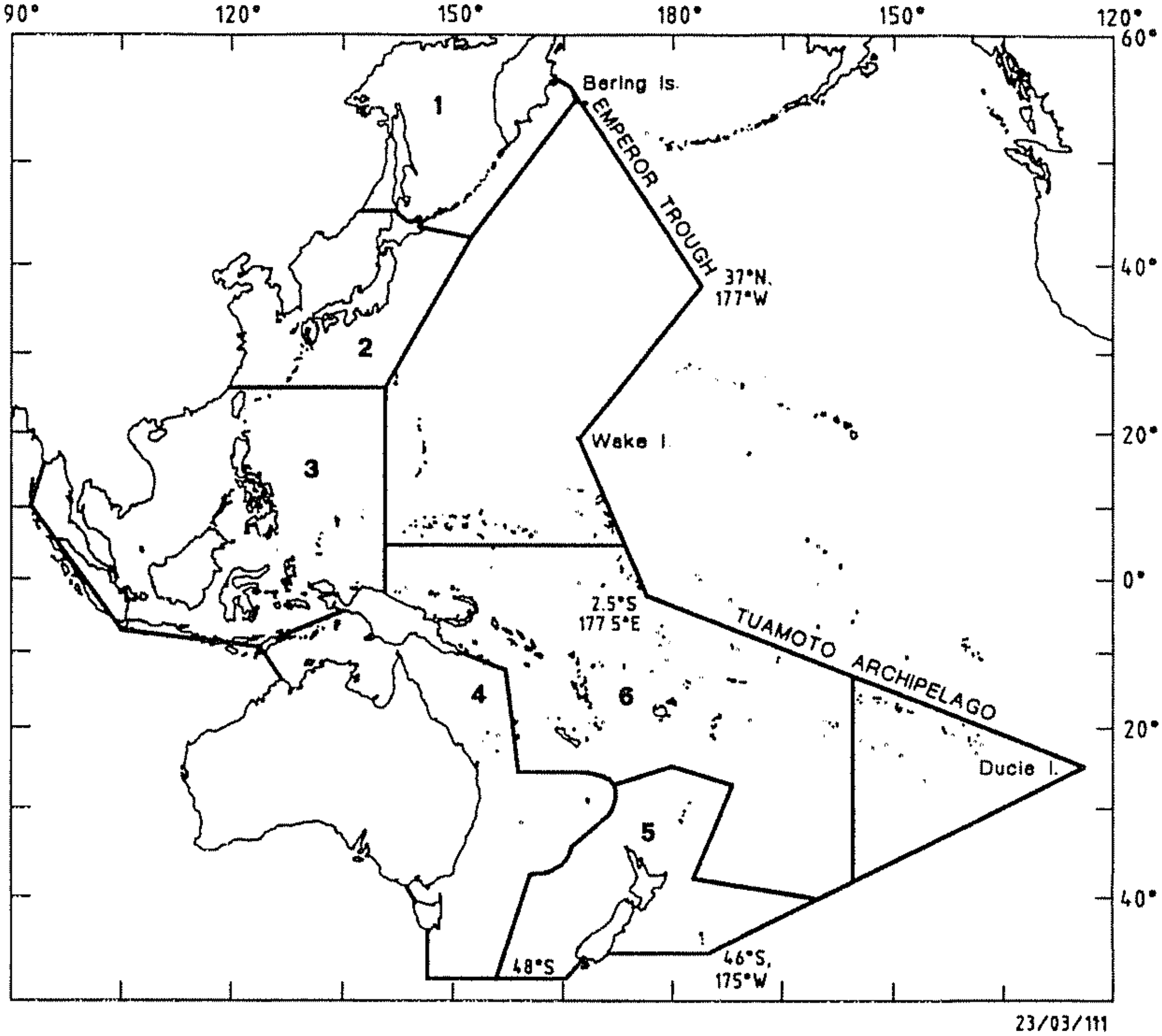
On the basis of the fair chart, data and literature, an appraisal meeting should be held with the participation of the IOC, IHO, the IBCWP Editorial Board, printing and publishing departments and earth scientists, to make an appropriate evaluation of the scientific and cartographic level of the fair chart, before finalizing the various technical requirements for chart production.

As a national marine institution, the China National Marine Data and Information Service maintains good co-operative relations with well-known earth scientists and computer experts both at home and abroad, so that the scientific nature and high quality of the marine cartographic products may be guaranteed. Since 1976, the Service has edited and published over 20 oceanographic atlases with various contents and editions, and over 200 kinds of special-subject charts which contain large amounts of topographic ocean sounding data.

The Service has become a department with prestige and distinctive features in the field of ocean mapping for national marine environmental elements and marine resources. We will follow with great interest this international co-operative mapping activity, and make great efforts to support it and seek financial aid for it, making our contribution to the editing, plotting and publication of the WESTPAC Bathymetric Chart.

APPROXIMATE LIMITS OF PROPOSED SUBREGIONS COVERING THE WESTERN PART OF THE WESTPAC AREA

Report of the ad hoc Group of Experts: annex VI




Subregions:

1. Sea of Okhotsk and SE Kamchatka
2. Japan sea and waters surrounding Japan
3. The Central Western Pacific
4. The Australian northern and eastern margin
5. Waters surrounding New Zealand
6. SOPAC area

## Specifications for the International Bathymetric Chart of the Western Pacific (IBCWP)

Report of the ad hoc Group of Experts: Annex VII

### *Section 100—General*

101 *Introduction*

A. International Bathymetric Charts produced under Regional Mapping Projects are a continuation and further development of the General Bathymetric Chart of the Oceans (GEBCO), under the general guidance of the IOC Consultative Group on Ocean Mapping. These charts are prepared and published with the co-operation of IHOs Volunteering Hydrographic Offices (VHOs) and/or groups of scientists from appropriate institutions.

B. For the IBCWP series, an Editorial Board will be established by the IOC Assembly or Executive Council, for the purpose of technical direction of its compilation and publication.

### *Section 200—Basic specifications*

201 *Projection*

All sheets shall be shown on Mercator Projection using the International Ellipsoid, WGS-84.

202 *Scale*

A. A scale of 1:1,000,000 at 33° Latitude shall be used for the western sheets as shown in the sheet Assembly Diagram (to be prepared by the Editorial Board). At a later stage it may be found desirable to produce some of the eastern sheets on a smaller scale

203 *Graticule*

A. A scaled border of each sheet shall be shown subdivided into 1 minute increments of latitude and longitude.

B. Meridians and parallels shall be drawn every 2°.

C. Labelling of the graticule shall be every 1°.

D. The tropics of Capricorn and Cancer shall be shown.

204 *Size*

The neat line size of each sheet shall not exceed 700 × 900 mm.

205 *Numbering*

A. For each chart a consecutive sheet number shall be used as shown in the Assembly Diagram.

B. Sheet numbers shall be printed in 8 mm Arabic figures in the lower right-hand and top left-hand corner of each sheet.

206 *Dating*

The date of the chart publication to be shown on each sheet shall be the date of going to press.

207 *Units of measurement*

Depths and topographic heights shall be shown in metres. Depths should be corrected from the latest edition of the Echo-Sounding Correction Tables, published by the United Kingdom Hydrographic Department, and this should be stated on the face of the chart.

208 *Marginal information*

A. All marginal information shall be in English (a Chinese or other language version of certain sheets may be printed if so wished).

B. This shall include:

1. The general title of the chart.
2. Sheet number.
3. Projection, ellipsoid and scale (see 201, 202).
4. Unit of measurement used for depths and heights.
5. Code of colours used to portray hypsometry.
6. Code of colours used to portray bathymetry.
7. An index of areas and names of countries whose Hydrographic Offices or groups of scientists prepared plotting sheets for the sheet.
8. The names of scientific co-ordinators of the chart series and of scientists responsible for the scientific content of the sheet.
9. The logo of the Intergovernmental Oceanographic Commission (IOC) of UNESCO.
10. Edition number and date of publication (see 206) followed by the statement: "Published by the ______ (name of publisher) under the authority of the IOC (of UNESCO)".
11. List of the sources of the data used (for the chart series).

### *Section 300—Topography*

301 For the land part, topographic maps shall be used

302 The World Vector Shoreline (WVS) shall be used. The coastline shall be shown as a firm line in black.

303 A. Contours on land shall be at 200 m intervals.

B. The thicker lines shall be at 200, 1,000, 2,000, 3,000, etc., m. intervals

C. Additional contours which may be required by the data must be shown.

D. A colour change for hypsometry shall be used at the following intervals: 0-200, 200-1,000, 1,000-2,000, etc., m.

E. Glaciers shall be shown by contours or by symbols. The significant heights shall be shown.

304 *Hydrology of the land*

On the chart shall be shown, as appropriate:

—rivers and channels;

—lakes;

—lagoons.

305 Major cities and towns, priority being given to those on the coast.

### *Section 400—Bathymetry*

401 Compilation sheets shall be prepared by the participants in the Project, according to agreed zones of responsibility, on a scale of the order of 1:250,000. The British Admiralty 1:250,000 plotting sheets may be used; they should be prepared according to the Appendix to these Specifications.

402 *Soundings*

A. A sparse pattern of numerical soundings shall be shown to indicate maximum and minimum (and other significant) depths, where known, over major undersea features in such a way as not to detract from the paramount objective of indicating sea floor relief by means of contours

The exact position of all numerical soundings shown shall be indicated by a dot. The depth shall be written as cartographically convenient against the dot using 1.5 mm sans-serif figures. Where space does not permit the juxtaposition of the figures they may be offset and linked by a fine line to the dot placed in the exact position.

B. In order to indicate contour reliability, all soundings used shall be shown as dots representing discrete soundings or lines representing continuously sounded traverses. Areas of detailed surveys, where soundings are denser than can be conveniently shown, shall be indicated by numbered boxes referenced in the margin.

403 *Depth contours and colours*

A. Basic contours shall be at 200 m intervals.

B. The 200 m contour line and all contours at 1,000 m intervals shall be drawn using thick lines.

C. 20, 50 and 100 m contours, if necessary, shall be drawn using thin lines.

D. A colour change for the bathymetry shall be used at the following intervals: 0-200, 200-1,000, 1,000-2,000, 2,000-3,000, etc., m.

*Section 500—Nomenclature and geographical names*

501 A. A proposed list of names for inclusion on each sheet will be forwarded to the GEBCO Subcommittee on Geographical Names and Nomenclature of Ocean Bottom Features, with a request for guidance on any that might be controversial. In preparing this list account should be taken of the guidelines contained in the GEBCO publication "Standardization of Undersea Feature Names".

B. As a general policy, local names (cities, towns, mountain ranges, rivers, etc.) shall be in exact agreement with the form prescribed by the most authoritative national source. However, in those cases where the national names differ substantially from the normal English usage, the English version shall be shown alongside in parenthesis.

C. The nomenclature for undersea features shall be shown in the English language.

# AGENDA ITEM 6

## Cartographic data recording, compilation and manipulation

### (a) *Large-scale topographic mapping*

### PRODUCTION OF TOPOGRAPHIC BASE MAPS IN SOUTH-EAST ASIA: SOME CONSIDERATIONS*

*Paper submitted by Germany*


## RÉSUMÉ

Dans ce document, l'auteur analyse plusieurs facteurs qui, selon lui, ont influencé la production de fonds de cartes topographiques en Asie du Sud-Est. Ses opinions ne sont pas le fruit d'une enquête systématique mais plutôt de considérations personnelles fondées sur ses contacts approfondis avec les organisations cartographiques de la région.


The paper expresses the author's assessment of a number of factors that in his opinion have influenced the production of topographic base maps in south-east Asia. The views expressed are not the results of a systematic investigation, but rather personal considerations based on the author's extensive exposure to mapping organizations in the region.

#### HAVE THE BASE MAPPING PROGRAMMES IN SOUTH-EAST ASIA KEPT PACE WITH NATIONAL NEEDS?

In the late sixties at the International Institute for Aerial Survey and Earth Sciences (ITC), a series of lectures was held on topographic mapping, in which particular stress was placed on the relevance of topographic base mapping as a prerequisite for the orderly planning of national development, in the developing countries.

Now, twenty years later, some of the developing countries have gone a long way down the road of industrialization and the questions could legitimately be asked:

Have the national base mapping programmes kept pace with those countries' basic needs?

If not, what has been the consequence of the lack of appropriate base maps on the economic and social development of the nation, the exploitation of renewable resources and the environment as a whole?

Answers to these questions could probably be found within the scope of an official investigation by some international body like the United Nations.

It is not inconceivable, however, that the lack of adequate base maps, in some form or another, has not seriously hampered national economic development. If this has been the case, however, the price paid in other ways has been significant.

As a vivid and topical example, one could look at the timber exploitation industry in the tropical rain forests: the lack of topographic base maps has often prevented adequate planning of logging roads. Poor planning has resulted in haphazard construction of these roads which have been the major cause of topsoil run-off, with disastrous consequences to the environment.[1]

#### IMPACT OF NEW TECHNOLOGIES ON THE PRODUCTION OF BASE MAPS

In the last few years a number of mapping-related technologies have evolved that have often influenced the base mapping programmes at national level. There is no doubt that some of these technologies have had, or will have in the future, significant positive impact. Others, however, may have been detrimental to the base mapping programme, mainly because scarce resources have been re-directed in the hope of a faster response to national mapping needs. Such technologies are:

Remote sensing from space (RS)

Geographic information systems (GIS)

Computer-aided mapping systems (CAM)

Rapid mapping systems (RMS)

Global Positioning Systems (GPS)

The impact that these technologies may have had on national topographic base map programmes is described below.

*Remote sensing from space*

Stereo SPOT has the potential to contribute to the topographic mapping programme in two ways: generating a digital terrain model, and updating man-made features. The latter application has been somewhat less successful than expected, in several test cases. Features of interest simply did not show up at all in the images.[2]

Although proven theoretically, and confirmed experimentally that a DTM could be generated from suitable geometric configuration, national mapping organizations have been slow to experiment with SPOT. The difficulty of obtaining stereo-images is possibly one of the reasons.

Another reason may be the potential provided by the combination of aerial photography and airborne GPS with

*The original text of this paper appeared as document E/CONF.85/INF.17.

the almost total elimination of ground control. In such cases the large coverage of SPOT would lose much of its attractiveness as an alternative to conventional aerial photography.

Some government mapping organizations in south-east Asia have allocated significant resources for the acquisition of remote sensing data processing and analysis capabilities. Whether or not the return on the investment has always fulfilled expectations, it can be confidently stated that remote sensing from satellites, with the notable exception of stereo SPOT, can only detect phenomena of transient nature, which may change very rapidly with time.

It has often been the apparent immediacy of the information obtained from such data that has captured the interest of the inexperienced user. Just as often the user forgets that this "information", possibly in captivating colours on a computer screen, may have looked totally different had the satellite passed over the same area one hour earlier or later.

It is the author's opinion that remote sensing technology has had, at best, a negligible influence on the national base mapping programmes, and at worst has had a negative influence inasmuch as it has diverted limited resources which could have been committed to base mapping programmes.

### *Geographic information systems*

With GIS technology we may once again be confronted with the same syndrome as with remote sensing some 15 years ago: i.e. a new and potentially interesting technology, which is being somewhat oversold. No doubt a functioning GIS system on a national basis, with the associated data base, is the final goal. However, meaningful GIS cannot exist without first having an adequate base map framework for thematic applications. It would be like attempting to construct a building from the roof.

Most mapping organizations in the south-east Asia region are experimenting with GIS. Experimenting, possibly with a low cost PC based system, is probably a wise course of action, which is necessary to assess the implications—technical, administrative, institutional and financial—of putting in place a meaningful GIS system at the national level.

The final goal of having a GIS system at the national level will provide additional impetus to the base mapping programme. It will also direct the mapping technology towards digital mapping output with structured databases.

There is, however, the real danger that excessive resources are prematurely allocated to a technology that has been developed to manipulate and manage data. Initially, resources are surely better allocated to provide that vital data, of which a map is the first and foremost.

### *Computer-aided mapping systems*

Computer aided mapping is today a mature and fully operational technology. Most State mapping organizations in south-east Asia have acquired some form of CAM capability, be it a simple PC-driven digitizer, an analytical plotter or a complex multistation acquisition and editing system.

Due to their data-editing facilities, CAM systems have a major impact in solving the cartographic bottleneck. Their significance, however, should go much further than providing powerful cartographic functions. Basically, CAM systems should have the capability of storing the mapping data into a structured digital database. This database is in itself a product of the mapping process, and as much of a national asset as the published map itself.

The introduction of CAM technology has, however, had its pitfalls.

Any computer-based system requires regular maintainence and strong regional service back-up by the manufacturers. The organization implementing CAM technology should budget, yearly, between 5 and 10 per cent of the initial purchase price of the capital equipment. This budget should be used to enter into service and maintenance contracts at expiration of the warranty period. Regular maintenance insures longer life of the equipment and less chances of breakdowns.

CAM technology is now the operational way to effect mapping at any scale, including national topographic base mapping. However, the word "operational" in the previous sentence should be stressed, since production organizations, especially those located at some distance from the suppliers of systems and equipment, would be well advised to shy away from technologies that have not been extensively proven in operational environments similar to their own.

### *Rapid mapping systems*

The last opinion expressed in the previous paragraph naturally leads to the as yet not well defined concept of "rapid mapping" systems, which regularly emerges, possibly nurtured by enthusiastic young graduates who have been exposed to scientific and technical literature originating from universities and from research institutes. In itself this is a natural and legitimate phenomenon: when young people stop being enthusiastic about their discipline it will be the end of technological development. Decision makers, however, should be aware that there is usually a significant gap in time between what is technically possible and what is operationally available, and only look at technologies that have been proven, possibly in operational environments similar to their own.

### *Global positioning systems*

The impact of GPS in most surveying and mapping fields is little short of revolutionary. For national topographic base map programmes, GPS is ideally suited to provide the necessary control framework. The possibility of using airborne GPS in conjunction with the aerial photography flight opens a totally new dimension for mapping in general, and for topo-mapping in particular.

There is, however, one prerequisite before GPS can be effectively used for that purpose. GPS provides geocentric coordinates. In order to be used for topographic mapping, it is first necessary to know the shape of the geoid over the area of application. The knowledge of the shape of the national geoid is in itself another national asset. Its establishment should have the highest priority because of its fundamental nature.

### *The need for training of personnel*

The introduction of the above-mentioned technologies requires basic changes in production methods which go hand in hand with the need to retrain personnel.

The cartographic technician has to become a workstation operator, and the photogrammetric operator to acquire a broader knowledge of the whole mapping process. The boundary between cartography and photogrammetry is becoming undefined within modern CAM systems.

A huge volume of data has to be manipulated, stored and retrieved, sophisticated computer systems have to be managed and the integrity of digital data preserved. These latter tasks are best performed by data processing specialists, who should provide a service function within the map production process.

The basic profile of the core personnel, such as workstation photogrammetric operators and floor managers, has to remain first and foremost that of a mapping specialist. In other words, the tool may be changing, but not the discipline.

Several years of experience in training mapping personnel in using computer based systems in this part of the world, has shown the author that people adapt very quickly once they overcome certain initial reservations. This has been the case also with the recent introduction of full fledged digital mapping systems.

Any consideration of training and education in the mapping field in south-east Asia, and its impact on national development would be incomplete without some reference to the role of the ITC, past and present. As a graduate and former staff member of this institution, I believe that I am entitled a few comments.

The majority of personnel who are now at top and middle level of management in mapping organizations have an ITC background. Those who have reached top management position would have most probably done so with or without their ITC training. It is in the training of middle management position that the ITC in my opinion has been most relevant.

The training of personnel who are intended to actually operate instrumentation in the production environment, has however been less successful. This has been recognized by the ITC, and such courses have been discontinued. This type of training is best done on the job in the personnel's own working environment. It is indeed at this level that the manufacturers of mapping equipment have played a major role, since training is usually offered as a component of the purchase of new equipment. This type of training often goes far beyond mere familiarization with the new instrumentation.

### Conclusions

Topographic base mapping is still very much a prerequisite for national development and for the management of natural resources. As society gradually changes from predominantly agricultural to industrial and service economies, the scale of base mapping reflects its needs. We have in fact seen that need for mapping actually increases with the level of social and economic development.

A quote attributed to Prof. Schermerhomal runs, "It is unlikely that a politician will ever be elected to public office if his election campaign was based on the promise of adequate mapping . . ." He was both a politician and an eminent cartographer, and would have known.

Politicians of the 1950s and 1960s did not have the benefit of GIS (possibly with the multicolour enhancement of remote sensing) but it is doubtful that if they had it would have changed the course of history.

It must also be admitted that the realities of life often require that third parties, be it a minister or a potential customer, be convinced of the relevance of certain services or products. The benefits of GIS are strong and convincing arguments; the need to have first a topographic database on which to anchor the GIS is somewhat more difficult to turn into a convincing argument, especially when presented to those outside the cartographic discipline. This will be one of the major challenges facing decision makers in the various mapping organizations in south-east Asia in the coming years.

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### Notes

[1]"Forestry in Sabah" (Sabah Forestry Department, 1989).

[2]R. J. Priebbenow and E. Clerici, "Cartographic application of SPOT imagery". In *Proceedings of SPOT 1 Image Utilization, Assessment and Results Symposium, Paris, 23-27 November, 1987.*

## (c) *Cadastral mapping*

## MAPPING AND SURVEYING TO SUPPORT LAND ADMINISTRATION IN THAILAND: THE FIRST SIX YEARS OF THE LAND TITLING PROJECT*

*Paper submitted by Australia*

### RÉSUMÉ

Le Projet de cadastre thaïlandais est né d'une recommandation formulée en 1980 par le Sous-Comité de la politique foncière du Comité national de développement rural, visant à accélérer la délivrance de titres d'occupation garantis et à améliorer les opérations du Ministère de l'aménagement du territoire. En 1980, l'agriculture employait plus de 70 % de la population active du pays et représentait 58 % de ses exportations. A cette époque, on a estimé qu'il serait difficile d'augmenter les revenus sans dégrader l'environnement, à moins de mettre en place de nouvelles politiques. Pour inciter les agriculteurs à investir davantage et de manière plus "intelligente" dans les terres arables, on a jugé indispensable de garantir le droit à l'occupation et de faciliter l'accès au crédit institutionnel. Les besoins du secteur urbain et l'amélioration du fonctionnement du Ministère étaient considérés comme secondaires.

Le projet cadastral est passé par une phase d'étude (1981), de préparation (1982/83) et d'évaluation (1984), avec un financement de l'Australian International Development Assistance Bureau (AIDAB) et de la Banque internationale pour la reconstruction et le développement (BIRD). La première étape a débuté le 1<sup>er</sup> octobre 1984 grâce à un fi-

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nancement de la BIRD (prêt au Gouvernement thaïlandais), à une contribution de contrepartie du Gouvernement et à une subvention de l'AIDAB sous forme de conseils techniques, de formation et d'enseignement. Elle s'est achevée le 30 septembre 1990. Une deuxième étape de quatre ans a immédiatement pris le relais, avec les mêmes sources de financement.

Dans le présent document, on résume les résultats de la première étape pour ce qui concerne les levés et l'établissement de cartes. On constate à cette occasion qu'un vaste projet a été mis sur pied et rapidement entrepris, ce qui a été possible grâce à une remarquable mobilisation de ressources : organisation, gestion, formation, transfert de technologie, nouveaux équipements, opérations et pratiques nouvelles.

Outre les levés et l'établissement de cartes, le projet porte sur l'administration foncière, l'évaluation, l'organisation et la gestion. Les produits essentiels de la première étape sont les suivants : *a*) levés de contrôle et cartographie photographique, et *b*) cartographie cadastrale.

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The Thailand Land Titling Project (TLTP) has its roots in a land policy subcommittee of the National Rural Development Committee recommendation of 1980 to accelerate the issuance of secure rights to land and improve the operations of the Department of Lands (DOL). In 1980 agriculture provided employment for over 70 per cent of the country's labour force and contributed 58 per cent of exports. At that time it was concluded that further improvement to incomes could not be easily obtained without degrading the environment unless new policies were initiated; security of tenure and easier access to institutional credit were seen as incentives to more intensive and "smarter" investment by farmers on existing arable lands. The needs in the urban sector and in improved departmental operations were considered secondary.

The TLTP was created in steps, through project identification (1981), preparation (1982/83) and appraisal (1984), assisted with funding by the Australian International Development Assistance Bureau (AIDAB) and the International Bank for Reconstruction Development (IBRD). The first phase began on 1 October 1984 with funding by IBRD (loan to the Royal Thai Government), government counterpart funds and AIDAB grant for technical advisers, training and education. Phase I ended on 30 September 1990 after six years. Phase II began immediately, with the same sources of funding, for a four-year period.

The present paper summarizes the first phase results in the survey and mapping components. In presenting these results it will be seen that during Phase I a very large project was mobilized and quickly put into production. This was achieved by a quite remarkable marshalling of resources; organization, management, training, technology transfer, new equipment, operations and new practices.

In addition to survey and mapping, other operational components of the project are land administration, valuation and organization and management.

Key summary outputs of Phase I, in survey, photomapping and cadastral mapping, are shown in tables 1 and 2.

TABLE 1   CONTROL SURVEYS AND PHOTOMAPPING: SIX YEARS

| *Output* | *Rural* | *Urban* |
|---|---|---|
| 1 Control traverse (km). | 110 000 | 4 840 |
| 2 Satellite marks (Doppler. GPS) | 968 | — |
| 3 Photomaps (and scale) | 12 700<br>(1:4 000) | 5 700<br>(1:1 000) |

TABLE 2. CADASTRAL MAPPING: SIX YEARS

| | *Number of land parcels (Number of maps)* | | |
|---|---|---|---|
| *Map compilation* | *Scale 1:4,000* | *Scale 1:1,000*[a] | *Total* |
| 1 Office based. from existing map and plan documents | 586 000<br>(5 800) | 862 000<br>(7 100) | 1 448 000<br>12 900) |
| 2 Data from new field surveys and adjudications | 251 000<br>(maps included in 1) | 798 000<br>(24 400) | 1 049 000<br>(24 400) |
| TOTAL | 837 000<br>(5 800) | 1 660 000<br>(31 500) | 2 497 000<br>(37 300) |

[a]Mostly 1:1,000, with a few 1:2.000 and 1:500 maps

## PROJECT GOALS AND ROLE OF SURVEY AND MAPPING

The Land Titling Project has the following goals;

(*a*) Accelerated issuance of title deeds to valid occupiers of land parcels outside forest lands, completing coverage of the entire country within 20 years (estimated to be 14 million new title deeds);

(*b*) Production of new cadastral maps at suitable map scales and on one Universal Transverse Mercator (UTM) mapping system showing all land parcels; both existing title deeds (6.7 million parcels in 1987) and land parcels to be titled (estimated as 14 million);

(*c*) Improved effectiveness of land administration operations;

(*d*) Strengthening of the Central Valuation Authority to undertake the role as the Government's provider of property valuations.

In Phase I, nine of the country's 73 provinces were subject to the systematic cadastral project. In Phase II (1991-1994) work will be undertaken in a further 30 provinces.

The necessary role of surveying and mapping in land titling and registration is not obvious since it varies from jurisdiction to jurisdiction depending on land law, regulations and culture. Indeed, the broader role of land administration in land and economic management is not well established owing to many factors. In the context of developing countries many development agencies have recognized the limitations to rural economic development caused by the lack of a basic land administration framework. As evidence of this are the many third world land administration projects begun in the 1980s in south-east Asia and South America A recent contribution on this subject is Burns and others (1990).

## ROLE OF CADASTRAL SURVEYING AND MAPPING IN THE THAI SYSTEM

Cadastral surveying and mapping in private lands are conducted by staff of the Department of Lands; there is no private sector. Issuance of land ownership documents on newly registered parcels are brought about through well established survey and adjudication practices that identify the boundaries of the subject and adjacent parcels by agreement among those people with rights in the parcels (Angus-Leppan and Burns, 1986). The land code provides for marks to be placed on the boundary of the parcel to be titled and the boundaries to be measured by appropriate methods. All title deeds show a parcel diagram. Title deeds may be transferred on the Register without a field re-survey.

Boundaries of title deed parcels may be established either by:

(*a*) First class methods (less than 10 per cent): angle and distance are measured from control traverses by theodolite and 40 metre steel tape; or

(*b*) Second-class methods, two cases: (i) where boundary corners are visible on an existing 1:4,000 scale rectified photomap they are photo-identified, marked on tne photobase and transferred to an overlay (boundary sides measured and areas calculated graphically); and (ii) where photomaps are unavailable or unsuitable, boundary corners are located by square offset measurements from control traverses using an optical square and tape (boundary sides measured and areas calculated using derived triangles).

Based on the adjudication and survey, title deed(s) may be prepared for approval by the head of the land office. Thus, the role of cadastral surveying is well established.

There are two types of cadastral maps in DOL;

(*a*) *Line maps*, produced by either first or second class survey measurements at suitable scales (1:4,000 to 1:500) and indexing a survey file containing survey data, calculations and a plan;

(*b*) *Rectified photomap with clear overlay*, being both an index map and graphical record of survey (no survey plan). These maps, begun in 1962, are not numerous.

Departmental regulations require all titled parcels to be shown on a cadastral map; update of the cadastral map in the land office is a part of the normal mutation process. However, realization of this role has proven difficult to sustain. Owing to resource constraints and the high rate of parcel subdivisions, particularly in urban and semi-urban lands, problems have occurred: overlapping maps exist; parcels have not always been updated on the map (the regulation was waived in 1971 as it applied to Bangkok); some maps are in very poor physical condition and partly illegible; maps have historically been based on 29 different original coordinate systems. The result is that maps are not being most effectively used for land office purposes and are not available for multi-purpose and external agency usage.

These map-related issues were addressed during Phase I of the project. In particular, the second method of map compilation was chosen for the accelerated issuance of title deeds under TLTP since it is far quicker than field measurement methods and of sufficient accuracy in rural lands, given the attitude to adjudication and the fact that the land is generally flat.

## TUNING SURVEY AND MAPPING FUNCTIONS TO MEET THE NEEDS OF TITLE ISSUANCE AND LAND ADMINISTRATION

The following basic survey and mapping methodology was adopted to meet the goals of the project:

1. All parcels, both existing titled and newly titled parcels, are to be shown on one new uniform series of cadastral maps on the UTM mapping system and based on the national geodetic datum.

2. A cadastral map showing newly titled parcels established by second class survey methods is the basis for title deed preparation.

3. Office transformation of existing certificates of utilization (NS3K) parcels onto new 1:4,000 UTM maps is to be performed where existing records are reliable and these maps will be used for title deed preparation. This will save enormous time since there are 7.1 million NS3K, the majority of which were adjudicated and drafted on 1:5,000 overlays to unrectified photo enlargements during the 1970s. Amendments were made to the Land Code to permit these parcels to be upgraded to title deed without field survey.

4. 1:4,000 photomaps with UTM grid are to be provided to assist both field adjudication in open farm lands and NS3K transformation.

5. 1:1,000 photomaps with UTM grid are to be provided over major urban centres to allow compilation of new Cadastral Index Maps (CIM) showing existing title deed parcels transferred from existing survey plans and maps.

6. In rural villages 1:1,000 maps (some 1:2,000 and 1:500 as required) are to be drawn from second class ground surveys.

7. All parcels are to be allotted a new unique parcel identifier based on the 1:4,000 UTM sheet, further;

(*a*) All maps are to be drawn on film to ensure a longer life than existing paper/linen maps;

(*b*) Cadastral Index Maps are to show a minimum of detail to facilitate copying and multi-purpose use as a basemap for external agencies, to maximize life as subdivisions occur, and to facilitate any future conversion to computer (digital) form.

8. Hilly areas within private lands that would cause significant relief displacement on the photomap are to be field surveyed but fortunately constitute only a small proportion of the land.

This methodology has been successfully implemented during the first six-year phase.

## PHASE I: RESULTS, TECHNIQUES AND TECHNICAL ASSISTANCE

The performance of survey and mapping functions during the first six years is shown in table 3 for control surveys, mapping (photomaps and cadastral maps), cadastral surveys, and organization and management.

### *Control Surveys*

Thailand has a well established national primary geodetic network of about 350 stations, which is maintained by the Royal Thai Survey Department to Indian datum 1975, and this datum has been adopted by the Department for further densification. The project's major control provides the densification needed for endpoint control of minor control traverses. During Phase 1, the work progressed faster than predicted and the traverse teams were recently directed into minor control surveys.

TABLE 3. THAILAND LAND TITLING PROJECT: PHASE I (1985-1990). SURVEY AND MAPPING PERFORMANCE

| *Goals* | *Performance indicators* | *Target (6 years)*[a] | *Achieved (6 years)* |
|---|---|---|---|
| 1. *Control Surveys* Provide survey control on Indian Datum 1975 with UTM coordinates in aerotriangulation blocks and in all villages and urban centres to meet the work progress of the land titling programme | 1 Progress of Major Control | 58 provinces | 58 provinces |
| | Establishment of co-ordinated marks in target provinces | | |
| | 1.1 satellite control stations | 744 (Doppler) | 830 (Doppler) / 138 (GPS) |
| | 1.2 traverse length | 18.000 km | 22.000 km |
| | 2 Progress of Minor Control | | |
| | Establishment of co-ordinated marks in target provinces | 30 provinces | 30 provinces |
| | 2.1 traverse length | 87,000 km | 88,000 km |
| | 2.2 survey marks | 277.000 marks | 332.000 marks |
| | 3 Progress of establishment of co-ordinated marks in target urban centres and districts of Bangkok. to support large-scale map compilation | | |
| | 3.1 Bangkok traverses | 2.440 km | 2.620 km |
| | 3.2 provincial urban centres traverses | 1,780 km | 2,220 km |
| 2. *Mapping* Provide a uniform series of cadastral maps showing all parcels with title deed tenure, at appropriate scale and with UTM grid, and to meet the work progress of the land titling programme. | 4. Output level of 1:4,000-scale rectified photomaps over non-forest lands in target provinces | 12,000 maps | 12,700 maps |
| | 5. Output level of 1:1,000-scale rectified photomaps over major urban centres in target provinces and districts of Bangkok | 3,300 maps | 5,700 maps |
| | 6 Number of parcels shown on new 1:4.000-scale cadastral maps obtained by transformation from existing 1:5.000-(approx.) scale maps in target provinces | 606.000 parcels (n/a maps) 919.000 parcels total | 586.000 parcels (5.800 maps) 862.000 parcels total |
| | 7 Number of parcels shown on new large scale cadastral maps (mostly 1:1,000) obtained by transformation from existing large-scale maps and isolated survey plans in | | |
| | 7.1 target urban centres provincial | 431,000 parcels (2,900 maps) | 370.000 parcels (3,400 maps) |
| | 7.2 target districts of Bangkok | 488.000 parcels (3.600 maps) | 492,000 parcels (3.700 maps) |
| 3. *Cadastral Surveys* Provide cadastral descriptions of land parcels by adjudication and cadastral surveys in areas of inadequate documentation. to meet the work progress of the land titling programme. | 8. Number of parcels adjudicated. surveyed, marks placed and description recorded on new cadastral maps. over non-forest lands in target provinces | 1.016.000 parcels total | 1,049,000 parcels total |
| | 8.1 parcels on 1:4.000 maps | 310,000 parcels (maps included at 6) | 251.000 parcels total (maps included at 6) |
| | 8.2 parcels on large scale maps (mostly 1:1,000) | 706.000 parcels (n/a maps) | 798,000 parcels (24.400 maps) |
| 4 *Organization and Management—Survey and Mapping* Strengthen the Department and the Education Institutions to be able to sustain the project for the 20 years and meet the output targets. | 9 Establishment of re-organized survey and mapping sector with new divisional status for photmapping. map transformation. adjudication and titling functions | 3 new Divisions | 3 new Divisions |
| | 10 Construct a new special-purpose survey and mapping building and begin operations | open in 1988 | open in 1988 |
| | 11 Number of undergraduates in the Chula University surveying course accepting DOL bonds | 120 students | 108 students (23 already graduated) |
| | 12. Chula course structure strengthened by inclusion of cadastral subjects | | |
| | 12.1 number of cadastral subjects offered | n/a | 4 subjects |

[a]Targets taken from annual work plan

Minor control is placed for two different purposes; control for cadastral surveys of parcel boundaries (especially in villages) and secondly, control for aerotriangulation in rural areas. In urban centres minor control is primarily used to provide control for aerotriangulation; and secondly, especially in Bangkok, to control the building of a mosaic of the individual survey plans from which the CIM is produced. The total control traversing in Phase I was equivalent to almost 3 circumnavigations of the globe.

The techniques used involve traversing between satellite determined control points or major control points with traverse lengths usually no more than 25 to 30 km in rural areas. Solar azimuths are taken. Marks are carefully placed, witness marks measured and recorded. Modern equipment was purchased at the start of Phase I; one-second theodolites, electronic distance measurement (EDM), constrained centring, and Doppler sets. In 1990 GPS positioning equipment was put into production to replace the Doppler. Computing facilities were procured to process and document the huge amount of calculations.

Technical assistance was important beyond just preparing tender documents. Within the Department advisers assisted in introducing satellite positioning; planning field-work, field observation procedures, computations, user documentation and training and most recently, error detection and GPS to local datum (Indian 1975) coordinate transformation. An EDM calibration baseline was designed and operational practices developed. Training in network adjustments and the application of small geodetic corrections to computations were given. Further, several staff were sent for postgraduate study to Australia and have returned with master's degrees in surveying. These people have proven to be an important asset to the Department, which augurs well for the future.

### Mapping

*Photomapping*

Given that the approach taken to accelerate cadastral mapping is to use rectified photomaps, the quality and production flow of these photomaps are a key output. On a format of 50 x 50 cm with 5-cm UTM grid lines, the black and white images are produced at scale 1:4,000 in rural lands (outside forest land) and scale 1:1,000 in major urban areas. Over 18,000 photomaps were produced in Phase I.

Techniques introduced to achieve the output involve annual aerial photography sorties during the flying season, under contract; use of high-level photography and digital aerotriangulation techniques with block adjustment by PAT-MR software to produce control for low-level rectification photography; automated plotting of control sheets and grids for rectification; and use of the low level photography for one step rectification from the centre of the photo.

Technical assistance for production planning and the many bid documents (aerial photography, analytical plotters, point transfer devices, computers, software, rectifiers, contact printers, automatic processing machines and LOG-E printers) was provided. Training and user documentation was important in aerotriangulation techniques and in photo development quality control.

*Cadastral map production by map transformation*

Cadastral maps on drafting film are drawn as overlays to the photomaps in both rural and urban programmes, depicting existing land parcels, and with UTM grid. No extra field work is required to draw these maps unless the records are known to be unreliable. In Phase I a total of 1.4 million parcels were transformed onto a total of 12,900 UTM maps.

In the rural areas manual transformation of existing NS3K parcels from photo enlargements has been by the "calibrated eyeball" technique, comparing detail on the old photo with that on the new photomap. It is being progressively replaced by digitizing the old maps, which provides higher quality, greater completeness and higher productivity. A total of 586,000 parcels were transformed from existing NS3K records during Phase I.

For existing title deed parcels there are two cases. First, in Bangkok, existing isolated survey plans are fitted to form a mosaic as an overlay to the photomap. Secondly, in the provinces existing maps are usually reliable and can be transformed directly. In both cases, control surveys provide coordinates of selected points such as when ground detail in the photomap is obscured by buildings or by foliage or is missing (i.e., not occupied). A total of 862,000 parcels were transformed from existing title deed maps and plans during Phase I.

Technical assistance provided the guidance for the initial studies on how best to undertake the tasks and to secure resources and organize them; to test alternative mapping methods, productivity rates, input needs and direct costs through the use of pilot studies within the Department for both manual and computer techniques. Long-term plans were developed and organizational units established. An automated mapping system was procured and put into production in late 1989, and an efficient work-flow methodology established and training given to all staff.

### *Cadastral surveys*

Cadastral surveys and adjudications of parcels occur systematically in rural areas, province by province, and in step with the other TLTP activities. Field documents and completed maps are used to prepare title deeds. In Phase I a total of 1,049,000 parcels were adjudicated and surveyed. The number of large-scale maps drawn from field data (24,400) was well beyond expectations, reflecting the very many villages that exist in rural Thailand.

In open farmlands the 1:4,000 photomap with overlay of existing parcels, obtained from the map transformation stage, provides a convenient basis for rapid completion of the cadastral pattern. In villages, field surveys are less efficient as parcel corners are coordinated by using measuring chain and offset from minor control traverses.

Technical assistance has not been required in this component because methods were already well established prior to the commencement of the project (UTM coordinates excepted).

### *Organization and management*

The organization and management component of the project has been very important to control and direct the sudden input of large resources, to coordinate the many project activities and ensure that the project is sustainable. Implementing change in a large organization is never to be taken lightly, and senior managers of the Department and advisers have worked together successfully to change, where appropriate, long-standing practices.

Three new survey and mapping related divisions have been created within the Department; Photomapping, Land Document Issuance and Urban Mapping. In addition, two existing divisions have been strengthened and reorganized; the Surveying and Computing Divisions.

The project's future depends upon people, and steps have been taken to provide well qualified recruits. The Department is bonding undergraduates in the Chulalongkorn University Surveying course, and so far 108 students have accepted; 23 have already graduated from among the first years' students. Also, the course has been modified to include four cadastral subjects (Cadastre 1 and 2, Cadastral Surveying, and land information systems (LIS)). Further, the departmental staff from all activity areas of the project have attended work experience training at organizations of the Australian Government and the private sector. Courses have been designed to meet the specialist needs of the attendees and have lasted one to three months each. Senior management have been sent on study tours to Australia to gain a broad appreciation of land management, especially opportunities and alternative approaches to existing problems.

Technical assistance has focused on change management through sustainable and effective technology, skills training and revision of existing practices. Planning and re-organization have been important contributions and advisers have worked closely with counterparts for best results. Visiting associate professors to Chulalongkorn have provided subject lecturing, lecture notes and course re-design inputs in cadastral and control survey, cadastral systems, land registration and LIS subjects.

## Conclusions

### *Phase I (1985-1990)*

The surveying and mapping outputs have provided an information base for the accelerated issuance of land title deeds. A total of 1.6 million were issued during Phase I. The new maps are on one national mapping system showing all parcels, are drafted on durable material and therefore provide an improved product over existing documents for both land office and external agency use. In particular, the Bangkok LIS pilot study involving four agencies is using the new cadastral index maps to develop a digital base over their study area. Control survey densification in urban and village areas provides for more efficient cadastral surveys, now and into the future. The foundation of a future integrated LIS is being laid.

Many resources have been successfully mobilized into an integrated multidisciplinary project. The success is due in no small part to people being committed to working together to change existing practices, where appropriate, and organizational and institutional structures, where essential, in order to reach the output targets set by the titling project. Nor has it occurred by dismantling long-held customs or institutional norms.

*Phase II (1991-1994)*

During Phase II the annual output rates will increase to ensure that the project will finish the titling of the country in the twentieth year. The main increases will be from the automated mapping system, by increasing the number of workstations, and from adjudication, by increasing the number of field teams. The Phase II output is planned and resourced over four years to output 3 million title deeds.

Technical assistance, funded by AIDAB in Phase II, will focus on improving the operations and management of the Department of Lands; in particular, it will focus on introducing information systems to operational, support and planning functional sectors. The Department has seen a rapid growth in land transactions over the last few years which has placed a strain on the organization. The transaction value of properties registered at land offices increased from Baht 140 billion to 540 billion between 1986 and 1989. Consequently, the Department is giving high priority to internal efficiency and service levels to the public.

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## PRESENT PROBLEMS OF CADASTRAL MAP DIGITIZATION AND GEOMETRICAL IMPROVEMENT*

*Submitted by Germany*

### RÉSUMÉ

Les données spatiales de base pour des systèmes d'information géographiques se référant aux biens-fonds ne peuvent être saisies économiquement que par la numérisation des présents plans cadastraux. La conception du système DAVID répond à ces exigences. DAVID fait fonction d'outil de numérisation, d'amélioration géométrique et de mise à jour des cartes et des plans à grande échelle. De plus, le système se distingue par sa rentabilité. Pour l'échange des données avec des systèmes d'information géographiques plusieurs fonctions sont disponibles. Grâce à ses multiples possibilités d'adaptation, DAVID peut également être utilisé pour diverses tâches en mensuration et cartographie. A cause de ses structures modulaires et de l'emploi de standards, c'est un système ouvert qui sera élargi successivement par des fonctions additionnelles.

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In the map series of the land registry cadastre, there is available a complete graphic record of landed properties in the Federal Republic of Germany. Such a landed properties-related, geometrical reference basis is needed as the foundation for various kinds of information. The objective of the project "Automation of the Property Map" (ALK) is therefore the establishment and management of standardized planimetric data which place the mapping and surveying part of the land registry cadastre at the user's disposal as a basis for a landed properties-related information system.

Spatial reference bases for geo-information systems require point fields for which all the coordinates are known. However, in order to be able to dispose of these geometrical bases in the cadastre in justifiable periods of time as a standardized spatial reference basis, pragmatic solutions must be given priority during the phase of initial acquisition of the digital data over perfectionist hypotheses, such as complete resurveying and calculation.

If the temporal and economic framework conditions are observed, then, for the foreseeable future, the surveying administrations will be able to find a solution only by digitizing the cadastral maps already available. In doing so, inhomogeneities must be taken into consideration which appear in the form of gaps between the calculated and the graphically-obtained coordinates, as well as at the edges and margins of neighbouring non-fullsheet maps. In the digital planimetric data stock, the coordinates that have been measured with a high degree of accuracy, or that are to be calculated on the basis of future measurements, must be used as determining elements, without the relative position of the purely graphically determined points being negatively affected.

The graphic system DAVID was conceived for this problem, that is, for finding the most economic method of digitization while at the same time taking the functional requirements into consideration, which are given for the proper establishment of geometrical bases. The integrated functionality of geometrical map improvement offers comprehensive possibilities for using suitable homogenization algorithms to prepare the data stocks that have been acquired

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through digitization. In this, DAVID is to be seen as the preprocessing component that is independent of the target system and which carries out mass acquisition as well as geometrical improvement. The data compiled in this manner are sent via interfaces to the target system. Through the bidirectional character of the interfaces, the overall strategy of a transference of the analog map series into a digital data stock with the objective of achieving gradual map renewal has been taken into consideration. In future, coordinates arrived at through new surveying will be able to be used for the continual improvement of the map geometry.

### Requirements of a graphics system

Possibilities for information processing in the graphics components of geoinformation systems are characterized by the comprehensive standard functionality of graphics data processing. Although specific problems may be executed with these graphics systems, this is often not the optimal solution, since these have not been specially customized to such applications.

The mass acquisition of cadastral maps, especially taking into consideration the geometrical improvement of the digitized map series and continual map renewal through the integration of new surveying results, is just such a special function. Universal graphic-interactive systems have not been developed for this specialist task. Their use in such tasks is not justifiable, especially with regard to economic and technical aspects, such as:

(*a*) Through the system-overhead of an information system, they are much too cumbersome for such mass processing;

(*b*) The user shell and operating interface are insufficiently related to the functional problems involved;

(*c*) Only a very small and limited part of their universal possibilities is really needed;

(*d*) The hardware costs are relatively high;

(*e*) The functionality for geometrical map improvement is not given.

For these reasons, the transfer of these extensive specialist tasks to an appropriately conceived subsystem is expedient. With the DAVID system all tasks arising in connection with the acquisition, updating and geometrical improvement of large-scale maps can be resolved. It distinguishes itself above all through the following functionality:

(*a*) An online digitizing system for the economical map acquisition of cadastral maps, while taking into consideration all the requirements resulting from geometrical improvement;

(*b*) Geometrical improvement, using information from all reference points as well as from the gaps at the edges of non-full-sheet maps and taking into consideration the geometric conditions;

(*c*) The ability to tie in programmes for geodetic evaluation and calculation on the basis of the planimetric data already stored;

(*d*) Redundance-free storage of the geometry with the user-selectable encrypting of functional information and variable defining of the symbol legend;

(*e*) An operating interface that is easy to learn and user-friendly;

(*f*) Data interfaces to geo-information systems.

The optimized system run-times in DAVID lead to short response and image-creation times and so form the basis for numerous special functions in the course of map acquisition.

### Setting the system parameters

The organization of graphic-interactive systems requires a structuring of the specific job functionality during alignment to the respective user-requirements that remains as variable as possible. Appropriate initialization of the DAVID system is carried through by, among other things, setting parameter files. These offer the user the possibility of determining acquisition functions, functional definition, their effects on the geometry as well as the form of representation according to the user's own application requirements:

(*a*) Functional definitions of geometrical elements have been stored in an encrypting catalogue that can be freely defined by the user;

(*b*) Relationships between individual functional definitions may be set by parameters; this was conceived with a view to achieving a flexible alignment of the geometry treatment to the functional definition. In this way it is possible, among other things, to determine the functional definitions of points which would prove to be bending points for the respective line definition. Further, it is possible to set those functional definitions to which a functional definition must be added or even functional definitions which are mutually exclusive (for example, marked and unmarked border points);

(*c*) Digitizer menu, the keyboard allocation for the digitizer cursor and the menus on the graphics monitor may be set freely.

The settings for the graphic representation are also stored in parameter files:

(*a*) The presentation list determines the elements of the data stock that are to be represented on the monitor or plot. This basic value may be interactively altered. In this way, DAVID permits certain contents of the data basis to be faded in and out and so avoids a screen that becomes overcrowded with information. This leads to a high degree of evaluative capability of processing stocks and of work processes;

(*b*) Representation of the geometrical and functional information on the graphics monitor, respectively, on the plot, is also controlled by a parameter file. This symbol-regulation file contains all the information required for the structuring of the relevant version (this means the specimen sheet that is to be used in each case). Thus it is possible to structure user-related representations so that, for example, one and the same data stock may be variously represented through the use of different symbol-regulations.

### DAVID: Digitizer component

The digitizer component in DAVID has been specifically designed for the mass acquisition of large-scale maps and plans. This includes a convenient and user-friendly operating interface as well as function-related plausibility checks. Together with the representation on the graphics monitor, they contribute towards the ability to discover mistakes immediately during the digitization process. Many functional checks may be previously defined by the user in presetting files, as explained in the section on parameter settings. All the requirements of geometrical map improvement are supported in the digitizer component.

#### *Conceptional features*

From the viewpoint of geometrical improvement, the digitizing process is characterized by the following points:

(*a*) Prior to map fitting, transformation units or models may be set. In many cases a model will correspond to a whole map; for previously known and clearly delimitable inhomogeneities within one map, such as can occur through different forms of origin (for example, original acquisition, land consolidation, cadastral resurveying), this map will be subdivided into several models in the course of the further steps; these are then each treated as independent maps;

(*b*) Each model is fitted using a few control points (for example, grid sections) so that the Gauss-Krüger coordinates can be calculated. The model fitting has been conceived in such a way that, for example, during post-digitization, the use of the same control points is guaranteed. Geometrically improved Gauss-Krüger coordinates, however, arise only in the course of the processing steps designed for this;

(*c*) Digitized coordinates may be allocated to calculated coordinates without the necessity of a coordinate exchange. Thus, the possibility is given for decisions having to be made only after complete digitization—supported by statistical tests—as to which reference points might not need to be considered during the homogenization steps. In each case, the information of all reference points is used for the final fitting into the reference system;

(*d*) Gaps at the map edges also form a potential for information for geometrical map improvement. Model edges are therefore acquired and stored as a special map content element, during which the various coordinates from each model are stored for the identical points;

(*e*) Geometrical conditions are—as a rule, implicitly or semi-automatically—acquired, tested for plausibility, allocated and stored. Similarly, corrections and post-acquisition of the geometrical conditions are possible. Their restoration follows as the last step of geometrical improvement through two-dimensionally active adjustment. Immediate restoration makes no sense because the conditions are partially destroyed again through the improvement measures that follow;

(*f*) The effects of functional definitions on geometry acquisition and processing are taken into consideration.

### *Features relating to acquisition*

The content of a cadastral map is structured in line with special aspects of digitization including subsequent geometrical improvement into:

(*a*) Geometry and geometry parameter;

(*b*) Technical functions of the geometrical elements;

(*c*) Information specific to homogenization (for example edge and reference points etc.).

The DAVID digitizing system was conceived so that in the course of a processing step as many of the named map information items as possible, for example, geometrical conditions, can be acquired. Furthermore, plausibility tests and sampling are integrated.

The logical data structure forming the basis of this is independently created and updated by the system regardless of the order of acquisition of map elements. The user is thus in a position to carry out the digitization process with the greatest degree of flexibility. Since the graphic symbol system of a cadastral map is largely based on lines, or can be deduced back to these via the outer borderlines of two-dimensional objects, a line-by-line process of acquisition would also seem sensible. Other procedural methods are possible, however, so that, depending on the respective application of the control requirements, economy aspects, training level of the operator etc., the digitization process can be varied. The program run is steered using "switches" as basic settings; these are, for example:

Coordinate treatment (mean/old/new/question)
Search for points (yes/no)
Search for reference points (yes/no)
Search for lines (yes/no)
Enter point in discovered line (yes/no), etc.

These switches have been conceived as permanent switches, that is, they retain their validity up to the next change. In order to reverse these standard assumptions during acquisition, supplementary switches are available for most of the switches. Their activation merely reverses the definition of the permanent switch for the next point to be acquired.

### *Acquisition of map geometry*

Map geometry may be divided into a point geometry, a line geometry and geometrical structures. It is described by points, linking information as well as by geometrical interdependencies and conditions.

The acquisition of the line geometry is as a rule uncomplicated as long as there are no interdependencies in the form of geometrical conditions between the line elements. A possibility of acquisition for such geometrical structures is given through constructive digitization: coordinates which are bound into geometrical conditions do not appear directly, but rather after consideration of the constructive features that form the line network. Manual drawing is imitated during this. In this, it is for example necessary to first digitize the superior lines, and only then are the intermediate points acquired and strictly calculated into the equation, in most cases from lines lying to one side; line elements that are parallel and at right angles to each other are directly constructed. This procedural method requires, however, that a point location that has been determined retains its validity even in the case of a renewed digitization of the relevant point, because otherwise the geometrical structure, which had been determined on account of the construction, would be destroyed again.

Using this method of acquisition, a satisfactory map can only be produced from the point of view of optical impression. From a geodetic viewpoint it must be stated that for the constructive method of acquisition—above all in maps with only few coordinated points—the information potential available, which also lies in the two-dimensional interdependencies of continual conditions, makes no contribution to the improvement of the neighbouring precision. Rather, the geometrical conditions are locally implemented, that is, without reference to the map elements in the neighbourhood. Moreover, this method has an unfavourable error reproduction, since digitization errors are extrapolated in continued point construction. A further disadvantage is to be found in the fact that the method is very time-consuming and therefore cost intensive.

In the DAVID digitization component, the system is merely informed in the preset values as to such characteristics as straightness of lines, rectangularity, circle continuity, parallelism, distance, etc., and the conditions stored. The restoration is undertaken only as the final step of the geometrical improvement using two-dimensionally effective adjustment. In this, conditions are formulated as a function of the homogenized digitizing point locations, the most plausible point shifts emanate from the mediating effect between neighbouring conditions. This procedural method is more exact and still considerably faster than constructive digitizing:

(*a*) Restoration occurs not because of a method which is dependent on the procedural method adopted by the operator, but rather through numerical evaluation which is independent of subjective influences;

(*b*) Restoration occurs in the homogenized point data stock, that is, after removal of irregular distortions between graphic map information and the corresponding numerical evidence; points with reference coordinates in this stand for geometrical conditions with the uppermost priority;

(*c*) Since it is always the original coordinates that are stored, a mean may be formed after several digitization processes. In this, the gain in precision through multiple acquisition is also exhausted.

The conditions arise as additional information during digitization with DAVID. They may be simultaneously acquired along with the remaining map content, whereby the flowing acquisition of points and lines is not obstructed through the recognition of conditions. A multiple acquisition of points for the sole purpose of defining geometrical conditions can be dispensed with. The "conditional line" switch for straightness of lines and rectangles controls automatic acquisition in the course of the digitization whereby the conditions of freely selectable tolerance levels occur. Through the inclusion of the conditional analysis into the digitization process, acquisition is additionally tested. The automatically or semiautomatically defined conditions are stored as additional information. In so far as the conditions relate to already digitized points, they may be post-acquired or changed using a separate function.

The acquisition of the geometry is supported by relevant functions for geometry treatment. Among these there are, above all, the linking of just digitized geometry with already existent geometry and, what is more, possibly under consideration of the effects of functional definitions.

An inner and an outer circle are designed to search around points and along lines. The catching is automatic if an element is within the inner circle and if it is the only element that was found. If, by contrast, the point only lies within the outer circle or if there are several elements within the inner circle, then the operator is offered the elements of the inner as well as of the outer circle, sorted according to distance. In such cases, the operator can and must decide. Through defining the circle sizes, which may be set according to the presented map, the operator has, for example, the choice of reducing the system queries to a minimum.

### *Acquisition of functional definitions*

In addition to the linking information and possibly the geometrical conditions, the functional definition must be given for a digitized point as well as for a line. A catalogue for the encryption of functional definitions for map elements may be customized by the user.

The point and line functional definitions that are currently to be given are to be found in the point functional definition lists or in one-line functional definition list. The second-point functional definition list serves the acceleration of acquisition, since it may be selected for the next point, instead of the first-point functional definition list via an alternate switch.

The functional definition that has been respectively set is tested for plausibility upon coincidence of functional definitions. These checks are based on the relationships between the individual functional definitions which were set at the commencement of work in corresponding parameter files, for example the fixing of a determinant point for a line functional definition or mutually exclusive functional definitions. Moreover, along the current line the same functional definition is searched for after crossed lines. Any intersections are marked.

### Geometrical map improvement

The functionality of geometrical map improvement is not only applied to map renewal. It is also of necessity for pipeline or cable documentation where the homogeneity between graphical records and the calculated coordinates has to be established. Improvement measures are similarly the pre-condition for the use of digital maps in two-dimensional information systems in which the data access is to be kept immediately available in a map sheet independent form with no interruptions, as well as for their updating together with modern geodetic acquisition and evaluation methods. These are of necessity for both non-fullsheet and full-sheet maps, although to differing extents.

The geometrical improvement of large-scale maps and plans consists of the gap-free fitting into the Gauss-Krüger reference system—the homogenization—as well as the restoration of geometrical conditions. In this, the gaps between the digitization coordinates and the calculation points within the reference points are used for the improvement of all the other map points.

Any further information is, if needed, taken from the gaps between the edges of full-sheet maps. The procedure runs through several progressive working stages:

(*a*) Using globally effective (possibly chained) affine transformations, those gaps are first removed which are systematically spread over a whole map sheet;

(*b*) Following this, the remaining, at most locally systematic, residual gaps are completely removed using locally effective interpolation methods;

(*c*) Finally, the geometrical conditions that are attached to map geometry (for example straightness of lines, rectangularity, parallelism, distance, etc.) are restored using two-dimensionally effective adjustment methods.

The results of each of these work stages is represented on the monitor in a user-friendly form, so that a proper evaluation and optimal control of the geometric improvement can be guaranteed. Furthermore, each result may be documented in the form of a plot. This is further complemented by the clear result protocols which are produced after each stage.

As preparation for homogenization, all of the available reference points for a map receive their respective digitized point. This is already possible during digitization, although it may have a disruptive effect on the work routine. The allocation may therefore also be undertaken after digitization and, what is more, it may then be semi-automatic using the double circle method. Operator access is only necessary during this if no unambiguous allocation is possible through the system. The allocation of identical edge points (tie points) as a pre-condition for the numeric tieing of neighbouring models runs simultaneously. The common edge line is found during this without any operator intervention. On account of the principal importance of the reference and tie points for the homogenization measures, the allocations are tested with statistic checks.

Only when this has led to reliable statements on the discrepancies present in the reference points being available, can the transformation with those control points in which the gaps correspond to the distortion trend in the model be implemented for the removal of the model-wide systematic map distortions. On account of the affine character of the remaining map, the affine transformation is used as the transformation form. There are two procedural methods available for the proper execution of this, which merely differ in the degree of inclusion of tie points.

In the first procedure, a chained transformation is possible with independent models in accordance with the principle of block adjustment. The adjustment results in this case are the transformation constants for the individual models, as well as the reference positions of the tie points. As an alternative to this, it is possible with a single transformation to calculate the transformation constants from the control points of each model alone. The reference positions of any control points that are possibly present are then gathered, using the (weighted) mean of the coordinates from the respectively affected models.

Chained and single affine transformations may also be combined within one process. The use of the former is basically limited to full-sheet maps. The condition for their use is that conclusions can be made for the whole model from the model edges. Furthermore, such models for which there are too few or too poorly distributed reference points may also be transferred to the reference system using this. Single affine transformations are generally used with adjoining-sheet maps, as well as the full-sheet maps whose edge lines allow no conclusions to be made for the whole model.

Owing to the affine transformation, the gaps at the reference and tie points may be minimized, but they are not totally removed. If, in order to remove these residual gaps, only a coordinate exchange were used at these points, then the neighbourhood reference to the other map points would be damaged. With the introduction of the reference coordinates these must therefore be accompanied by an improvement of the other points, retaining an accurate spatial relationship. It is possible to choose between the multiquadratic interpolation method or the "transformation through distance weighting" methods for residual error removal.

After this step, there may still be a homogeneous point data stock. However, the geometrical conditions between the map elements have not yet been expressly considered in the steps taken. They may have been disturbed for several reasons, essentially through inaccuracies in the cadastral map and through digitization inaccuracies. Moreover, the homogenization measures, partially, have the effect of producing irregular coordinate changes. In this respect, the geometrical conditions would then have to be restructured for each case if they were implemented directly, subsequently to digitization. For this reason, the conditions in the DAVID system are stored as additional information and the homogenization and conditional restoration carried out on the basis of the original digitized data.

The restoration of the geometrical conditions is carried out model-wide by adjustment—including the use of transmodel conditions. In this way, a best possible integration of the geometrical conditions into the homogeneous data stock (following residual error removal) is achieved. The adjustment is undertaken separately for hierarchically structured object groups (for example model edges, parcel boundaries, buildings, other geometry elements). Point positions calculated in a hierarchy stage follow into the subordinate hierarchical stages as reference positions. In this way, the conditions of a lower hierarchical stage are forced to be fitted into the previously geometrically implemented object groups in the proper form and with the proper reference. Points with reference coordinates are then, in principle, halted as being unchangeable.

As a final measure, there is a (partially automatic) reprocessing of the edge lines of the models with respect to those points which have not been used as tie points. Next to the positional testing of the map edges, there is an additional test with regard to the functional definitions and the geometrical conditions at the edge points and lines. Any discrepancies at these points may be immediately interactively removed. The adaptation of the edges of adjoining-sheet maps also occurs semi-automatically with the assistance of "auxiliary points" which were digitized as intersections of lines with the map edge. An edge test automatically checks the position of these auxiliary points as well as the functional definitions of departing line sections and the elimination of auxiliary points in each case.

### Adoption of data from third-party systems

Interfaces to existing graphics systems guarantee that even data that have been acquired in these systems may be included into the preparation and improvement measures or that the data that have been acquired and improved with this subsystem can be ported to these systems. Similarly, the data exchanges with regard to gradual integration of new surveying results for the purpose of a continual improvement of the digital planimetric data stocks are undertaken via these interfaces.

In so far as acquisition has been carried through with a graphics system that allowed no storage of geometrical conditions, then these may later be interactively post-allocated. Furthermore, a semiautomatic "snooping" of geometrical conditions, using staged and differentiated tolerance values is envisaged, that are determined depending on the geometrical reliability of the respective condition and may be varied in accordance with the map original. Moreover, such procedures of semiautomatic condition acquisition are especially necessary with regard to an automatic digitization of maps using scanning and pattern recognition methods.

### Additional DAVID functions

As a user-orientated graphics system, DAVID comprises easy-to-use graphics editing functions, variable display possibilities as well as integrated surveying calculus. This makes DAVID ideal for deployment in a great variety of map-making and land-surveying tasks.

Through the linking facilities with other programme systems (register tachymeter evaluation, land-surveying programmes, balancing programmes, coordinate interfaces) DAVID provides an all-round solution for the work of land-surveying offices, cadastral authorities and energy supply companies. For this, an uninterrupted data flow from the field registration to the map has been established. As an option, the surveying calculus may be fully integrated into graphics. All the calculations may then be executed on the basis of the stored planimetric data using the graphics-oriented user interface. The identification of coordinated points is possible both by inputting the point-number as well as by using the cursor control unit on the graphics monitor or via the digitizer cursor. The graphics system permits immediate continued processing of recalculated points.

A stock of point and planimetric data is integrated into DAVID, providing a basis for interactive sketch processing. Using DAVID it is possible to create, process, structure and store plans and large-scale maps. The comprehensive functionality of the convenient graphics editor is available for this. The differing display possibilities for all point and line elements facilitate specific cartographic structuring.

### Conclusion

In today's industrial society, cartographical information forms an indispensable basis for numerous decisions in administration and industry. For this, numerous individual items of information must be available in computer-aided information systems and must be interdisciplinarily and independently linkable with each other. The need for corresponding cartographic basic data, for example in planning, in environmental protection or for pipeline or cable operators can be fulfilled only with digital cadastral maps. The DAVID graphics subsystem was conceived for the comprehensive problems which arise in relation to the structuring of a State-wide, homogeneous, geometrical reference system for computer-aided information systems. In its large-scale oriented digitizing components it contains complete functionality for far-reaching geometrical improvement of the map planimetric data. Through its modular structure, and its ability for parameter setting, as well as through its use of standards, numerous possibilities for further development are moreover guaranteed. DAVID was presented to the public on the occasion of the German Geodesist Conference (Deutscher Geodätentag), 1988, in Berlin. The programme has been in practical use at the State Surveying Office in the Rhineland-Palatinate since the beginning of 1989. Further planning foresees the gradual equipping of all land registry offices in the Rhineland-Palatinate with DAVID.

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## (d) *Navigational and bathymetric charting*

## STATUS OF INTERNATIONAL (INT) CHARTS*

*Paper submitted by International Hydrographic Bureau*


### RÉSUMÉ

La nécessité de normaliser davantage les cartes marines de façon à renforcer la sécurité de la navigation internationale est à l'origine de la création, en 1921, de l'Organisation hydrographique internationale (OHI). Toutefois, ce n'est qu'en 1967 qu'il a été décidé d'envisager une série internationale de cartes marines qui seraient compilées et établies selon des règles acceptées sur le plan international.

Les spécifications techniques définies par l'OHI pour la série internationale ont été mises au point et adoptées en 1982. Parallèlement, on a élaboré le plan d'établissement des cartes, la première phase ne portant que sur des cartes à petite échelle — 79 d'entre elles ont été réalisées dans les années 70 et 80 — et la deuxième, sur des cartes à moyenne et à grande échelle. A cette fin, il a été créé, dès 1986, des commissions régionales d'établissement de cartes marines pour l'ensemble de la planète, trois d'entre elles ayant leur siège dans la région de l'Asie et du Pacifique occidental. A ce jour, 211 cartes marines de la série internationale à moyenne et grande échelle ont été établies, qui portent principalement sur les eaux du nord-ouest de l'Europe. Pour ce qui est de la région du Pacifique occidental, le plan d'établissement des cartes de la série internationale a été mis au point et adopté en 1990, les travaux étant coordonnés par le Japon. Deux autres plans concernant l'Asie sont en cours d'élaboration.


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### Concept of the international chart

The International Hydrographic Organization was formed as the result of a desire for greater standardization of nautical charts and associated publications and consequently for greater safety for mariners. It was felt that this standardization could be achieved in such a way that language differences would be minimized and that a chart produced by one country would be perfectly comprehensible to a navigator from another country.

Although measures have been taken since the formation of the International Hydrographic Bureau (IHB) in 1921 to develop standards to be followed nationally when producing charts and publications, it was not until 1967 that the concept of an international chart was proposed. It was felt that, instead of several different hydrographic offices, each producing different charts of the same ocean area, often with differing data, scales and limits, it would be both more economic and safer if one hydrographic office would compile and produce an original chart, to internationally agreed specifications, which hydrographic offices would be able to print using the basic reproductive material provided by the original producer nation but substituting their own language, if they wished.

The first step was to agree on the standardization of the format and symbols to be used on international charts. The 1967 International Hydrographic Conference established a

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Commission which, working by correspondence, developed the "Chart specifications of the IHO" which were adopted at the 1982 International Hydrographic Conference. These specifications are published as IHO publication MP-004, of which a new edition, composed of six sections, was published in 1989/90. The specifications are applicable to all International (INT) Charts and recommended also for all national chart series.

It was also necessary to develop an agreed scheme, at agreed scales, to provide world-wide coverage. A system of two series of small-scale charts at scales of 1:10 million (19 charts) and 1:3.5 million (60 charts) was agreed. The two series were published during a 15-year period starting in 1972. This provided international shipping with uniform modern chart coverage for all ocean passages.

In 1982, the success of the small-scale INT Chart Series led to the consideration of extending the concept to include charts at medium and large scales. Following the International Hydrographic Conference of that year, the North Sea Hydrographic Commission began to assess the problem by making a pilot study of the North Sea. Once again the member States involved had to agree to a chart scheme that would satisfy the needs of international shipping for that area. It was agreed that this would include medium-scale charts of coastal and sea areas at scales between 1:150,000 and 1:1.5 million, and approach and harbour charts at scales greater than 1:150,000. Agreement had been reached that the maximum paper size should be defined as being AO (1,189 × 841 mm).

Following the study of INT Charts at medium and large scales for the North Sea, regional chart commissions were established for all of the other regions around the world. Their task is to develop chart schemes for their regions, leading eventually to a total world coverage of INT Charts at medium and large scales for all of the world's main shipping routes, ports and port approaches.

This coverage may be complemented by large-scale national charts for navigation by mariners requiring a more detailed knowledge of a country's waters. As of November 1990, 211 INT Charts at medium and large scales had been published, primarily of the waters of north-west Europe.

While emphasis has been given to the production of charts, it has been realized that there may be some benefit in having all hydrographic publications, such as *Sailing Directions, Light Lists* and *Tide Tables*, standardized. Several studies have been undertaken but it has been shown that, due to language differences and particular national requirements, such standardization is impractical except in terms of standardizing the lay-out and overall presentation of these complementary publications.

At present, nationally produced charts and other publications are maintained up to date by a system of national *Notices to Mariners*, and even though the INT Charts form part of an international folio, they are maintained up-to-date by the producer nation. As the INT Chart becomes a more truly international series, it is conceivable that a complementary set of international *Notices to Mariners* may be developed.

## Status of INT Charts at medium and large scales in the Asia area

As stated above, the International Hydrographic Conference decided, in 1982, to develop a world-wide coverage of international charts at medium and large scales.

The work was carried out on the initiative of the IHB, in consultation with the IHO member States. The first step consisted of forming regional working groups for the production of large- and medium-scale INT Charts. Starting points were:

(*a*) Existing national charting schemes;

(*b*) The World Wide Navigational Warning Service (WWNWS);

(*c*) Existing Regional Hydrographic Commissions (e.g. the East Asia Hydrographic Commission, EAHC);

(*d*) The small-scale INT Chart Series at scale 1:3.5 million.

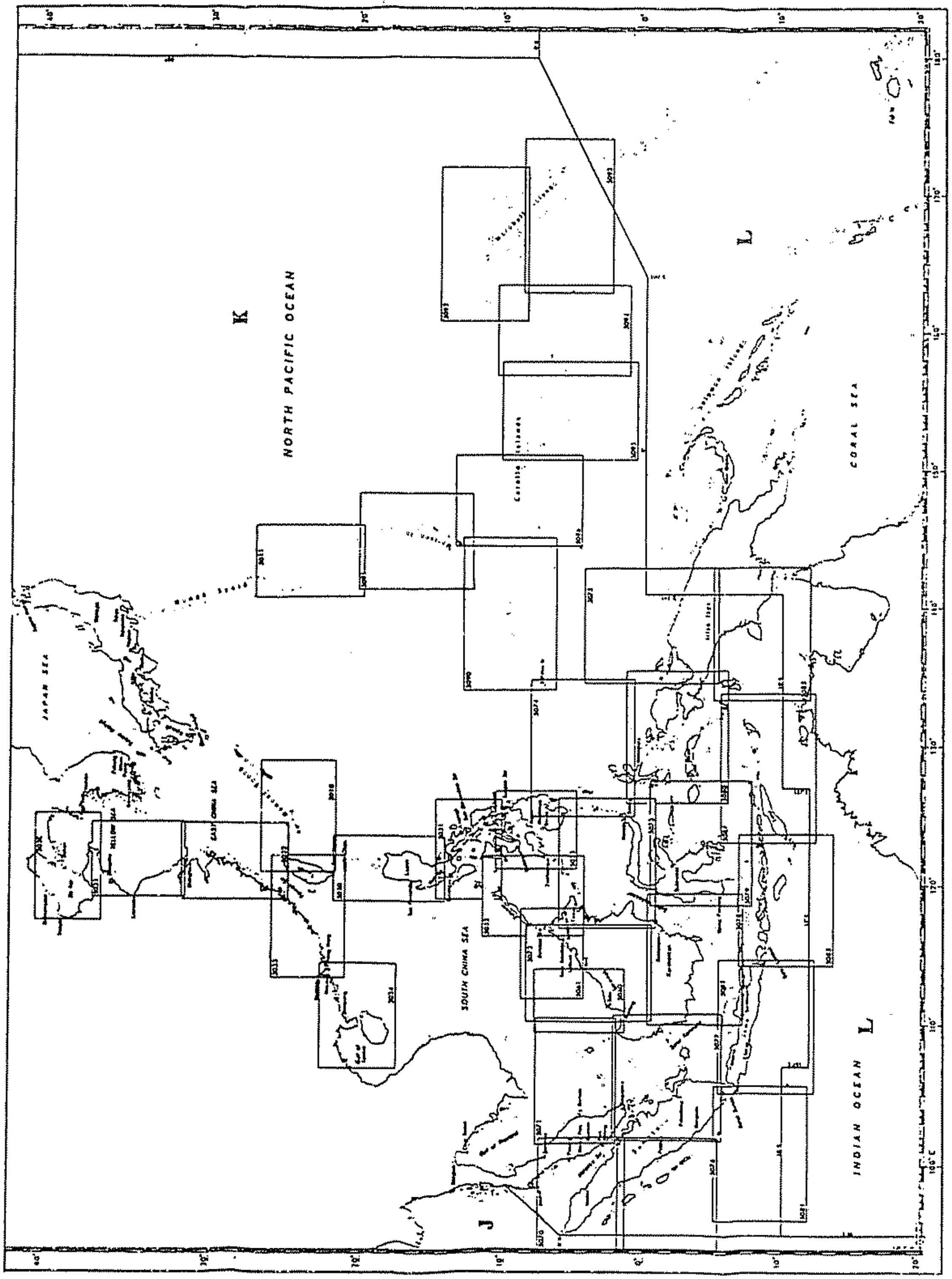
The formation of 12 regional charting areas was achieved in 1986, numbered from A to L. The Asia and Pacific area is covered by regions J, K and L. Since 1986, INT Chart schemes have been developed within each region under the chairmanship of a coordinator country: India for Region J, Japan for Region K and Australia for Region L.

Countries involved in the preparation of each scheme include IHO member States of the region, other IHO member States who publish charts in the region, and non-member States of the region who have a genuine interest in nautical charting.

Schemes for Regions J and L are almost agreed and the scheme for Region K was accepted in October 1990. In addition to Japan, the following countries participated in the work: China, Indonesia, Malaysia, Philippines, Thailand, Singapore, Republic of Korea, Australia, France, Federal Republic of Germany, United Kingdom, Portugal, USSR and United States. The final Region K INT Chart Scheme at medium scales 1:1,000,000-1:510,000 is attached as an annex.

ANNEX

**INT Chart scheme at medium scales for Region K**
*(Coordinator: Japan)*



## (e) *Thematic mapping*

### TÉLÉDÉTECTION SPATIALE ET INVENTAIRES FORESTIERS*

*Document présenté par la France*


#### SUMMARY

The aim of this study is to assess the role of the SPOT high resolution visible (HRV) data in forest inventory planning and to set up the best combination between the available information levels: ground, aerial photos and satellite images.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Pour la réalisation d'inventaires forestiers plusieurs stratégies sont possibles en fonction du type d'inventaire à établir, mais le schéma le plus couramment utilisé fait intervenir les trois étapes suivantes :

*a*) Stratification du peuplement, cartographie, surfaces;

*b*) Sondages terrain;

*c*) Dépouillements statistiques des données et interprétation des résultats.

Les photographies aériennes ont été jusqu'à maintenant les principaux documents utilisés pour la stratification mais, compte tenu des contraintes liées à leur disponibilité, leur coût et leur délai d'exploitation, les données de satellite peuvent être susceptibles d'offrir une alternative, encore reste-il à connaître le degré d'intégration des informations satellitaires dans un dispositif d'inventaire.

La recherche se situe au Sud-Mali sur 50 000 ha, à 200 km environ de Bamako, en raison d'une part, de sa "relative richesse en ligneux". et, d'autre part, de l'existence d'une zone-test inventoriée lors du "Projet d'Inventaire des formations ligneuses du Mali".

#### LES PRINCIPALES CARACTÉRISTIQUES DU MILIEU NATUREL

Appartenant au domaine soudano-guinéen (1 200 à 1 500 mm de pluies sur environ six mois), dès le mois d'octobre l'humidité atmosphérique régresse très vite et la période optimale pour l'étude des ligneux se situe normalement entre le 15 décembre et le 15 janvier.

Le paysage morphopédologique est marqué par des plateaux et des collines fortement cuirassées, des vallées alluvio-colluviales, rejoignant un ensemble alluvionnaire formé par le Fié, affluent du Niger.

La végétation ligneuse se compose en grande partie d'une forêt claire à *Isoberlinia doka* colonisant à peu près toutes les positions topographiques et présentant de nombreux faciès de dégradation. Par ailleurs les forêts galeries, bien reconnaissables sur images de satellite, constituent un milieu au potentiel ligneux important.

Enfin, le quart de la zone est occupé par une formation herbeuse, assez caractéristique : le bowal, plateau fossilisé par une cuirasse affleurante ou sub-affleurante, avec par endroit une formation ligneuse originale : la brousse tigrée ou tachetée.

#### LES TROIS NIVEAUX D'INFORMATION

*SPOT*

Scène 40-327

*a*) Données numériques : CCT XS 10/12/86

*b*) Données visuelles : Composition colorée 1/ 60 000 31/03/86
Composition colorée 1/100 000 10/12/86
Composition colorée 1/100 000 10/01/87

*Photos aériennes*

Danchromatiques, 1/50 000 : Mission MAL 097, 28/11/87
Mission de 1975
Couverture partielle de 1983

Les missions de 1975 et 1983 ayant été exploitées pour l'inventaire, seuls les produits résultants ont été utilisés : cartes de la végétation et de la morphopédologie.

*Terrain*

*a*) Résultats de l'inventaire : sous forme d'estimations du potentiel ligneux de la région à partir du sondage de 16 unités de 15 ha chacune, (UP);

*b*) Données de terrain acquises dans le cadre de l'ATP.

#### MÉTHODOLOGIE ET PREMIERS RÉSULTATS

*Stratification à partir des données SPOT*

Les traitements numériques, réalisés à l'EJN, ont utilisé la classification numérique supervisée selon l'algorithme du maximum de vraisemblance.

Dix thèmes ont été retenus : forêt galerie, forêt claire, savane boisée, savane arborée, bowal (typique ou arboré), prairie, culture, brûlis, reprise de végétation sur brûlis. Des procédures spécifiques (forme, compacité, érosion, dilatation etc.) ont amélioré la classification originelle et permis de discriminer des thèmes à radiométrie voisine.

Pour juger de la qualité des résultats de la classification, deux matrices de confusion ont été calculées : la première sur les zones d'entraînement a conduit au regroupement des deux types de bowé (typique et arboré). La seconde matrice compare, sur le tiers de la zone, la classification SPOT et la photo-interprétation et met en évidence les difficultés à appréhender avec précision certains thèmes qui représentent néanmoins en terme de potentiel ligneux des unités différentes. D'où la nécessité d'étudier une autre démarche faisant intervenir davantage la texture des formations végétales à confusion systématique. Cette étape est en cours de réalisation sur plusieurs fenêtres de l'image.

Les traitements visuels, en cours également, ont à partir des trois compositions colorées fourni une liste de variables descriptives qui ont été classées automatiquement (hiérarchique et correspondance). L'évaluation thématique des résultats obtenus par utilisation des cartes de végétation et morphopédologique a permis de vérifier l'homogénéité des classes et ainsi d'isoler les variables jugées les plus pertinentes.

*The original text of this paper appeared as document E/CONF 83/L 43

*Approche quantitative*

On dispose d'estimations de volume sur 16 unités d'inventaire de 15 ha et de 4 types de stratification :

Morphopédologique,
Végétation,
Densité de couvert/occupation du sol,
Classification sur image SPOT.
} photo-interprétation

L'objectif est d'estimer le volume de bois total sur la zone qui s'étend sur environ 50 000 hectares et de chiffrer la précision obtenue.

Plusieurs approches, avec ou sans stratification, ont été testées :

*a*) La méthode directe consiste à considérer la productivité à l'hectare comme une variable aléatoire pour laquelle on connaît 16 mesures. La moyenne empirique est une estimation de la productivité moyenne et l'intervalle de confiance est donné par la loi de Student. Le volume total de la zone est obtenu par multiplication par la surface.

*b*) La deuxième méthode considère que la productivité est une variable correlée avec la densité de bois et dans cette optique l'indice de végétatio (IR-R/IR + R) est utilisé pour la régression.

*c*) La classification supervisée ayant défini 10 thèmes dont 7 ont une densité de bois non nulle, sur chaque UP est calculée la proportion des thèmes puis on résoud par moindres carrés le système.

*d*) La photo-interprétation basée sur la densité du couvert n'a été réalisée que sur les UP de l'inventaire, aussi les surfaces totales ont été calculées à partir de la classification en considérant la matrice de confusion comme matrice de passage.

Comparaison des résultats :

ESTIMATIONS SANS STRATIFICATION

| | *Estimation directe* | *Estimation sur indice de végétation SPOT* |
|---|---|---|
| Ecart-type $m^3$/ha | 31,54 | 18,07 (coefficient de corrélation = 0,6878) |

Ces deux méthodes supposent un tirage aléatoire des échantillons de mesure. Les chiffres ne sont donc pas directement comparables aux chiffres obtenus par stratification puisque les échantillons ne sont pas aléatoires.

Néanmoins, l'apport de l'indice de végétation permet de presque doubler la précision.

ESTIMATIONS SANS STRATIFICATION

| *Ecart type* $m^3$/ha | *Morphopédologique (1)* | *Végétation (2)* | *Densité du couvert (3)* | *Classification SPOT (3)* |
|---|---|---|---|---|
| Résiduel aux observations | 8,25 | 3,72 | 3,77 | 6,70 |
| Pour une population optimale | 8,96 | 4,14 | 5,54 | 19,76 |
| Pour ce plan de sondage et cette stratification | 43,69 | 5,06 | 16 74 | 25,92 |

L'apport de la stratification par elle-même est donné par l'écart-type résiduel des observations. La qualité du plan de sondage (par rapport à la stratification) est évaluée en examinant le degré de liaison des équations et la représentativité des échantillons par rapport aux populations réelles :

1) Approche de stratification inintéressante.

2) et 3) Stratification de qualité égale. Le plan de sondage utilisé a été conçu pour la stratification (2)

4) Plan de sondage inadapté mais stratification correcte.

## CONCLUSION

Ces premiers résultats montrent qu'il est tout à fait envisageable d'utiliser SPOT dans l'optique d'un inventaire forestier en zone sèche; la classification numérique fournissant une première stratification du milieu éventuellement complétée, par un échantillonnage sur photo aérienne. D'autres données à venir préciseront ces premières constatations qui seront ensuite testées sur une autre scène SPOT dans la même région écologique

RÉFÉRENCE

Nasi, R., et M. Sabatier (1988). Projet inventaire des ressources ligneuses au Mali : les formations végétales. Rapport de synthèse, 197 pages CTFT/CIRAD–SCET/AGRI. Etude financée par le Ministère de la coopération française

# UTILISATION DES MESURES SAISIES EN VOL EN AÉROTRIANGULATION : GPS, CAPTEURS DE PRESSION, TÉLÉMÈTRE-LASER*

*Document présenté par la France*

## SUMMARY

During the short summers of 1986 and 1987 the Institut géographique national of France conducted nine experiments to assess the capabilities of airborne measurements to reduce the need for ground control in aerial triangulation.

First, aerial triangulation with very dense ground control and check points was used in all experiments, as a basis of comparison to evaluate the accuracy of airborne measurement data. When the degree of accuracy reached was considered sufficient, the second step was to use this data as observations in the adjustment with photogrammetric measurements and reduced ground control; when possible, the third step was to eliminate all ground control points, except one.

*The original text of this paper, prepared by Claude Million, Institut géographique national, appeared as document E/CONF 83/L 42

In all three steps the results were evaluated by computing the root mean square error on the check points.

The first two tests involved the combined use of statoscope and laser range measurements from a Falcon 20 flying over a wooded and hilly rural region of central France. Unfortunately the statoscope froze at the elevation of 16,000 feet

The *precise* identification of the ground point targetted by the laser beam remained, at that time, an unsolved problem

The accuracy of the range measured by the laser can be defined with a standard deviation of 1.80 m and a bias which has to be computed as an unknown parameter in the adjustment. This bias was different in all flights involving the laser rangefinder.

The third and fourth tests were made in June 1986 over the Southern Suburbs of Amiens Township in the north of France with a SERCEL GPS receiver TR5 SB from an Aerocommander which is a slow and low flying aircraft. The ground control, not targeted, was poor, sparse and old. Nevertheless the results were good enough to eliminate all ground control points, which were then used as check points. A fictitious control point was kept to comply with the functional model, which involved three translations.

The fifth test duplicated the first and the second, over a smaller part of the same rural region in central France, with the laser rangefinder and the statoscope working together simultaneously.

With the statoscope measurements alone and four control points located in the area common to two strips, the adjustment residuals were 0.40 m for elevations in control points, and 1.05 m with statoscope measurements. The root mean square of the discrepancies in the 129 check points was 0 75 m.

With the combined measurements from the statoscope and the laser and the same four control points the adjustment residuals were:

0.30 m in control points

0.60 m with the statoscope

1.20 m for laser ranges.

But 40 per cent of the laser measurements were eliminated before the adjustment; their elimination during the adjustment proved to be unreliable, because an important residual did not consistently appear in the incorrect point but, often, in neighbouring points.

The sixth and seventh experiments were conducted in August 1987, with an airborne GPS receiver and two different statoscopes to be tested from a Falcon 20 with a new receiving antenna maintaining a speed of 400 mph at an elevation of 17,000 feet.

The two flights were made over the suburbs of Montpellier, a town in the south of France, on the Mediterranean Sea, and over Vichy, a town in the center of France. Both photoscales were 1:30,000.

*To stiffen* the block, two additional N. S. strips were flown, crossing the four E-W main strips.

The two different statoscope measurements, with only four ground control points, gave the same results as for the fifth test described before: for check points, rms of the discrepancies was from 0.60 to 0.70 m.

The GPS coordinates, adjusted in combination with the photogrammetric measurements, without any ground control point, had the following adjustment residuals:

| *Montpellier* | *Vichy* | |
|---|---|---|
| 0.40 m | 0.25 m | for horizontal coordinates |
| 0.50 m | 0.35 m | for elevations |

After bias elimination, the standard errors of the discrepancies in the check points are:

| | | |
|---|---|---|
| 0.70 m | 0.50 m | for horizontal coordinates |
| 0.50 m | 0.70 m | for elevations |

The statoscope and the GPS measurements have both been used in the same adjustment in order to adjust a block in a reduced satellite configuration, when the usual minimum of four satellites was not available. In such a weak configuration, the GPS was expected to provide good horizontal coordinates, and the statoscope, the elevations.

Two more flights were made over Manosque and over Albertville, after Montpellier and Vichy respectively, with only three satellites in sight. The adjustment was made, the block being controlled by one point of which only the horizontal coordinates were known, and by five known elevation points; the residuals were:

| *Manosque* | *Albertville* | |
|---|---|---|
| 1,00 m | 5,00 m | for horizontal coordinates |
| 1,35 m | 1,00 m | for elevations |

After bias elimination the standard errors of the discrepancies in the check points were:

| | | |
|---|---|---|
| 1,40 m | 3,90 m | for horizontal coordinates |
| 1,10 m | 1,05 m | for elevations |

The HDOP was bad for Manosque and very bad for Albertville, but the elevations remained as good as they were in the experiments involving the statoscope and terrain control points.

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## Projet de recherche

Un projet de recherche lancé par l'institut géographique national (IGN) en 1985 avait pour objet initial d'utiliser les mesures faites avec un statoscope et un laser aéroportés. Il s'agissait :

*a*) D'une part, d'essayer en vol des capteurs de navigation fournissant la position de l'avion photographe et de tenter d'exploiter en aérotriangulation les mesures ainsi faites;

*b*) D'autre part, de saisir toutes les opportunités qui se présenteraient afin de tenter d'exploiter, en aérotriangulation, les données des appareils de navigation.

C'est ainsi que, par la suite, on a été amené à exploiter deux vols effectués en associant à la prise de vue l'utilisation d'un récepteur NAVSTAR/GPS embarqué, essentiellement dans un but qui aurait pu se limiter à l'aide à la navigation pendant la prise de vue. Cette étude a été poursuivie afin de vérifier si les mesures GPS pouvaient être utilisées pour déterminer la position des sommets des faisceaux perspectifs. Cette expérience ayant donné des résultats prometteurs a été poursuivie l'année suivante.

En définitive, on a utilisé trois types de mesures aéroportées : télémètre laser, capteur de pression, récepteur de signaux des satellites NAVSTAR/GPS, en les combinant entre elles afin qu'elles s'apportent mutuellement de l'aide et fournissent un ensemble d'appuis redondant.

Les mesures aéroportées et la prise des photographies étaient quasi simultanées et, par conséquent, on peut considérer qu'elles correspondent aux mêmes sommets perspectifs. De plus, les calculs de compensation, lorsque cela restait possible, ont été également faits en introduisant soit les mesures brutes (laser et capteur de pression), soit des mesures déjà compensées de façon autonome et indépendante (GPS).

Les capteurs, que ce soit le statoscope ou le laser, ont été exactement les mêmes que ceux utilisés pour les relevés de profils aéroportés (APR); néanmoins, leur déclenchement devant être rigoureusement synchronisé avec la prise de vue, cela n'a pas été sans poser des problèmes (Brossier, 1984). Il ne s'agissait plus de mesurer des profils suivant la ligne de vol, mais des altitudes en des points précis.

Le problème consistait donc à vérifier que les mesures étaient susceptibles de remplacer, au moins partiellement, des points d'appui au sol. L'élément de comparaison présenté dans les tableaux (voir ci-après) provient d'une aérotriangulation effectuée à l'aide de moyens classiques. Si ces essais se révélaient positifs, il convenait, par la suite, d'introduire ces mesures dans le programme de calcul utilisé à l'IGN.

En raison des coûts très élevés des stéréopréparations, on a privilégié le nombre des chantiers à la qualité des points au sol afin de vérifier sur le plus grand nombre de cas possibles la validité des modèles de mesures aéroportées qu'on a proposés. Si ces modèles sont très simples c'est justement parce qu'on a pu disposer des mesures de nombreux chantiers pour vérifier qu'ils restaient valables dans tous les cas. On avait en effet remarqué que les auteurs avaient toujours une tendance, bien naturelle, à les compliquer pour qu'ils s'ajustent parfaitement au chantier étudié en oubliant que les particularités d'un travail ne se retrouvent pas toujours sur les suivants, et que les résultats de tels ajustements, appréciés en examinant les résidus, n'ont aucun caractère de généralité.

On peut par une pondération appropriée des équations de stabilisation et par le choix de modèles de systématismes compliqués réduire autant qu'on le veut les résidus d'ajustement des mesures-cliché. De même, tous les résidus des mesures externes peuvent être réduits à volonté par d'adroites pondérations.

On a donc préféré éviter la surparamétrisation; aussi les mesures-cliché et aéroportées comportaient-elles des résidus de systématismes non modélisés.

Pour toutes ces raisons on a considéré que les résultats ne pouvaient être appréciés que par les écarts moyens quadratiques aux points de vérification.

## Matériels utilisés

Les appareils de mesures utilisés en vol ne seront évoqués, ici, que très sommairement. Ils comprennent les appareils suivants :

### *Capteurs de pression*

Des mesures de pression différentielles ont été tentées à l'aide d'un statoscope traditionnel; malheureusement cet appareil n'a pas fonctionné correctement et a été abandonné.

Des mesures de pression ont été faites ensuite, à l'aide d'un capteur de pression Crouzet type 44, les résultats étant exprimés en décimillivolts (la tension mesurée équilibrant une balance de force).

Par la suite les essais ont porté sur deux capteurs de pression Crouzet employés en parallèle ; le second, de type 2100, transforme la pression en fréquence, sous forme numérique et fournit des pressions absolues en hectopascals. Le 2100 est un capteur plus moderne, en principe peu sensible aux accélérations verticales, dont les mesures sont directement utilisables par un micro-ordinateur, alors que le type 44 nécessite l'emploi d'un convertisseur analogique-numérique.

Les statoscopes et les capteurs de pression comportaient tous une capsule manométrique, raccordée aux prises de pression extérieure et plongée dans une enceinte à la pression de référence; dans l'ancien statoscope WILD, décrit dans Brossier (1984), cette enceinte était thermostatée par des résistances chauffantes, dans le statoscope utilisé par de l'eau glacée, et dans les capteurs de pression Crouzet, l'enceinte était sous vide.

Le manomètre numérique à quartz, type 2100, à visualisation LCD, exploite les informations d'un ou deux capteurs de pression à quartz type 51, la mesure de la déformation du soufflet de la capsule se fait en butant le fléau de mesure sur un monocristal de quartz, dont la fréquence de résonance est fonction de la contrainte appliquée. On utilise ainsi l'effet piézoélectrique du quartz pour le mettre en vibration et mesurer sa fréquence de résonance. Une sonde résistive, placée à l'intérieur du capteur et associée à un oscillateur, mesure la température interne du capteur : il serait souhaitable que le fabricant puisse afficher la température de l'air dont on mesure la pression, ou qu'il donne directement le gradient dp/dZ ou dM/dZ qui pourrait être calculé par le micro-processeur qui est incorporé à l'appareil.

A partir de ces deux informations, pression et température, on accède à la pression exacte par un modèle polynomial, dont les coefficients caractéristiques sont stockés dans la mémoire interne du capteur.

### Télémètre laser

La mesure de la distance quasi verticale avion-sol a été faite à l'aide d'un télémètre laser TAY 130 de la Cilas; les distances sont données en mètres, mais la quantité réellement mesurée est le temps mis par l'impulsion laser pour faire le trajet aller et retour entre l'émetteur et le récepteur placés à bord de l'avion. La distance est fournie par la formule :

$$\text{Distance} = C.t/2$$

C étant la célérité de la lumière, fixée dans l'appareil à $299{,}71 \cdot 10^6$ m/sec.

Par conséquent les effets retardateurs de l'atmosphère ne sont pas pris en compte; par ailleurs l'arrêt de la mesure du temps de parcours de l'impulsion étant commandé par un seuil d'énergie reçue, qui est réglable, quelques problèmes sont apparus pour le définir correctement.

### Récepteur GPS

On a utilisé les mesures d'un récepteur NAVSTAR/GPS de la société Sercel, embarqué une première fois à bord d'un Aerocommander. L'antenne employée, qui faisait saillie sur le fuselage de l'avion, n'aurait pas pu équiper un avion rapide tel que le *Mystère 20*.

Les coordonnées géographiques ont été obtenues en reliant l'appareil à une calculatrice HP 9825 et correspondent à l'ellipsoïde de référence WGS 72 puis WGS 84. Ces coordonnées ont été fournies par Sercel, qui participait à l'expérience. Dans les dernières expériences, la Sercel a remodelé les résultats de son premier logiciel de sortie, pour tenir compte de mesures faites à poste fixe, ce qui permettait de connaître les différents sauts et dérives affectant les résultats.

Les coordonnées obtenues par le premier logiciel sont appelées "pseudo-distances lissées par la phase", les secondes sont appelées "trajectographie".

Un essai a été mené en calculant les coordonnées des sommets à l'aide des pseudo-distances seules.

### Chantiers

#### *Chantiers "laser"*

On a utilisé le laser dans les trois chantiers suivants : Argenton-Bourganeuf, Magnac-Laval, La Souterraine.

La mesure simultanée des hauteurs laser du point de vue et des mesures-statoscope n'a pas pu être réalisée dès les deux premières missions, le statoscope n'ayant pas fonctionné.

Ce n'est que sur le troisième chantier qu'il a été possible d'employer un capteur de pression Crouzet type 44.

Les deux premiers vols se sont donc réduits à des mesures-laser seules qu'on a tenté d'exploiter surtout pour connaître la précision réelle du télémètre et pour préparer les essais ultérieurs.

#### *Chantier "statoscope seul"*

Il s'agissait d'un chantier de production utilisant un statoscope pour mesurer l'altitude de la chambre de prise de vue au cours du vol.

Les vols se sont échelonnés au cours du mois de septembre 1987 entre le 3 et le 18, et avaient pour objet de dresser une carte au 1 : 25 000 de la partie de la Guyane dénommée "Bloc de Saint-Laurent". Le projet initial prévoyait d'utiliser un récepteur GPS mais, hélas, les heures favorables de réception des quelques satellites encore utilisables, se situant vers 2 heures du matin, il fallut se contenter des mesures du capteur de pression Crouzet 44, qui avait donné des résultats très satisfaisants lors du vol sur la Souterraine.

La région survolée était couverte d'une forêt équatoriale dense, simplement entrecoupée de quelques pistes créées par les forestiers pour le débardage des grumes, d'une route longeant la côte, là où la forêt a été défrichée le plus largement, et de quelques rivières qui permettent de pénétrer cette zone perpendiculairement à la partie habitée, réduite à la bande côtière.

Dans ces conditions les mesures aéroportées pouvaient apporter une contribution maximale pour alléger le canevas d'appui au sol dont les points avaient été placés le long des pistes et le long du fleuve Maroni. Le vol comportait six bandes observées à une altitude de 4 590 m, et totalisait 128 clichés au 1 : 30 000.

Les opérateurs avaient signalé, à l'issue de la mission, que le capteur de pression avait eu des défaillances au cours du vol, rendant les mesures soit mauvaises soit douteuses. Toutefois, elles ont pu être exploitées après élimination des fautes.

#### *Chantier "statoscope + laser"*

Le troisième chantier décrit en 3.1 a été repris, en le réduisant à la dimension d'une feuille de la carte au 1 : 50 000, et en remplaçant le statoscope Zeiss défaillant par un capteur de pression Crouzet type 44. Ce chantier dit de "La Souterraine", pour le distinguer des deux qui l'on précédé, comporte 56 clichés, en quatre bandes observées à l'altitude de 4 700 m, avec une chambre RC 10, de focale 152 mm. La troisième bande a dû être partiellement reprise, par suite de la défaillance des trois premiers tirs laser, lors du premier passage, sur environ sa première moitié.

#### *Chantiers "GPS"*

Pour chaque opération l'IGN a utilisé un récepteur TR5-S B construit par la Sercel (Brossier *et al.*, 1986). L'équipement comprenait : une antenne de réception, différente pour les avions lents de celle utilisée sur les avions rapides, son préamplificateur, une unité de réception et de traitement, un écran de visualisation, et un clavier de commande.

Cet ensemble, encore expérimental à cette époque, pouvait recevoir et traiter simultanément les signaux de cinq satellites NAVSTAR en code C/A sur la fréquence L1; il était conçu pour réaliser une mesure précise de la phase et des pseudo-distances dans cinq canaux séparés, à la cadence d'une mesure toutes les 0,6 seconde.

Le TR5-S B était équipé d'un processeur interne pour le calcul en temps réel d'une solution complète 3D + T, en utilisant les pseudo-distances lissées par la phase. Lorsque le nombre *n* de satellites susceptibles d'être reçus correctement devenait insuffisant ($n < 4$), il calculait, pour $n = 3$ par exemple, une solution 2D + T, c'est-à-dire les coordonnées horizontales et le temps qu'il était possible d'associer à des mesures-statoscope : on a fait des simulations en configuration dégradée à Lunel et Vichy et des essais sur les chantiers d'Albertville et de Manosque.

La conception de l'antenne a fait l'objet d'un soin particulier, d'abord pour s'adapter aux impératifs de sa fixation sur le fuselage de l'avion, puis pour obtenir un retard et une position du centre de phase indépendants de la direction considérée sur l'hémisphère supérieur, et éviter les réflexions parasites provoquant des erreurs de "trajets multiples".

C'est en partant de la version statique de son récepteur, mis au point pour les besoins de la géodésie, que la Sercel avait étendu le domaine d'application du TR5-SB au positionnement dynamique en mer, puis sur avion. L'essentiel des modifications du matériel avait porté sur la mise au point d'antennes adaptées à la vitesse du mobile, et sur les logiciels correspondants. Pour le traitement des données, les améliorations avaient porté sur l'intégration de la phase et son utilisation avec les pseudo-distances.

L'objectif visé était de prendre en compte les déplacements du véhicule porteur avec une précision décimétrique en se limitant, pour les deux premiers essais, à une vitesse de 200 nœuds et une accélération de 1 g.

Ces premiers essais, sur Amiens, avaient été effectués avec un *Aerocommander*, avion lent, seul capable de recevoir alors l'antenne qui avait été développée auparavant pour les applications maritimes.

Les résultats encourageants obtenus ayant montré l'intérêt qu'il y avait à étendre les possibilités du récepteur à de plus grandes vitesses de déplacement, l'année suivante (1987), on a utilisé une antenne multidirectionnelle Dorne-Margolin, de forme hémisphérique, compatible avec la vitesse de 350 nœuds et que l'on a montée sur un avion rapide *MY-20* (*Mystère 20*) (Brossier *et al.*, 1988).

### *Chantiers "GPS et capteurs de pression associés"*

#### *Les essais sur avion rapide*

Les essais sur avion rapide avaient pour double objectif de tester des capteurs embarqués sur le *MY-20* à plus grande altitude (environ 5 000 m), et d'essayer d'exploiter les mesures en les associant, au cours des calculs, à celles du bloc photogrammétrique, et aux points de terrain, en tenant compte de l'expérience accumulée au cours des vols précédents d'Amiens.

On a donc utilisé simultanément, un récepteur GPS TR5-S B de Sercel et deux capteurs de pression Crouzet types 44 et 2100.

#### *Les conditions de prise de vue*

Les essais se sont trouvés largement handicapés par le petit nombre de satellites NAVSTAR observables dans des conditions de précision satisfaisantes, c'est-à-dire avec une dilution géométrique de la précision inférieure à 5 (GDOP < 5), à des heures où les prises de vues photogrammétriques sont encore possibles au point de vue éclairement et importance des ombres.

Rappelons qu'en 1988 la situation des satellites NAVSTAR était tout à fait critique, en raison de l'accident survenu à la navette spatiale et des délais imprévus qui ont précédé la reprise du programme. La situation s'est améliorée depuis et l'on est passé de 6 satellites utilisables à 9 et de nouveaux lancements sont annoncés, mais il est aussi question de dégrader les données transmises par les satellites.

L'antenne Dorne-Margolin, mise au point sur le *MY-20* par la Sercel, n'a été disponible qu'une semaine au cours de laquelle les conditions de réception du GPS n'ont été favorables que pendant seulement une heure et demie par jour ! Les conditions de prise de vue se sont trouvées tout à fait limités et la longueur des ombres, un peu forte, a gêné l'exploitation cartographique des photographies de Vichy.

### TRAITEMENT DES INFORMATIONS

#### *Stéréopréparation*

Pour les différents chantiers expérimentaux on a généralement procédé de la même façon en reprenant, comme points d'appui ou de vérification, les points de stéréopréparation provenant de missions antérieures de cartographie, ce qui est économiquement avantageux mais offre une moins bonne qualité sur ces points de canevas. En revanche, pour les missions de Vichy, d'Albertville et de Guyane, qui étaient des chantiers de production, la préparation a été faite directement sur le terrain, immédiatement après la prise de vue.

#### *Traitement des points d'impact laser*

C'est un problème technologique mal résolu que celui de l'identification, sur le terrain, du point sur lequel le tir laser s'est réfléchi. Aucune des solutions envisagées par divers auteurs [5] n'est réellement praticable. La méthode qu'on a employée correspond au matériel décrit par Brossier (1984); il s'agit d'un télémètre laser Cilas, de conception et de réalisation déjà anciennes, utilisé dans les travaux courants d'APR. En conséquence, elle ne saurait être généralisée à d'autres matériels. En effet, la chambre RC 10 était totalement indépendante du télémètre laser, lui-même solidaire d'une petite chambre 35 mm, qui lui était attachée de façon rigide, ce qui n'était pas le cas dans D. D. Light.

Ceci a eu pour conséquence que, selon l'attitude de l'appareil, le point d'impact laser se déplaçait dans le champ du cliché pris par la chambre RC 10.

Les déclenchements de la chambre RC 10 et du tir laser n'étaient pas totalement simultanés, mais de très peu. La zone de l'impact du tir laser était photographiée par une chambre Camematic de 35 mm; le retard entre l'impulsion et le déclenchement de cette petite chambre était de 72 millisecondes, ce qui est considérable ! d'autant qu'après une vérification on a trouvé une valeur de 84 ms. Cette indécision est un facteur limitant de ce procédé et malheureusement ce n'est pas le seul. En effet, avant d'effectuer les mesures des coordonnées-cliché, il faut reporter le point d'impact du tir laser sur le cliché photogrammétrique 24 × 24 cm pris par la chambre RC 10. La procédure mise au point était la suivante:

*a*) Report du repère central du cliché 35 mm, appelé vignette, sur les différentes vues. En effet, les vues 35 mm ne portaient aucun repère : celui-ci ne figurant que sur les premiers clichés "muets" précisément destinés à ce repérage. Il était donc nécessaire de reporter sa position sur les vignettes suivantes au marqueur PuG, en superposant les bandes des clichés portant une image du repère, à celles des clichés portant les images du terrain, la coïncidence entre les deux clichés se faisant en superposant, sous fort grossissement, les bords des deux catégories de clichés.

*b*) Report de la position du repère du cliché 35 mm au cliché RC 10 par superposition stéréoscopique sous des grossissements différents, les deux vues n'étant pas à la même échelle, avec marquage du point au PG.

*c*) Enfin, lors de la mesure sur stéréocomparateur, décalage de la position du point marqué d'une longueur correspondant au déplacement de l'avion pendant 72 ms, soit entre 11 et 12 mètres à l'échelle du cliché mesuré soit 1 : 30 000.

La succession de ces opérations n'a pas permis d'obtenir toute la précision désirable. Il semblerait souhaitable de pouvoir se passer de la vignette prise par la chambre 35 mm, en rendant le tir laser colinéaire ou parallèle à l'axe de la chambre métrique RC 10. Les deux événements, ouverture du diaphragme de la chambre RC 10 et tir laser n'étant séparés que de 4 ms, ce qui correspond pratiquement au temps d'obturation utilisé, cette solution peut en effet s'envisager.

La nécessité de passer par l'intermédiaire de la vignette a entraîné une indétermination sur la position de l'impact au sol de 2,50 m à l'échelle considérée. En terrain couvert, irrégulier, ou en pente, cette erreur est beaucoup trop forte, sinon rédhibitoire.

De surcroît, on a dû faire une première exploitation du bloc pour calculer, dans chaque bande, la vitesse de l'avion par rapport au sol, la vitesse mesurée à bord étant toujours celle par rapport à l'air. On pourrait, pour une exploitation normale utiliser le récepteur TR5-S B de la Sercel qui donne la vitesse de l'avion avec une précision très suffisante, mais dans les essais en question, il n'a pas pu être associé aux mesures laser.

*Mesures du statoscope (ou des capteurs de pression)*

Les mesures ont pu être faites à la cadence très élevée de quatre mesures toutes les 1,6 seconde et ont fait l'objet d'un traitement particulier à Lunel, Vichy, Albertville, et en Guyane, où elles étaient répétées sur un même sommet. Il a permis de mettre en évidence la dispersion des mesures brutes et d'essayer de départager les deux capteurs. On s'attendait à ce que le second capteur de pression soit plus précis que le premier, mais les deux capteurs Crouzet, bien que de conceptions très différentes, ont donné des résultats comparables. La précision du résultat ne dépend donc probablement pas, de façon déterminante, de celle des mesures de l'appareil, mais de causes extérieures telle que la fluctuation aléatoire de la surface isobare à laquelle on se réfère.

*Mesures "GPS" de position des sommets perspectifs*

Les essais d'utilisation directe des mesures GPS en temps réel s'étant révélés infructueux, le fabricant du récepteur a mis au point un logiciel de traitement en temps légèrement différé. Il appartient à une catégorie bien connue de logiciels de calcul de mesures GPS (Kleusberg, 1986) et utilise à la fois les mesures de pseudo-distances, lesquelles sont bruitées de plusieurs mètres, un comptage de battements entre le récepteur et l'émetteur pour calculer l'effet Doppler, et la phase, dont le bruit n'est que de quelques centimètres.

Le traitement commence par un passage mettant en œuvre simultanément deux sommets consécutifs, et reprenant, dans chaque séquence de calcul, la position du second sommet calculée dans la séquence précédente, les mesures des pseudo-distances et l'intégration des battements Doppler.

Le calcul en retour est identique, il lisse les résultats du calcul précédent. On ne manipule, dans un pas de calcul, que six ou huit inconnues à la fois : trois inconnues de position sur deux sommets et un biais d'horloge par sommet, sauf si ce dernier peut être considéré comme constant ou bien être modélisé, ou éliminé, comme dans Kreusberg (1986), par des différences faites entre les mesures.

Les résultats sont légèrement différents de ceux qui seraient obtenus dans un calcul classique par moindres carrés, prenant simultanément en compte toutes les mesures. On démontre que c'est la précision des mesures de pseudo-distances et la durée de la réception qui conditionnent la précision des résultats du calcul.

La Sercel fixe la précision des résultats à :

$$(\sigma p + \sigma d) / \sqrt{(n-1)}$$

Avec :

$\sigma p$ écart-type sur la position déterminée à l'aide des pseudo-distances,

$\sigma d$ écart-type sur la position déterminée par les mesures Doppler,

$n$ nombre de sommets mesurés soit un toutes les 0,6 seconde pour le récepteur de la Sercel,

où $\sigma d$ étant négligeable devant $\sigma p$ et $n$ très grand :

$$\sigma p / \sqrt{n}$$

On a pu dire qu'on utilisait les signaux de basse fréquence pour résoudre les ambiguïtés de GPS, et les signaux de haute fréquence pour mesurer les distances.

Le fait d'utiliser *toutes* les pseudo-distances pour calculer toutes les positions successives des sommets, et de les relier par les mesures Doppler, revient à placer les résultats dans un système de référence défini comme la moyenne des référentiels des positions obtenues par les pseudo-distances, même si le récepteur s'est déplacé au cours de la mesure. Cette moyenne a un écart type beaucoup plus faible que celui affectant une mesure individuelle car l'intervalle de temps qui s'écoule entre deux mesures du récepteur Sercel étant de 0,6 seconde, le nombre des mesures est donc très important; mais la mesure des pseudo-distances ayant une limite de résolution de 0,12 m on ne peut pas atteindre une précision aussi grande que celle obtenue par l'intégration Doppler. En outre, il ne faut pas perdre de vue que les positions déterminées ne sont pas celles des sommets perspectifs eux-mêmes, mais celles de points de la trajectoire de l'avion définis à des intervalles réguliers par le récepteur GPS, et à partir desquels les positions des sommets perspectifs sont interpolées linéairement; l'instant de la prise de vue étant déterminé à quelque 1 : 1 000 de seconde près, et l'avion parcourant 0,16 m par millième de seconde, l'erreur n'est donc pas négligeable.

Divers auteurs ont utilisé des méthodes d'interpolation plus compliquées (Lucas, 1988), mais cela ne saurait rattraper l'erreur commise sur la synchronisation. Malgré tout ce qui a été publié il ne semble pas raisonnable d'attendre mieux que 0,20 m à 0,25 m sur l'écart type de chaque coordonnée.

Les résultats fournis par le fabricant sont exprimés en coordonnées géographiques : latitude - longitude - hauteur au-dessus de l'ellipsoïde du système WGS 72 puis WGS 84.

Les latitudes et longitudes étaient exprimées en degrés, minutes et dix millièmes de minutes alors que la résolution des mesures était bien supérieure : quelques centimètres pour les pseudo-distances, et quelques millimètres pour la phase, soit 1/1 000 de tour; il ne fallait pas s'attendre à mieux que 0,14 m en $x$ et 0,19 en $Y$. On verra qu'on était proche de ces valeurs.

Après transformation des coordonnées géographiques WGS 72 ou 84 en coordonnées Lambert II pour Vichy et Albertville, Lambert III pour Lunel, sur l'ellipsoïde de

Clarke Français, ces données ont été entrées dans le programme "Faisceau" de l'IGN transformé pour accepter dans sa version VII les données GPS et Statoscope, associées ou non. Dans une exploitation normale, il serait plus simple que les résultats du calcul GPS soient fournis directement en tridimensionnel WGS 84.

S'il était un jour possible de se passer totalement de points d'appui au sol, il serait alors préférable de passer du système tridimensionnel GPS à un système tridimensionnel local, dans lequel d'ailleurs le programme Faisceaux exécute les calculs. Il est certain que le calcul simultané du bloc et des mesures brutes GPS permettrait de prendre en compte les corrélations qui pourraient exister entre les mesures Doppler, au prix de difficultés supplémentaires.

Les vols de Vichy et de Lunel comportent chacun environ 75 clichés, Albertville en comporte seulement 60.

Afin de ne pas encombrer les fichiers, on pourrait envisager de ne prendre en compte que les mesures associées aux points encadrant les sommets, puisqu'en 0,6 seconde l'avion ne parcourt que 100 mètres, on aurait de l'ordre de 150 points GPS avec de six à huit équations d'observation par sommet. La charge de calcul resterait supportable mais on améliorerait beaucoup moins le bruit sur les positions des sommets calculées par les pseudo-distances seules ($\sqrt{150}$ nk 12).

Prendre en compte toutes les mesures impliquerait, pour un vol d'une heure, la prise en charge de 6 000 points (3 600/0,6) avec toujours de six à huit équations par sommet soit de 36 000 à 48 000 équations d'observation ce qui paraît difficile actuellement, mais pas impossible à l'avenir; encore faudrait-il y trouver un avantage, ce qui n'est pas absolument certain.

Aucune proposition ne peut être rejetée à priori, on n'est qu'au début de l'expérimentation réelle dans ce domaine. On pourra sans doute maîtriser le nombre minimum de points pris en compte pour améliorer le bruit sur les points calculés par les pseudo-distances seules, tout en restant dans les limites raisonnables quant au nombre des équations d'observation à manipuler au cours des calculs.

Par ailleurs, la prise en compte des mesures des pseudo-distances ne s'imposerait probablement plus; seules les mesures de comptage des battements et de la phase pourraient être employées. L'avantage serait de ne plus prendre en compte que les mesures encadrant un sommet perspectif, ce qui allégerait l'encombrement en mémoire. Il s'agirait évidemment d'un tout autre logiciel, associant les mesures GPS brutes aux mesures photogrammétriques. En outre les méthodes de calcul s'apparenteraient plus aux procédés de compensation dits "GPS cinématique" (Willes, 1989) qu'à celui mettant en œuvre simultanément les mesures de battements et les pseudo-distances.

## Résultats obtenus

### *Mesures laser*

De toutes les façons qu'on considère le problème, les mesures laser, même bien faites, bien enregistrées, et fiables intrinsèquement, ne pourront exprimer leurs qualités qu'au-dessus des terrains nus et moyennement accidentés, la végétation, les constructions, la pente étant autant d'obstacles à une bonne identification du point frappé par l'éclair laser. Cette identification reste la clef de voûte, fragile, du système : le défaut de la mesure laser sera toujours de se rattacher à n'importe quel point; or un point photogrammétrique correct qui serait un bon réflecteur laser ne sera jamais n'importe quel point, il doit posséder de nombreuses qualités, que le seul hasard ne saurait lui apporter.

Quels que puissent être les progrès dans la technologie de la mesure, on se heurtera toujours à ce facteur limitant fondamental.

Compte tenu de l'indécision qui existe sur l'altitude des sommets perspectifs de l'ordre de 0,70 m à 0,80 m, pour les essais présentés, et des systématismes qui peuvent subsister malgré les corrections apportées par les inconnues de systématisme, les résultats peuvent être résumés comme suit:

Les écarts sont ceux relevés entre les hauteurs calculées par rapport aux altitudes données par le bloc photogrammétrique sur tous ses appuis et les mêmes hauteurs mesurées par le télémètre laser :

| *Chantiers* | *Ecart m qu sur la mesure de hauteur* |
|---|---|
| Argenton-Bourganeuf | 1,08 m |
| Magnac-Laval | 1,34 m |
| La Souterraine | 1,80 m |

La précision réelle, en écart type, doit être bien supérieure, de l'ordre de 0,70 à 0,80 m. On doit, pour preuve, signaler le bon comportement du laser associé au capteur de pression; donnons brièvement les résultats de La Souterraine:

Ecarts types en mètres sur les points de vérification

| *Réseau comple d'appuis au sol* | *Appuis réduits et mesures aéroportées* |
|---|---|
| $X - Y = 0\ 70$ m | Pas de contrôle |
| $Z = 0\ 45$m | 0,50 m |

Les points associés aux mesures aéroportées étaient au nombre de trois points connus dans leurs trois coordonnées (voir fig. I).

### *Mesures des capteurs de pression atmosphérique (statoscopes)*

La présence de mesures fausses, difficiles à déceler, a rendu le travail difficile. Les données des chantiers de Guyane ont été un peu décevantes, mais les résultats d'un nouveau chantier de production réalisé outre-mer permettent de corriger cette mauvaise impression. Celle d'Albertville, en tant que mesures effectuées dans une région montagneuse, de parcours difficile, se sont révélées très prometteuses.

Les méthodes de compensation robustes utilisées sur une partie des mesures pour éliminer les fautes impossibles à détecter "à priori", n'apportent rien sur les raisons de l'élimination d'une mesure, mais "fragilisent" aussi les autres catégories de mesures, car si la faute n'est pas imputable à la mesure faisant l'objet de la compensation "robuste" c'est pourtant cette dernière, et elle seule, qui sera éliminée, la faute restant masquée et restant en place.

Le professeur Ackermann rappelle, fort opportunément, que les mesures de pression atmosphériques sont les *moins chères et les plus efficaces* des mesures aéroportées. Ces raisons incitent à poursuivre des recherches qui seront toujours payantes en ce domaine.

Néanmoins, il conviendra encore de souligner que ces mesures seront toujours rapportées à une surface isobare

Figure I. *Chantier de Lunel* appuyé sur *un seul point connu* au sol (le triangle poché au centre) et sur les mesures GPS aéroportées. Les vecteurs figurent les écarts constatés sur les points de vérification en altimétrie entre la détermination photogrammétrique et les mesures au sol. Ces dernières sont affectées de l'erreur d'identification du point naturel sur la photo

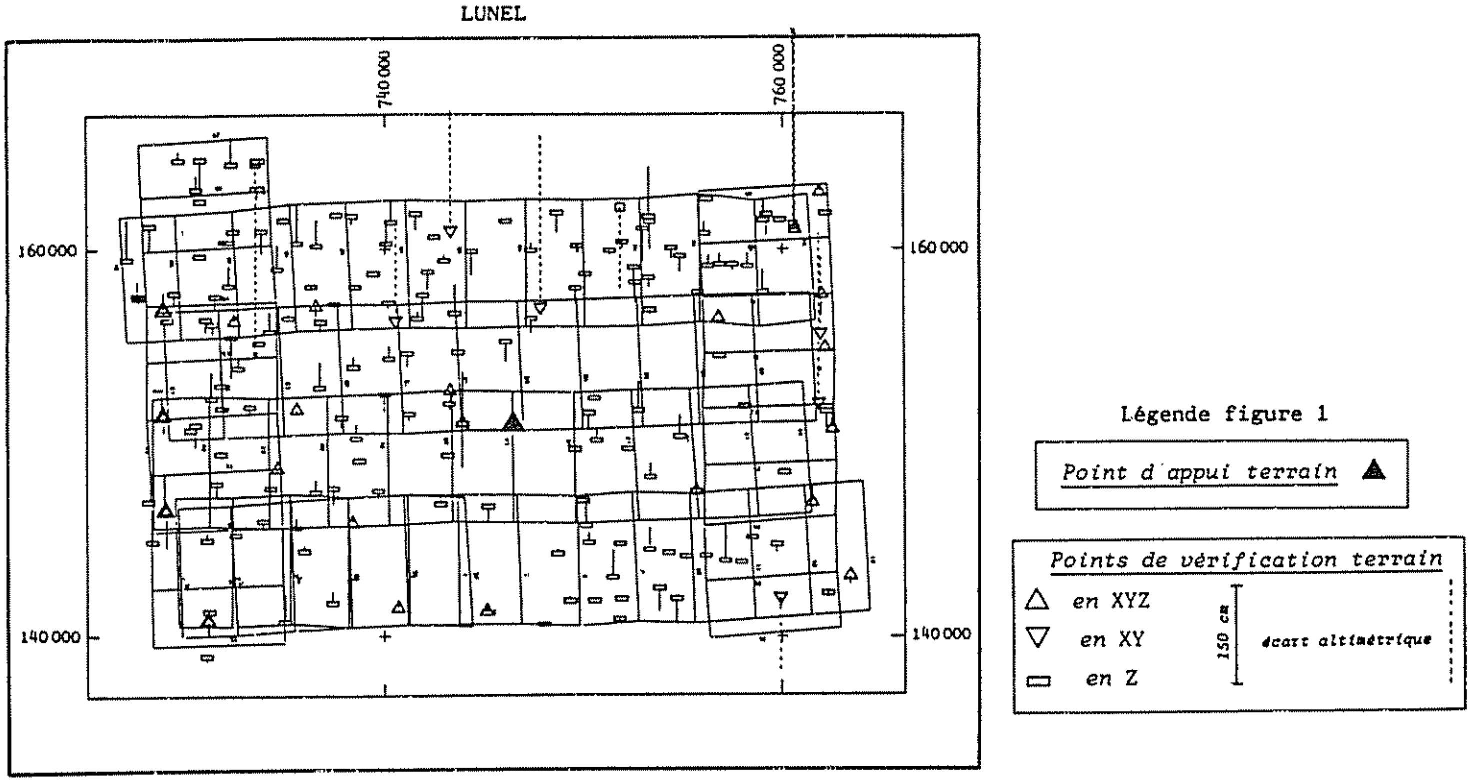
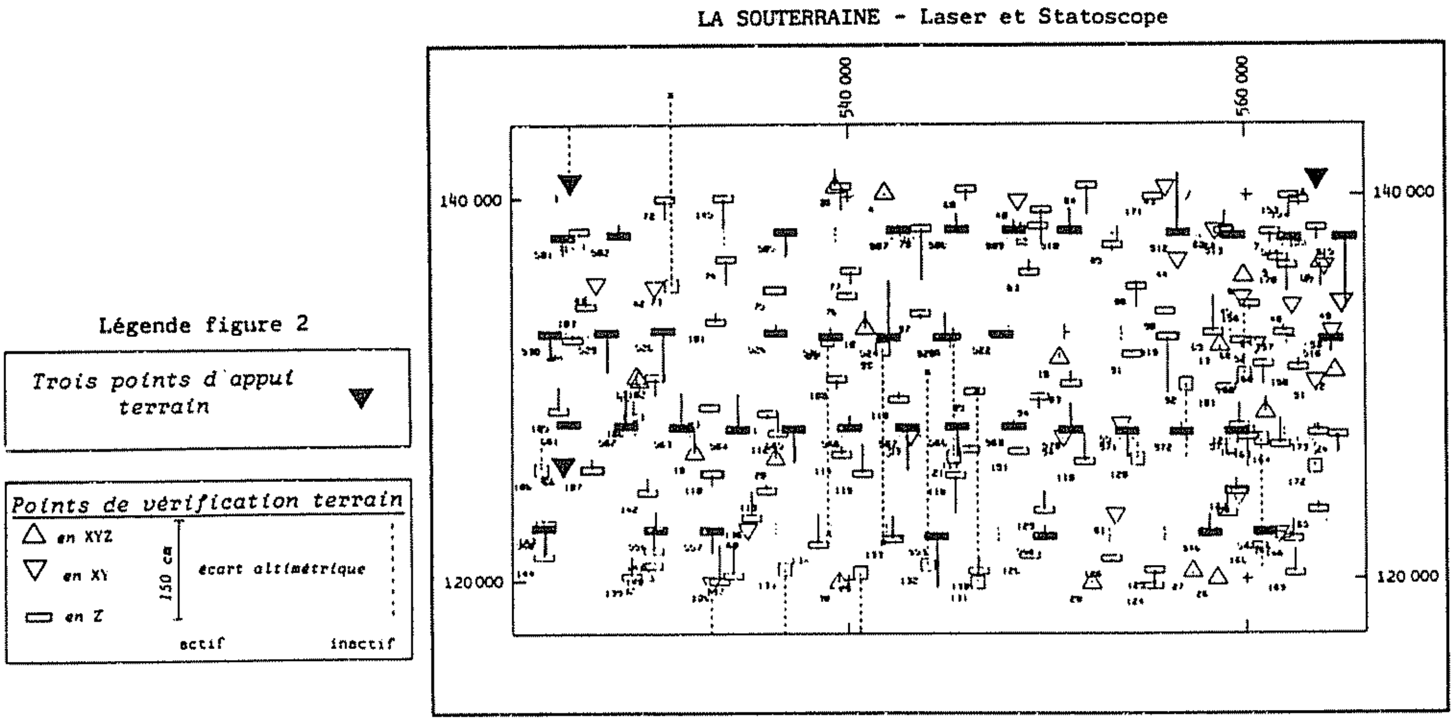



Figure II. *Chantier de La Souterraine* appuyé sur *trois points connus* au sol (les triangles pochés) et sur les mesures d'un capteur de pression associées à des mesures laser. Les rectangles pochés représentent les points d'impact laser et le vecteur associé le résidu d'ajustement en ce point. Aux points de vérification, laissés en clair, le vecteur associé représente les écarts entre la détermination photogrammétrique du point et les mesures au sol (ces dernières doivent être surtout appréciées en fonction de l'identification du point)



plus ou moins régulière et stable, dont les défauts sont soit de nature physique, soit de nature géométrique, sans que l'on puisse jamais en connaître les causes exactes. Inévitablement ces mesures, aussi précises puissent-elles devenir, ne vaudront que ce que leur référentiel vaudra lui-même; il s'agira toujours d'une limite infranchissable au-delà de laquelle il sera inutile de pousser la précision des capteurs eux-mêmes.

En première urgence, il semble indispensable d'enregistrer la température à laquelle le vol a été fait afin d'estimer correctement la valeur du coefficient dM/dZ qui devenant ainsi une mesure, échapperait à la compensation et à ses incertitudes.

On peut résumer les résultats sur les mesures des capteurs de pression par le tableau suivant :

ECARTS-TYPES EN MÈTRES SUR LES POINTS DE VÉRIFICATION

| *Chantier* | *Réseau complet d'appuis au sol* | *Réseau d'appuis réduit et capteur de pression* |
|---|---|---|
| La Souterraine | $X - Y = 0{,}70$ | Pas de contrôle |
| | $Z = 0{,}45$ | 0,75 |
| Lunel | $X - Y = 0{,}75$ | 0,70 |
| | $Z = 0{,}45$ | 0,55 |
| Vichy | $X - Y = 0{,}55$ | 0,70 |
| | $Z = 0{,}45$ | 0,55 |
| Guyane | Néant | $X = 0{,}60$ |
| | | $Y = 1{,}10$ |
| | | $Z = 0{,}55$ |

Les réseaux d'appuis réduits comportent le nombre de points strictement nécessaire pour que le bloc acquiert une rigidité transversale suffisante lorsqu'il ne bénéficie pas d'un recouvrement suffisant dans ce sens, ou que des bandes perpendiculaires n'ont pas été observées.

Les vols de Lunel et de Vichy, comportant des donnés auxiliaires issues des capteurs de pression, et des bandes transversales, n'ont eu besoin, pour être appuyés correctement, que de deux points connus en planimétrie et d'un seul connu en altimétrie; par contre, le vol de La Souterraine a nécessité, en plus des deux points connus en planimétrie, six points en altimétrie au lieu d'un seul, car ce bloc n'avait pas une rigidité transversale suffisante pour que l'économie des points d'appui puisse être poussée plus loin.

Pour le vol de Guyane, on se rapportera à la figure III, où presque tous les points sont placés en appuis, car il s'agit d'un chantier de production effectué dans des conditions difficiles, nécessitant l'emploi de données aériennes auxiliaires, et pour lequel on ne dispose pas des résultats d'un calcul classique comme élément de comparaison.

*Mesures des coordonnées des sommets perspectifs par un récepteur GPS aéroporté*

Les résultats, très encourageants, incitent à l'emploi de cette méthode, dans la mesure où :

*a*) La constellation des satellites utilisables qui n'était pas complète, devrait l'être rapidement.

*b*) Les émissions des satellites ne seront pas bruitées pour des motifs relevant des impératifs de la défense nationale des Etats-Unis. On ne rappelera jamais assez que ce système est avant tout *militaire;* les applications civiles n'en sont que des sous-produits.

Les essais entrepris devraient normalement se poursuivre afin de pouvoir appuyer des cartes à grandes échelles et réaliser des tentatives de photogéodésie. Les polygones d'essai devraient alors être prébalisés. Il y aurait également intérêt à ce que la réception des signaux ne soit pas interrompue au cours des virages de l'avion en bout de bande. Enfin il n'est pas certain que la précision attendue puisse être atteinte par la méthode de calcul dite des pseudo-distances lissées par la phase: la variance du résultat reste surtout dépente de la précision de la mesure sur les pseudo-distances (PD), qui pourrait être bruitée, et de la durée de la réception *continue* :

variance = variance des PD/nombre de mesures

Avec : nombre des mesures = durée de la réception sans interruption en secondes/0,6 s (pour le récepteur Sercel, bien sûr).

Les pertes de réception des signaux GPS dans les virages de l'avion ne semblent pas, non plus, être une fatalité : Lucas rapporte que, dans les essais qu'il a exploités, les expérimentateurs étaient parvenus a loger l'antenne de réception au sommet de l'empennage vertical de dérive de l'avion photographe *Aerocommander*, ceci afin d'éviter les masques formés par les ailes, lorsqu'il s'incline autour de son axe de roulis ($x$) pour tourner.

Nos essais ont montré que les algorithmes de rattrapage des cycles perdus dans les virages étaient restés en grande partie inopérants, et ce malgré les efforts de Sercel dans ce domaine, et le fait, très favorable, de la réception simultanée de cinq satellites, qui procure une mesure surabondante utilisable pour compenser toute perte de réception d'un satellite

Force est de constater d'après les résultats que, dans tous les cas, c'est le bloc photogrammétrique qui a assuré la continuité; il serait bien préférable de ne pas perdre cette réception et de n'avoir à déterminer que trois paramètres de translation par bloc, et non par bande avec en complément, éventuellement, trois dérives de ces translations dans le temps.

Les résulsats sur GPS peuvent se résumer comme suit :

ECARTS TYPES EN MÈTRES SUR LES POINTS DE VÉRIFICATION : CHANTIERS EXPÉRIMENTAUX

| *Chantier* | *Réseau complet d'appuis au sol* | *Réseau d'appuis réduit et mesures de GPS* |
|---|---|---|
| Amiens I | $X - Y = 0{,}30$ | 0,60 |
| | $Z = 0{,}40$ | 0,50 |
| Amie | $X - Y = 0{,}35$ | 0,75 |
| | $Z = 0{,}40$ | 0,80 |

Sur ces deux chantiers, la rigidité transversale du bloc n'étant pas suffisante, on a utilisé un seul point d'appui en planimétrie et cinq points d'appui en altimétrie ainsi que les mesures aéroportées auxiliaires.

CHANTIERS RÉELS

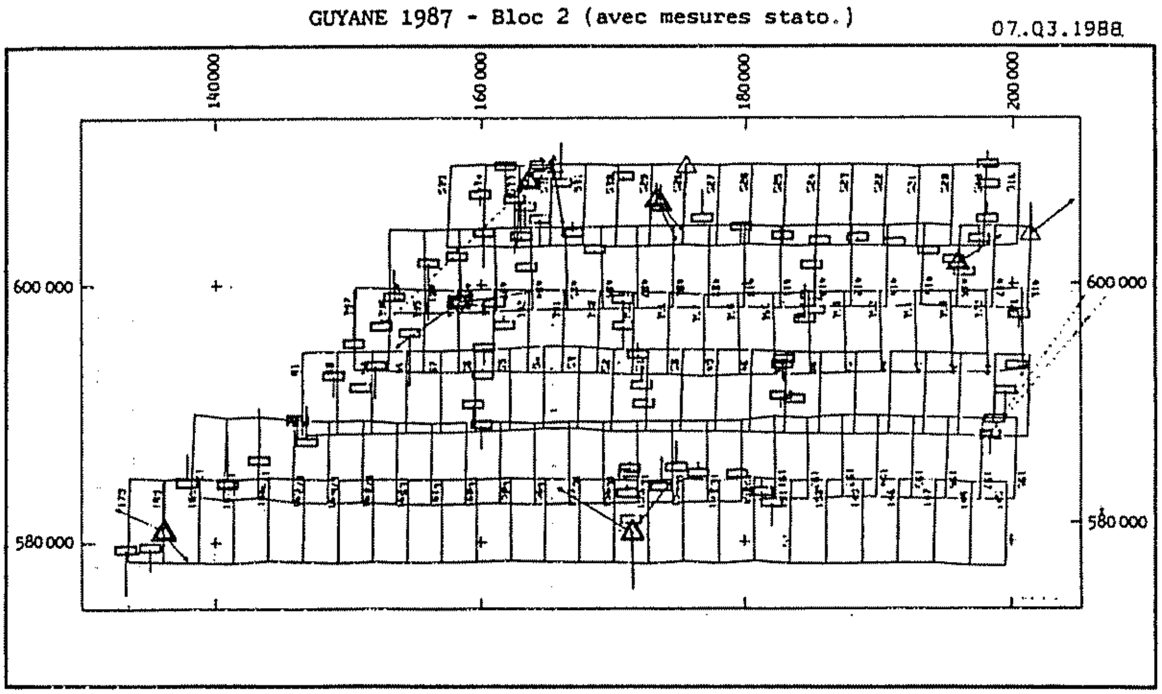
| *Chantier* | *Réseau complet d'appuis au sol* | *Réseau d'appuis réduit et mesures de GPS* |
|---|---|---|
| Lunel | $X - Y = 0{,}75$ | 0,75 |
| | $Z = 0{,}45$ | 0,50 |
| Vichy | $X - Y = 0{,}55$ | 0,55 |
| | $Z = 0{,}45$ | 0,60 |

Par contre, sur ces deux derniers chantiers, on a pu se limiter à un seul point d'appui connu dans ses trois coordonnées, en complément des "mesures GPS" (voir fig. I).

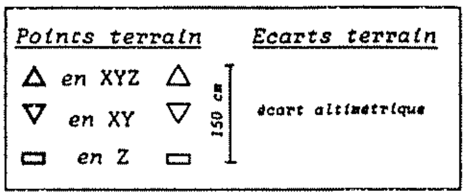
*Mesures combinées*

Il est facile d'imaginer les différentes combinaisons de mesures aéroportées qui pourraient être faites.

**Figure III.** *Chantier de Guyane* appuyé sur des points au sol et sur des mesures statoscope. Résidus d'ajustement aux points d'appui connus au sol. Les résultats les plus significatifs ont été obtenus sur les blandes situées en bas de la figure où les appuis étaient rares. Les points d'appui sont entourés d'un trait gras. Les points d vérification sont entourés d'un trait mince.




Légende figure 3




Ceci permettrait d'anticiper sur ce que donneraient des mesures GPS associées à des mesures laser sur des sols nus, si l'appareil de mesure était comparable à ceux décrits dans les expériences américaines et canadiennes, permettant de dresser des profils de terrains (Krabill *et al*, 1984; Morean et Jendi, 1986).

Dans les zones désertiques, la combinaison des mesures simultanées laser et capteur de pression, rappelant le système APR actuel, permettrait d'appuyer correctement des prises de vues au 1/30 000, avec une précision comparable à celle qu'on obtient avec de très nombreux points au sol. On a pu constater, à cette échelle, que le résultat serait comparable à celui obtenu habituellement par le procédé traditionnel, tout en se limitant à deux points au sol connus en altimétrie par cliché.

En règle générale on ne peut pas se fier à un seul système d'appui, il faut se réserver des possibilités de vérification comme celles qu'offrent les données aériennes auxiliaires, dont le coût est négligeable par rapport aux gains qu'elles permettent en cas d'incident ou d'incertitudes dues à des fautes commises sur le terrain. Une redondance élevée est nécessaire plus pour éliminer les fautes que pour améliorer la précision.

C'est ainsi que pour pallier le faible nombre de satellites GPS disponibles au moment où l'on pouvait prendre des photographies aériennes dans des conditions convenables, on a été amené à utiliser les données d'un capteur de pression tout en n'observant que trois satellites seulement. En effet, l'observation de trois satellites permet, dans certaines conditions bien précises, d'obtenir une position de l'avion en latitude en longitude, mais pas en altitude; on complète alors le système par les mesures d'un capteur de pression.

On peut résumer comme suit les résultats obtenus en combinant des mesures GPS sur une constellation dégradée et les mesures des capteurs de pression.

ECARTS TYPES EN MÈTRES SUR LES POINTS DE VÉRIFICATION : CHANTIERS RÉELS

| *Chantier* | *Réseau complet d appuis au sol* | *Réseau réduit d'appuis et mesures GPS et pression combinées* |
|---|---|---|
| Albertville | $X - Y = 0{,}90$ | 1.05 |
| | $Z = 0{,}80$ | 1.00 |
| Manosque | $X - Y = 0.90$ | 1.20 |
| | $Z = 0.70$ | 1,00 |

Le réseau réduit d'appui ne comprenait qu'un point au sol connu en planimétrie et sept points connus en altimétrie; les "mesures GPS" calculées sur trois satellites observés très près de l'horizon, ne fournissaient que les coordonnées horizontales et le temps. Des mesures de pression ont donc été introduites dans le calcul, et par simulation :

| Chantier | Réseau complet d'appuis au sol | Réseau réduit d'appuis et mesures GPS et pression combinées |
|---|---|---|
| Lunel | X – Y = 0,75 | 1,90 |
| | Z = 0,45 | 1,20 |
| Vichy | X – Y = 0,55 | 1,60 |
| | Z = 0,45 | 1,05 |

Le réseau réduit ne comportait qu'un seul point d'appui connu dans ses trois coordonnées associé aux "mesures GPS" prélevées de leur altitude et aux mesures d'un capteur de pression.

Globalement les résultats sont évidemment moins bons que ceux du paragraphe précédent, mais la "fenêtre" pendant laquelle les mesures étaient encore utilisables a été considérablement élargie.

## Conclusions

Les points acquis pendant ces trois dernières années sont très positifs et devraient être développés dans un avenir proche.

### *Laser et capteurs de pression*

Il paraît très souhaitable de continuer parallèlement les recherches sur les capteurs, les prises de pression, et des méthodes statistiquement correctes pour éliminer à priori les mesures fausses, pourvu qu'elles ne soient pas trop nombreuses. L'élimination de ces fautes, à posteriori, constituera toujours un échec, car on ne saura jamais les conséquences des fautes qui n'auraient pas pu être détectées à priori ou à posteriori, et qui, par conséquent, subsisteraient dans les appuis du réseau, déséquilibrant la compensation.

D'une façon générale, que ce soit pour les mesures laser et même les mesures statoscope, il reste de gros progrès à faire sur les matériels et les enregistrements. Il est certain que la qualité des mesures laser dépendra, non seulement des performances du matériel employé, mais aussi de l'identification du point touché. Toutefois les publications étrangères (Krabill *et al.*, 1984; Moreau et Jendi, 1986) font état de résultats moins pessimistes sur ce procédé de mesure. Dans le même ordre d'idées, les défaillances partielles du capteur de pression devront être corrigées. Il existe donc des progrès considérables à faire en matière de capteurs et de méthodes.

### *Mesures GPS des positions des sommets perspectifs*

Inversement, les données du récepteur NAVSTAR GPS TR5-S B de Sercel sont tout à fait remarquables par leur fiabilité. Toutefois il ne faudrait pas oublier les conditions dans lesquelles ces résultats ont été obtenus : ce n'est que par *trajectographie* que les résultats sont totalement fiables, c'est-à-dire en utilisant *deux récepteurs, simultanément*, l'un restant au sol à poste fixe au "voisinage" du chantier, l'autre étant embarqué dans l'avion.

Sans cette précaution, les coordonnées GPS ne sauraient être considérées comme exemptes de fautes, surtout pendant les périodes où la "géométrie des satellites" évolue rapidement. Tout "rafraichissement" des données de l'orbite en cours de réception provoque un saut de plusieurs mètres, qui étant enregistré par le récepteur mobile et le récepteur fixe, peut ainsi être facilement détecté. Si on a fait l'économie de ce dernier, c'est le bloc qui doit assurer seul la continuité en s'opposant au saut.

Les précisions annoncées par les participants au Congrès ISPRS de Kyoto en 1988 (Dorrer et Schwiertz; Friess, 1988; Lindenberger, 1988) sont susceptibles, si elles sont confirmées, de bouleverser la photogrammétrie et même la géodésie complémentaire, à condition qu'on traite correctement l'influence de la dérive, du cabrage et de l'inclinaison sur l'horizon, du vecteur antenne-chambre.

Il faut souligner que les précisions dont faisaient état presque toutes les interventions à ce Congrès, sauf la nôtre (Brossier *et al.*, 1988), étaient obtenues à partir des résidus d'ajustement, cette manière de faire est incorrecte du point de vue statistique, car il est possible, par une pondération appropriée, d'amener les résidus à toute valeur qu'on veut bien leur donner ; de plus elle est dangereuse du point de vue pratique, car elle risque de créer des illusions qui seront vite dissipées par les premières applications. A l'inverse, comme on l'a fait, la précision estimée par les écarts relevés sur les points de vérification est composée de l'erreur de détermination du point par le bloc photogrammétrique et de l'erreur d'identification du point de terrain, lorsque ceux-ci ne sont pas prébalisés.

Les résultats sur les précisions qu'on peut attendre sont déjà assez spectaculaires sans qu'il soit besoin de les peindre sous un jour encore plus flatteur par des artifices statistiques.

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# MAPPING SOCIO-ECONOMIC CHARACTERISTICS BY VALUE-BY-AREA CARTOGRAMS (ANAMORPHIC MAPS)*

*Paper submitted by Germany*

## RÉSUMÉ

Le présent rapport expose les problèmes liés aux cartogrammes avec valeurs et montre qu'il faut étudier le potentiel de ces cartogrammes comme instrument d'information spatiale, fixer des règles pour la construction cartographique avec valeurs et intégrer la notion de cartographie avec des valeurs par zone dans la notion générale de système d'information géographique.

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The development of the new information techniques and the implementation of various types of geographic information systems (GIS) has initiated vivid discussion on the role of maps and mapping within those information systems, their technical realization and their integration with other devices of information input and output (Muehrke, 1990).

One area of discussion of GIS centres on their data, data structure and data bank. It was initiated by the great variety of input data from surveys, maps, remote sensing and other sources, and the need to combine, correlate and integrate them in a common data bank. Raster data, vector data, raster-vector conversion and their organization in data banks of hierarchy, network or relational structures are key-words for this stage. Recently the more technical base of the discussion was replaced by an approach that perceives the data as characteristics of models of objects (Egenhofer and Frank, 1989). The object-oriented data model is built on the four basic concepts of abstraction: classification, generalization, association and aggregation. For modelling purposes, in generalization it replaces the concept of hierarchy by that of multiple inheritance. At the highest level it consists of four general superclasses, of which the first defines the geometric properties such as location, spatial relationships and spatial operators. In this way the discussion of GIS carries on the earlier analysis of maps as a tool of spatial information. "Maps are tools to acquire, analyse and communicate spacial knowledge . . . (In the past) maps were mostly viewed as symbolic representations of visible space, with various degrees of abstraction. The map products were essentially descriptive, static and deterministic. With the advent of computer, remote sensing and geographical information systems the nature of maps has undergone a dramatic change however. Most of the maps today are thematic maps, which emphasize the attributes rather than their location. They often give a probabilistic view of physio-socio-economic phenomena that are not thoroughly commensurable . . . Finally, their look is more than ever influenced by the use of higly versatile sophisticated graphics which may enhance or destroy their power of communication" (Muller, 1989, p. 675). In spite of the shift from topographic to thematic maps, maps by their nature have a "spatial bias". Also GIS, by their nature, have a "spatial bias" and prefer as input topographic and environmental data with distinct spatial properties (Rhind and Green, 1988).

Another area of discussion of GIS centres on their function in society. This discussion on "fundamental principles, of geographic information systems" carries on the earlier analysis of maps as tools of communication and extends it to include "a frame of reference—a common system of symbols, values and interpretation . . . that is called culture" (Chrisman, 1987 p. 35). Based on it, a new model takes shape in which the multilayered data structure of GIS is transferred to the multilayers of societiee institutions and people as mandates or custodians. Beyond the traditional GIS the more extended hypermedia-GIS creates similar problems of its social functions. In it, the traditional paper map may be replaced by a map that can be characterized as hypertext. The technical potential for do-it-yourself mapping exists nowadays and requires new concepts of geographical inquiry. They may be based on the concept of multidimensional territorial concern, a "total concern for all those creatures, both natural (made by nature) and artificial (artifacts made by culture), that make up the community . . . Instead of production and growth, the territorial concern must direct its attention towards re-production and healing—caring for the survival of urban man and community life" (Wallen, 1990, p. 1,129). But, even with the stated interest in environmental protection for the survival of society, the major concern of the map as hypertext remains the spatial dimension, the "spatial bias" as it is called by socio-economic statisticians.

The statisticians of national, State or communal institutions have the mandate to collect, process and present data of various types of various aspects of the socio-economic development of societies. In the annual international and national statistical yearbooks a great number and variety of data are presented to the public. They are just a selected few out of the rapidly increasing quantities of data that are being accumulated into statistical data banks; their selection considers economy and data control. Statistical yearbooks (Germany and Thailand, n.d.) list the stable spatial property of their respective areas, but their interest is focused on the dynamic phenomena of the socio-economic environment. In general they start with a section presenting detailed demographic data: population distribution, age and sex structure, growth and migration, urbanization and other facets of the population structure and mobility. Other sections present data that may be called infrastructure data: data on health, education, recreation, utilities. They are very closely related to the demographic data and provide arguments to explain or forecast population development trends. Other sections present data of economic nature, ranging from agricultural production to international trade. Although these sections are dominated by measuring units of weight or monetary value the tables of employment relate them to the demographic data. The last section, on finances, not only presents data on public and corporate income and expenditure, and on price development, but also on wages and household income and expenditures. In this way each section illustrates the fact that all data of the socio-economic environment are based on

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or related to the status, structure and development of population. Therefore it can be said that each statistical analysis and presentation has a "demographic bias" or a "cultural bias".

The problem of mapping socio-economic data is to solve the conflict between the "spatial bias" of the cartographer and the "demographic bias" of the statistician. Cartographers try to achieve spatial accuracy, statisticians are interested in demographic accuracy.

Until recently the mapping of socio-economic data was dominated by the cartographer's spatial bias, especially as the statisticians relied on the expert knowledge of cartographers to create a "correct map". The most popular solution for mapping those data was the so-called "choropleth" map. In general, such a map shows the extent of statistical or administrative areas with spatial accuracy by their boundaries, and inside the polygons of the reference areas the statistical data (as averaged for each reference area only) by visually discernible gradations of grey patterns or colours (for classified data only). The cartographers were aware of the shortcoming of this type of representation; they tried to improve its value or correctness by various classification procedures and the use of continuous grey scales (Freitag, 1987). But the fact remains that the visual search and analysis of these representations is guided or dictated by the size and shape of the areas rather than the grey or coloured fillings of the areas. Therefore these representations should only portray data that are related to those areas and they should be called area-density maps or, in short, area cartograms.

Area cartograms (choropleth maps) are extensively used in statistical mapping. Prominent among them are the statistical atlases of population. They are produced by censuses requested by the Constitution or proposed by the United Nations (Thailand, various years). All contain, at the beginning, a population density map. In it the population is related to the reference area and the area cartogram is rightly employed to portray the density of the area, that is, a topic-area relation. However, the majority of the maps do attempt to show topic-topic relations by using the area cartogram that portrays them as a topic-area relation. Topic-topic relations are the relations of sex or age groups to the total population, of births, literacy, school attendance and employment to age groups, or of employment groups to total employed population.

For socio-economic mapping, not the statistical area, but the number of population is the most important reference unit. It is necessary to put the population as reference figure onto the map.

Cartography offers the graduated symbol map as one solution to the problem of portraying quantitative topics in an accurate spatial setting. But this presentation is only an insufficient solution. People are not evenly distributed on land; they are scattered, or concentrated in urban centres. Their representation by graduated symbols results in diminutive symbols or in largely overlapping symbols, neither of which is a useful means of visual communication.

First attempts to put the population number as area figure on the map sheet were made as early as 1870 (Tobler, 1963). But, it was the growing awareness of the rapid increase of population in relation to the economic growth and the use of some imperfect but striking representations of population data in the shape of countries and continents (so-called distorted maps) in a world-wide survey of population development in 1953 that directed the attention of statisticians and cartographers to this problem of value versus area (Woytinski and Woytinski, 1953). The principal task was well defined: first, the transformation of statistical data of values into proportional geometric (area) figures that would allow the visual comparison of their sizes, and secondly the arrangement of these figures in a spatial context that would allow the recognition of their geographical setting and neighbourhood. Both operations, value transformation and context arrangement, cannot be achieved without distortions. The search began for minimizing the distortions and for rules to construct this new type of cartographic representation. It resulted in a variety of proposed solutions. It also led to a variety of names for this new type of "map", indicating the various concepts of the respective authors. These names are:

*Distorted map*

W S. Woytinski, and E S. Woytinski (1953) World population and production. *Trends and Outlook* (New York)

J V White (1984) Using charts and graphs: 1000 ideas for visual persuasion New York-London (*World Maps Distorted*, pp 109-110)

*Maps/Cartogram as projection*

W R Tobler (1963) Geographic Area and map projections *Geogr Rev.* 53: 59-;8

N Kadmon, and E Shlomi (1978): A polyfocal projection for statistical surfaces *Cart journ.*, No 15, pp 36-41

*Proportional map*

C F Schmid and St E Schmid (1979) Handbook of graphic presentation, 2nd ed (New York)

A Bremer (1988): Proportionalkarten. *Planning and Analyse*, No. 15, pp 210-216

*Isodemographic map*

L Skoda, and J C Robertson (1982) Isodemographic map of Canada Geog paper No 50, Lands Directorate, Department of Environment, Ottawa

*Piezopleth map*

C Cauvin, C Schneider and G Cherrier (1989). Cartographic transformations and the piezopleth maps method. *Cart Journ.*, No. 26, pp. 96-104

*Statistical cartogram*

E Raisz (1934) The rectangular statistical cartogram *Int. Geogr Rev.*, No 24, pp 292-296

*Quantitative cartogram*

J M Hunter and J C Young (1968). A technique for the construction of quantitative cartograms by physical accretion models *Prof Cart.*, No. 20, pp 402-407

*Value-by-area cartogram*

B D Dent (1975) Communication aspects of value-by-area cartograms *Amer Cart.*, No 2, pp 154-168

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*Area cartogram*

J. Olson (1976) Non-continuous area cartograms *Prof. Geogr.*, No 28, pp 371-380

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J A Dougenik, N R Chrisman and D R Niemeyer (1985) An algorithm to construct continuous area cartograms *Prof Geogr.*, No 37, pp 75-81.

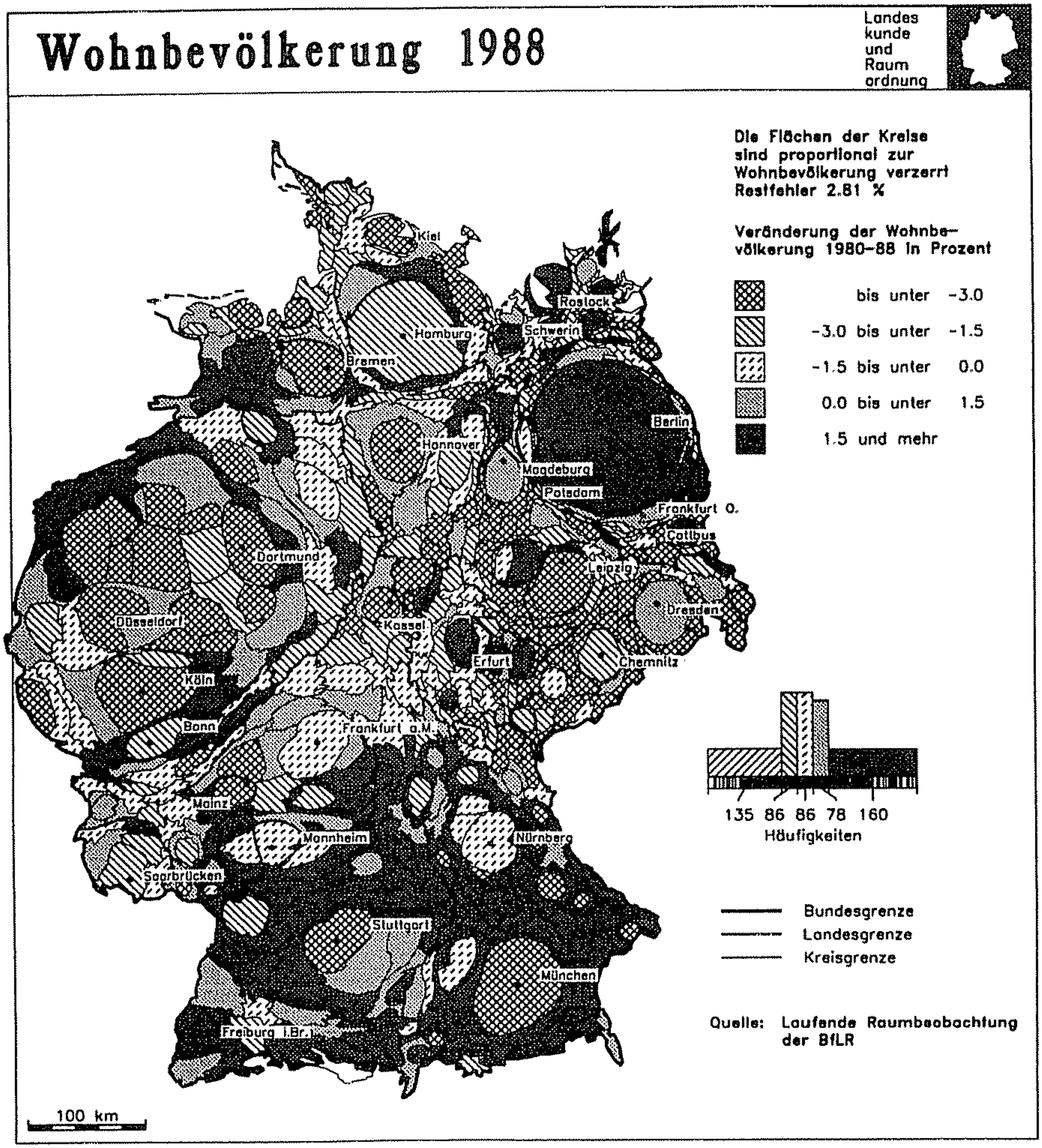
*Topological cartogram*

T L C Griffin (1983) Recognition of areal units on topological cartograms. *Amer Cart.* No. 10, pp 17-29

*Anamorphosis*

J Bertin (1967) Semiologie graphique Paris (Les Anamorphoses Geographiques, 120-121). (Translated into English, 1983, as cartogram).

Figure I. Value cartogram: residential population of the Federal Republic of Germany, 1980-1988 (percentage)




*Source* W. Rase.

Figure II. Value cartogram: population development of Thailand, 1980-1988

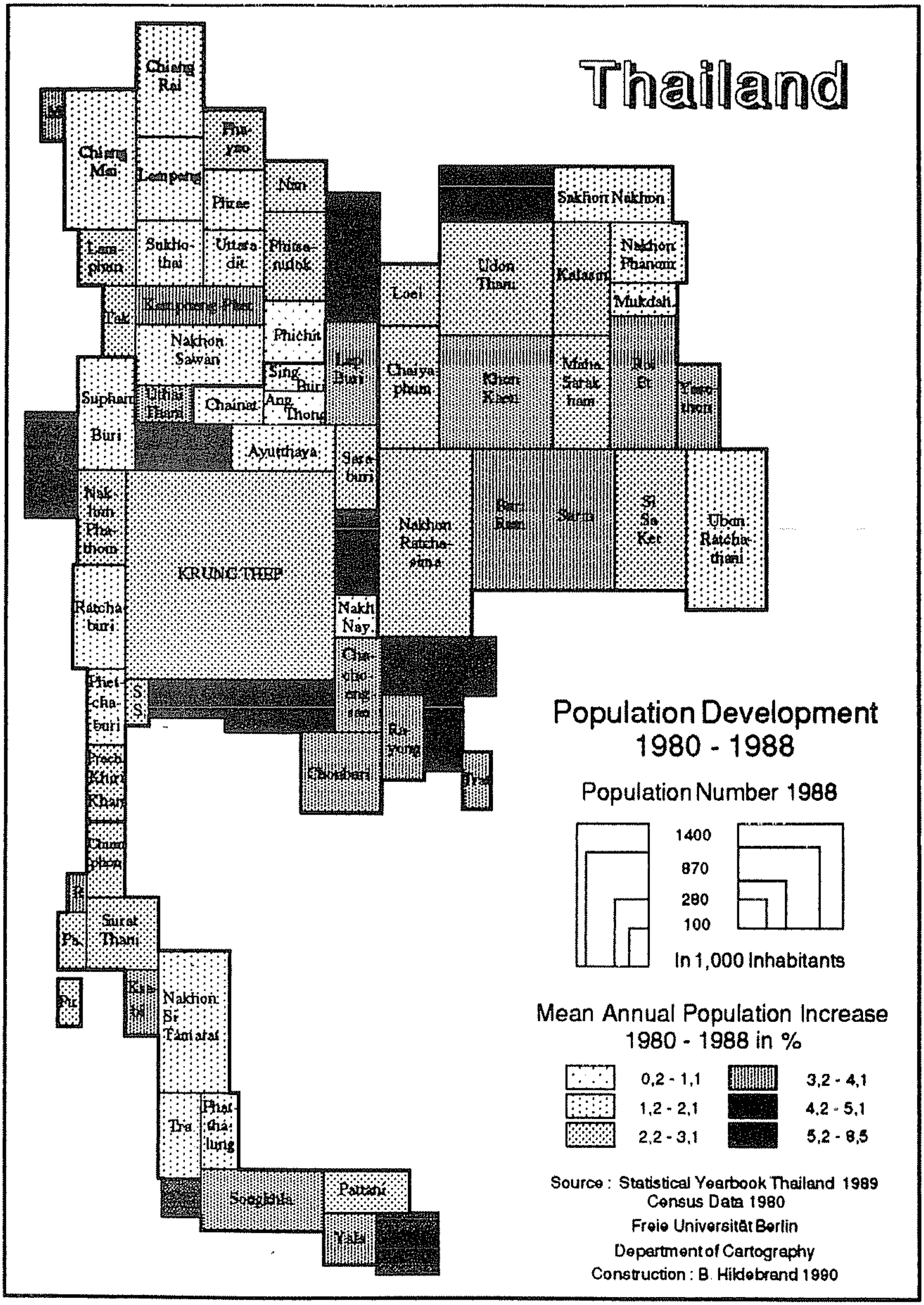


Figure III. Value cartogram: gross provincial product, Thailand, 1988

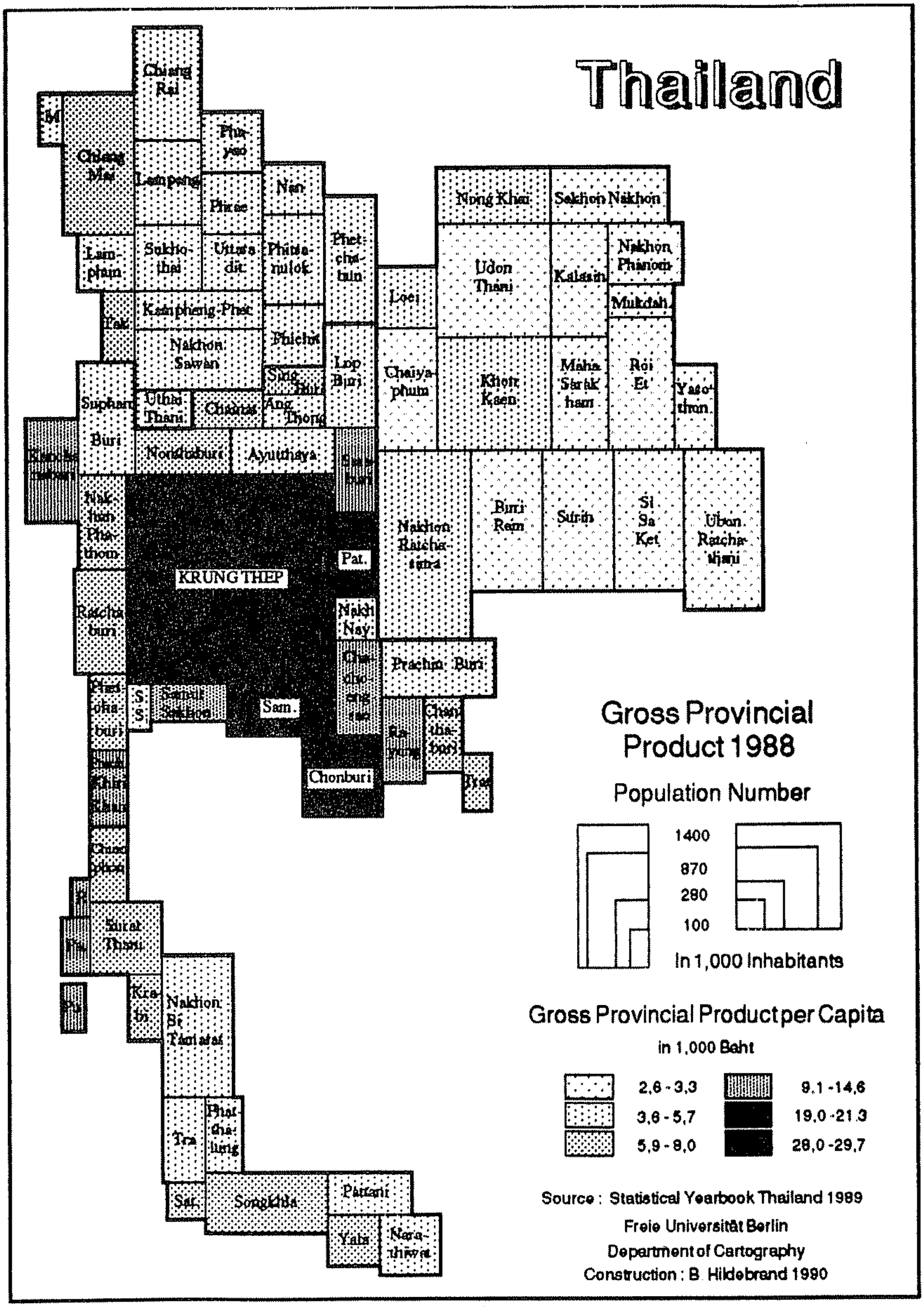
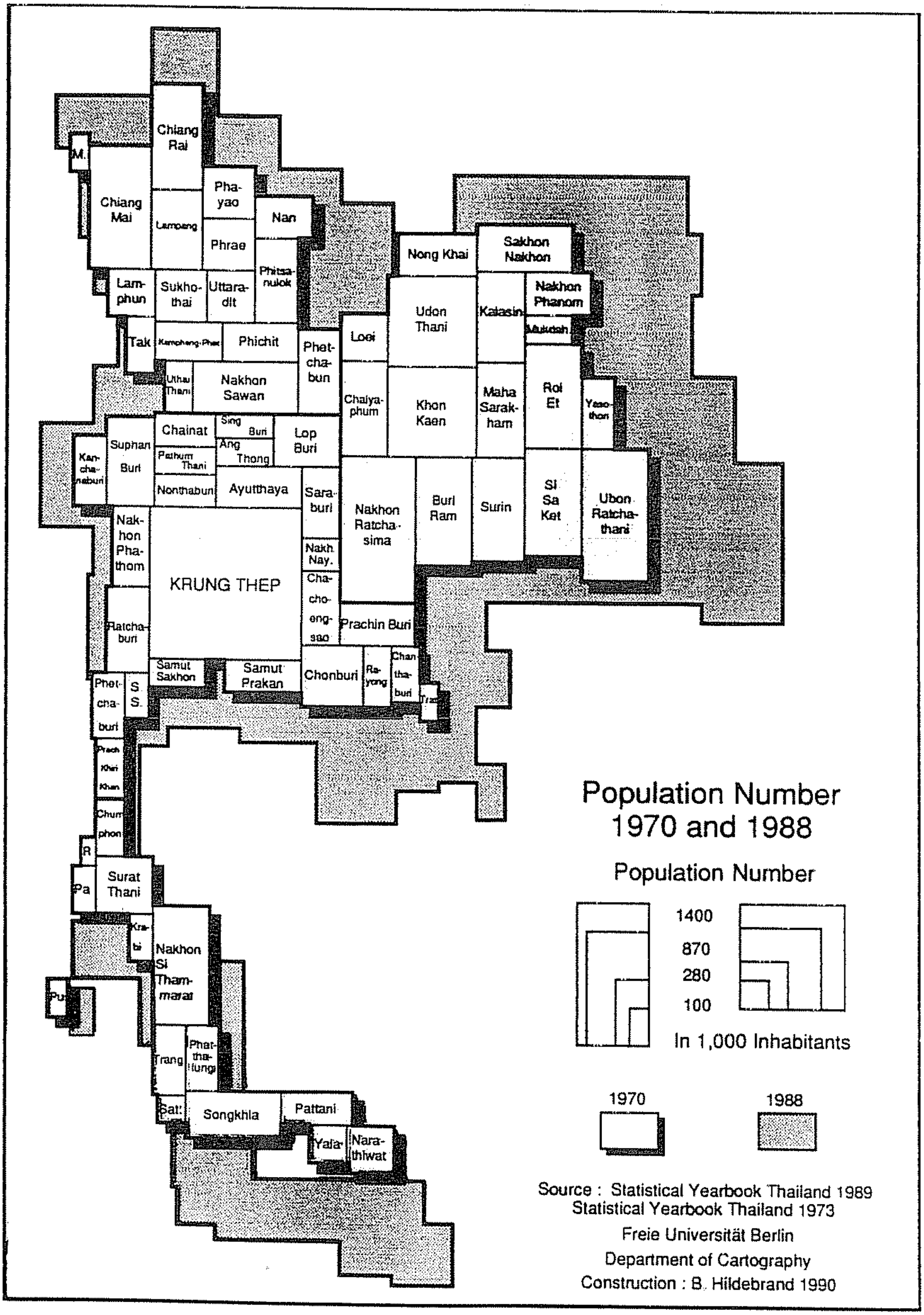


Figure IV. Value cartogram: population comparison, 1970 and 1988, Thailand



This list of different terms is not complete. The great variety of terms for graphic products that try to achieve the same single principal task indicates the absence of an agreement on the optimal solution of the value-versus-area problem. To pinpoint the problem and the expected graphic product we should at least use one common term for it. It should be called value-by-area cartogram or, in short, "value cartogram".

The evaluation of various proposals to construct value cartograms reveals again two different approaches which reflect the difference between the spatial bias and the demographic bias of the authors. Proposals with a spatial bias try to preserve in the value cartogram the spatial properties of individual shapes of statistical reference areas, or of the overall shape of all reference areas, as well as the connectivity or neighbourhood relations of the reference areas. Based on principles of multi-focal projections, algorithms to construct those cartograms were developed and employed (Dougenik and others, 1985). The resultant value cartograms resemble the forms of the natural or cultural areas of reality and are easily recognized as such. However, the individual reference areas are polygons of various forms which obstruct or prevent the comparison of the respective sizes. An example of this type of value cartograms is the representation of the residential population of Germany in 1988. By grey values, the population changes of 1980-1988 are indicated. This "map" was prepared by the Federal Research Institute of Regional Science and Regional Planning.

Proposals with a demographic bias try to display in value cartograms differences of value and to facilitate visual comparison. The results of visual perception research indicate that bars and squares should be employed as graphic figures to obtain the highest comparability. The resultant area cartograms facilitate comparison of value. However, the use of these basic geometric forms cannot create a composite figure that resembles the forms of the natural or cultural areas that we are used to finding on maps. Therefore the use of rectangles of fixed widths or heights or a combination of squares and rectangles of widths to heights is recommended to achieve some degree of spatial shape and connectivity. So far no algorithms were developed for the construction of such cartograms. It is a task for further cartographic research. One example of this type of value cartogram is shown in figure II, which presents the residential population of Thailand in 1988, with grey values representing population changes in the period 1970-1980, prepared at the Department of Cartography of the Free University, Berlin, for a study atlas of Thailand. Value cartograms of this type with a demographic bias can easily be constructed. While the construction of the map of Germany required the computing capabilities of a workstation, the map of Thailand required the capability of a personal computer only. The graphic quality of the PC maps depends on the output devices. Figures II and III illustrate the insufficient output from a 9-point plotter; figure IV is the result of a laser plotter.

Value cartograms of this type can be constructed in a similar way for other population data that are reference topics to other topics. The employed population in agriculture, or manufacturing or services, refers to the total employed population, the literate or school attending population refers to the population of ten years and older. The gross provincial product or other indicators of economic development very often refer to the total population (figure III). Value cartograms of this type can best be employed for two purposes:

(*a*) To present socio-economic data with a direct relation to those data that form the basis of the value cartogram; the classified related data are shown by grey patterns or colours. If the same number of classes and the same intensity screens are used, then the maps can be used with ease for comparative evaluation.

(*b*) To present socio-economic data at different periods of time, substituting for a time series of maps. The construction of comparative value cartograms requires additional considerations when the development of the data is variable and includes increases as well as decreases. Other considerations are necessary if cartograms are designed for presentation as overlays. However, they are a very good way to visualize the increase (or decrease) of the factors of the socio-economic environment (figure IV).

Several recent atlases on the so-called third world or the North-South conflict employ value cartograms to present a great variety of socio-economic data (Kidron and Segal, 1984; Crow, 1983). However, the choice of many reference topics perverts the underlying concept of comparability, and the seemingly arbitrary choice of colours for filling in the areas makes many area cartograms in these publications unattractive and misleading rather than attractive and informative means of communication. They represent an urgent call for the expert knowledge of cartographers to explore the potential of value cartograms as tools of spatial information for the large number of demographically biased members of society, establish rules for value cartographic construction and integrate the concept of value-by-area mapping into the general concept of geographic information systems.

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# THE GLOBAL PROBLEM OF BACKWARDNESS OF DEVELOPING COUNTRIES AND ITS INTERPRETATION IN COMPLEX ATLASES*

*Paper submitted by the Union of Soviet Socialist Republics*


## RÉSUMÉ

Le rapport traite de la question de la représentation cartographique des problèmes mondiaux actuels dans les atlas complexes de grandes régions du monde (continents et sous-continents). On y examine l'idée de réaliser des travaux cartographiques qui seraient conceptuellement, structurellement et fondamentalement nouveaux. Le rapport propose également divers indicateurs pour l'interprétation cartographique du problème mondial du sous-développement.


In the second part of the twentieth century humanity has realized, that the world's natural complexes and political, socio-economic and cultural structures are fragile; this is a contemporary global problem.

Global problems include those that have emerged in connection with the modern trends of economic development and the interaction of society and nature in speeding up scientific and technological progress. In the first place, there are the problems of abolishing the menace of nuclear war and maintaining peace on earth, the ecological problems connected with use of natural resources and energy, demographic and food problems and also the problem of overcoming backwardness in developing countries, which is most urgent for millions of inhabitants of Asia, Africa and Latin America.

Global problem studies have for an object a search for approaches to solving them. That is one of the main tasks of today's science, including geography. The task of geographic study of global problems includes perfecting the art of systematic mapping. We aim to create cartographic products that disclose thoroughly and completely the global problems of humanity, their genesis and interaction. Traditional regional geographic atlases are not equal to the task at hand. Some regions and countries present not one isolated problem but a whole complex of problems, which differs from region to region. In our opinion, systematic studies of global problems should be realized in the elaboration of the large regional atlas series.

The difficulty of mapping global problems lies in the fact that the regional trend of geographic problems has just begun to be researched. There is no common opinion among scientists concerning the definition of global problems, causes of their appearance, hierarchy and interaction. Such a situation gives us the right to formulate a point of departure and to define global problems for the solution of which the problem-oriented atlases are to be elaborated.

At a first approach, contemporary global problems may be defined as a complicated complex of phenomena and processes in nature and society, presenting the menace of regression and stagnation, even the annihilation, of human civilization. It is important that besides global changes in geographic cover and its components, the functioning of certain social forces can be a source of menace lying at the foundation of global problems. We speak not only about military and ecological security, but also about a socio-economic one. According to such interpretation the menace of isolation from determined trends of world development and exclusion from them, the menace of conservation and diffusion of social inequality, dependence, exploitation in different spheres appears to form the substance of the problem of backwardness of developing countries. The task of cartographic interpretation of this problem is to demonstrate the level of development of mapped regions.

Evaluation of the level of development, by country, has been conducted by Soviet and foreign scientists more than once, including cases when this was done to elaborate the regional geographic typology. There are a great number of approaches to constructing such classification schemes, using different criteria as basis. The most perceptive estimate of levels of development uses economic indices, which characterize both the productive forces and the relation of production to the culture. According to this method the "human factor" is included, without which any comparison is nonsense. The estimation of countries by level of development requires the application of a whole system of indices, reflecting the similarities and differences between countries, and their economies. The increase of the number of indices permits us to characterize the countries of a region in detail. But it can be done only to a certain extent because of a deficiency in international information materials.

Such a system of indices is proposed for mapping the problem of backwardness of developing countries in global regional geographic atlases. It consists of the following points.

(*a*) Summarized indices of the development of productive forces: they comprise gross national product per capita and its structure, national income per capita and industrialization factor. The situation (equal or not) in international division of labour can be demonstrated by the country percentage within the region in gross domestic product. The factor of industrialization, entered on a map, shows the differentiation among the countries according to the degree of industrial development;

(*b*) Indices that characterize the sectoral structure of economy, such as employment in different sectors;

(*c*) Indices showing level of technological and economic production and material productive forces development: they include indices of energy production and per capita consumption, territory transport development, degree of agricultural mechanization (the number of tractors per arable land unit etc.);

(*d*) Indices of scientific and technological production level, such as expenditures on scientific studies, research and development and the number of scientists and engineers per million residents;

(*e*) Indices characterizing the position of the countries of the region in terms of international division of labour: percentage of the regional countries in world trade; direction

*The original text of this paper, prepared by L.A. Fokina, *Kartografia*, Moscow, appeared as document E/CONF.83/L.20.

of foreign trade; share of export in gross national product; export and import volume and structure;

(*b*) Initial and calculated indices of foreign liabilities of the regional countries: they include not only total sums of accumulated debt, but information about the correlation of the foreign debt to the possibilities of economy, i.e. the share of debt in the gross national product and export volume in the currency reserve of the country etc. Using these indices, the solvency of any individual country can be estimated. The characteristics of loans applications taken from different credit sources is also important to reflect a country's socio-economic situation;

(*g*) Indices of level of cultural and health services, and consumption, showing the level of development of the human element of productive forces: the literacy rate by 1,000 persons; the number of students by 1,000 persons; percentage of students studying abroad; expenditures on education and health services; the number of inhabitants served by each doctor; average duration of life, degree of immunization of children; number of issues of newspapers per 1,000 residents; and the number of television and radio sets per 1,000 residents. To these can be added indices showing the degree of militarization of the economy, i.e. the relative level of military expenses and relative quantity of military forces. These indices should be supplied along with socio-demographic ones.

It should be stressed that these indices alone, or their complexes set out on a map, are of little importance. The reader should be able to compare visually these indices with the same indices for countries of other regions. It can be done in two ways: first, by using the world maps as additional ones; second, by simple indication of average world values indexed in legend scales. The latter is preferable for atlases of larger regions, because it greatly lowers the expense in time and labour, and makes it possible to produce more compact atlases.

The principle of "comparability" was successfully tested during the elaboration of the atlas for Africa, and we consider, that all problem-oriented regional geographic atlases worked out for large world regions should possess such properties. It will permit showing the specificity of global problem set and pick out territories (countries) where the problems are displayed sharply.

In elaborating the problem-oriented atlases it is necessary from the start to solve the whole set of metrological questions, concerning structure (expressed in the table of contents), selection of territorial units, and methods of representation.

These atlases can be constructed in different ways. All displays of particular global problems have a spatial structure to differing degrees and this can be taken into consideration in special atlas sections, while keeping within the limits of traditional frame of complex regional economic atlases. The structure of an atlas based on a typology of today's global problems is a new approach to the construction of a problem-oriented atlas. In this case the problem of backwardness should be considered in two interrelated sections.

The question of selection of the main cartographic unit for atlas elaboration of large world regions (continents and subcontinents), is solved in favour of the country. State boundaries outline the territory and its specific conditions: unit, political and administrative organization and economic regime, and also the peculiar ethno-demographical, cultural, educational and natural background that influence the display of global problems. Moreover, most indices picked out to characterize the global problem of backwardness, as indicated earlier, are given in international informational materials by country. This statement also concerns atlases of global scale. Naturally, atlases of separate countries or their parts call for different cartographic units.

The question of methods of interpretation is closely connected with that concerning cartographic units and indices. Such methods of mapping as choropleth and map diagram, including structural map diagram, are the most suitable, when selecting indices for the country.

Finally it should be mentioned, that at the present time the creation of fundamental global regional geographic atlases of scientific reference type is a difficult task and it is reasonable to work out from the first the methods of mapping contemporary global problems after the examples of popular scientific cartographic products.

## (f) *Special mapping (including mapping for the handicapped and the International Map of the World on the Millionth Scale (IMW))*

### TRIANGULATION SPATIALE D'UN BLOC D'IMAGES SPOT*

*Document présenté par la France*


### SUMMARY

Within the framework of SPOT development, evaluation and training activities (ADEF), the first experiments have been conducted in block spatial triangulation, also known as "spatiotriangulation" (by analogy with aerotriangulation), using data obtained for this purpose by the Institut géographique national.


C'est dans le cadre de l'ADEF, et grâce aux données acquises pour cette action engagée par l'IGN, qu'ont pu être menés les premiers essais de triangulation spatiale de bloc, également nommée "spatiotriangulation" par analogie avec l'aérotriangulation.

#### OBJECTIFS DE LA SPATIOTRIANGULATION

On sait que la réalisation d'une carte nécessite l'emploi d'un système de référence, qui permet ensuite à l'usager de

*The original text of this paper, prepared by Isabelle Veillet, Institut géographique national, appeared as document E/CONF.83/L.44

déterminer, d'après le document cartographique qu'il a entre les mains, la position géographique exacte, sur le terrain (en latitude, longitude ou coordonnées Lambert), de tout point ou objet qui y figure.

Bien entendu, le cartographe ne calcule pas les positions respectives de chacun des points qu'il restitue. Mais il les interpole dans l'image qu'il utilise pour faire la carte (qu'il s'agisse de photographies aériennes ou de scènes SPOT), à partir de quelques points bien définis dont il connaît avec précision la position sur le terrain.

On sait aussi que, pour extraire l'information altimétrique d'images aériennes ou spatiales, ou pour corriger les déformations planimétriques introduites sur l'image par le relief du terrain, il est nécessaire de disposer de deux images du même terrain, prises de deux points de vue différents. Ces deux images forment un couple stéréoscopique.

Ce couple stéréoscopique d'images SPOT sera mis en place ensuite sur un appareil permettant la restitution cartographique basée sur l'interpolation. Cette mise en place nécessite la connaissance de 6 à 8 points, dits points d'appui. Ce sont des points dont les coordonnées-terrain ont été directement déterminées dans le système de référence choisi, qui sont parfaitement identifiables sur le couple d'images SPOT, et dont les positions sur chacune des deux scènes du couple ont été mesurées, de façon à établir la correspondance entre les références terrain et image.

Il est ensuite possible de modéliser par le calcul la position et l'orientation des deux capteurs de prises de vue, ce qui permet ultérieurement de déterminer la position de tout point du couple.

Pour un projet cartographique couvrant plusieurs couples d'images SPOT, on pourrait, bien évidemment, déterminer par des travaux de terrain, les 6 à 8 points nécessaires à chaque couple; mais, d'une part, il est souhaitable que les mises en place de deux couples contigus soient cohérentes, et, d'autre part, le coût du travail d'équipement terrain étant directement lié au nombre de points à déterminer, il y a intérêt à réduire au maximum ce nombre.

Les calculs d'aérotriangulation avaient permis d'alléger considérablement les travaux de stéréopréparation de terrain préalables à la restitution d'un bloc de clichés aériens. Suivant cette même démarche, il fut envisagé une modélisation globale avec des couples d'images Spot, comme elle est pratiquée avec des couvertures aériennes stéréoscopiques.

Le calcul de triangulation spatiale de bloc est donc destiné à minimiser le nombre de points d'appui nécessaires et à assurer les raccords entre couples.

## Modélisation globale SPOT par segments

Le satellite SPOT acquiert les données en continu le long de sa trajectoire. Ces segments de données sont ensuite découpés en scènes. Sur une zone donnée, les scènes consécutives prises le même jour ne forment en fait qu'une même entité de prise de vue.

Un même nombre de points d'appui suffit à mettre en place un couple de segments comme un couple de scènes, car deux scènes consécutives d'un même segment sont déjà physiquement liées. La liaison Nord-Sud de celles-ci n'impose pas le pointé de points au sol communs. C'est de plus un gros avantage lorsque la partie commune ne comporte rien de pointable: couverture nuageuse trop dense ou surtout étendue d'eau. On cherche donc à ce que les images couvrent le chantier en formant au maximum des segments, en minimisant le nombre de scènes isolées.

Le segment de prise de vue sera l'élément de base de la modélisation. Celle-ci combine les mesures sur les points, les coordonnées-terrain des appuis, et les données auxiliaires de position et d'attitude du satellite.

Ces données auxiliaires n'ont pas la précision absolue requise pour la cartographie demandée, mais, par leur précision relative, elles apportent un complément fort utile qui permet de réduire le nombre de points d'appui.

## Chaîne de spatiotriangulation

Une chaîne de calcul de spatiotriangulation a été développée à l'IGN. Elle offre les mêmes fonctionnalités qu'une chaîne d'aérotriangulation. Elle est basée sur le principe d'une modélisation par segments. Implantée sur un VAX 730, elle fonctionne actuellement à titre expérimental.

Dans le traitement actuel, les coordonnées-image des points sont mesurées sur les films qui seront exploités ensuite en restitution. Ceci nécessite la génération de films, phase supplémentaire non exempte d'aléas.

## Le polygone d'essais de spatiotriangulation de l'ADEF

Le polygone français d'évaluation de la spatiotriangulation de bloc d'images SPOT se situe dans le sud-est de la France. Il s'étend de Grenoble à Aix-en-Provence, et du Puy à Montpellier, sur 200 km d'est en ouest et 220 km du nord au sud.

### *Acquisition SPOT*

Elle couvre 16 couples d'images SPOT. Pour ces tests, nous avons choisi d'acquérir 4 couples de segments. Chaque segment est long de quatre scènes.

Les 4 bandes ont été acquises les unes après les autres : été 86, printemps et automne 87 et été 88.

On trouvera dans l'article "Présentation générale de l'ADEF SPOT" de ce même bulletin, d'une part une carte localisant les scènes équipées, et d'autre part une liste détaillant, pour chacune d'entre elles, référence, position, date et angle de prise de vue et indicateur de couvert nuageux.

### *Points-terrain*

Des points-terrain, c'est-à-dire dont les coordonées-terrain sont connues, pouvant servir aussi bien de points d'appui ou de vérification ont été définis sur l'ensemble du polygone.

Le nombre de points finalement répertoriés s'élève à 550 environ (cf. fig.I).

Ces points sont connus, sauf exception, en $X$, $Y$ et $Z$.

*Origine des points-terrain*

Les points-terrain de ce polygone, destinés à être indifféremment utilisés comme points d'appui ou de vérification, proviennent d'origines fort diverses. On peut les classer ainsi :

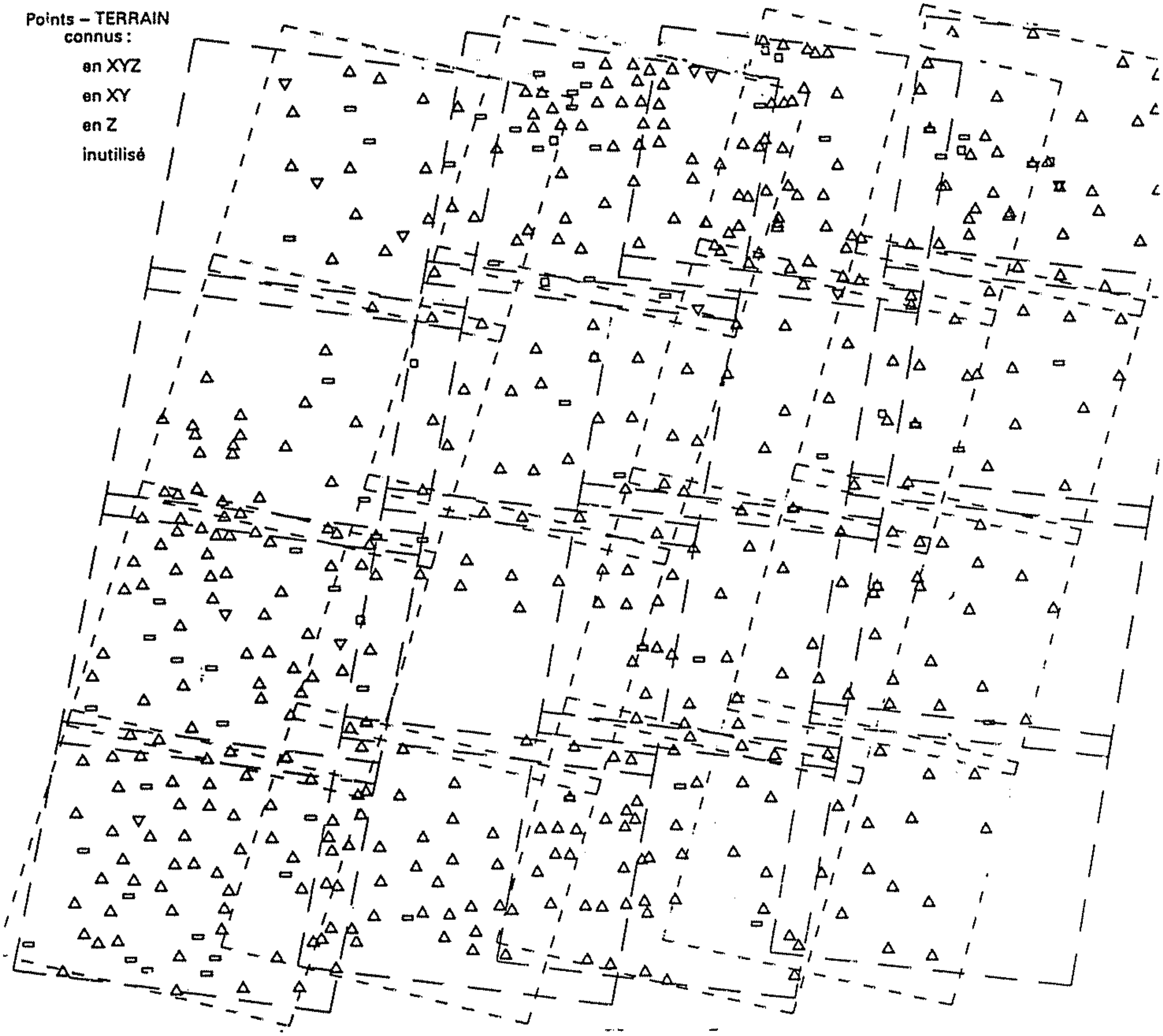
*a*) Points choisis et déterminés par stéréopréparation sur le terrain;

*b*) Points choisis sur clichés aériens à 1/30 000, et déterminés par aérotriangulation;

*c*) Points préparés pour la recette en vol, déterminés sur des couples de clichés aériens à 1/60 000, mais sélectionnés sans images SPOT;

*d*) Points extraits de cartes à 1/25 000.

**Figure I. ADEF : polygone d'essais de spatiotriangulation (Aix-en-Provence, Grenoble, Le Puy, Montpellier)**




*Source. Bull Inf. I.G.N.* 8913

La précision de détermination de ces points varie de 2 à 10 m sur le terrain, sans compter l'incertitude de définition, qui peut atteindre une dizaine de mètres.

*Type de points choisis*

Les détails sélectionnés comme points-terrain sont en très grande partie des intersections, principalement des carrefours de routes.

Les critères habituels de choix de points-terrain pour la stéréopréparation destinée à l'aérotriangulation ont prévalu. On recherche un élément net sur toutes les images où il est vu, symétrique afin d'être pointé en minimisant les erreurs. Il faut de plus s'assurer que l'élément observé sur les images est bien l'élément dont on peut déterminer les coordonnées.

*Répartition de ces points*

Il était prévu de préparer de 20 à 30 points par couple au minimum. Prévoyant un certain déchet dans les points tirés des cartes 1/25 000, ceux-ci ont été multipliés.

Ils sont répartis sur l'ensemble du polygone, avec, en moyenne, environ un point tous les 10 km. Leur densité est variable. Certaines zones déjà équipées, à l'occasion de la recette en vol, n'ont pas été densifiées; d'autres, trop nuageuses ou enneigées, n'ont pu être équipées.

*Points de liaison*

Le nombre de points-terrain observés en zone commune à deux couples étant suffisant pour lier ces couples entre eux, il n'a pas été nécessaire de créer des points de liaison supplémentaires.

*Mesures*

Les mesures ont été faites en stéréoscopie, sur restituteur analytique Traster (Matra). L'objectif de la spatiotriangulation étant, dans un premier temps, de fournir les éléments nécessaires à la restitution, il a semblé préférable de faire des pointés en stéréoscopie, avec la même qualité de pointé que celle des pointés préalables à la restitution.

Les couples de segments ont été mis en place sur le Traster, à l'aide d'un minimum de points d'appui; puis tous les points-terrain ont été mesurés, et des coordonnées-terrain provisoires calculées par le logiciel Traster dans chaque couple. Un certain nombre de points de liaison complémentaires ont été également mesurés. Les mesures (coordonnées-image et coordonnées-terrain provisoires) ont été ensuite transférées pour effectuer le calcul global.

Ces mesures ont été effectuées au fur et à mesure de l'acquisition des images, donc sur deux années, ce qui n'a pas favorisé l'homogénéité des mesures.

Un même jeu de mesures a été utilisé pour les différents essais.

## INFLUENCE DU RAPPORT BASE/HAUTEUR

La première bande acquise, sur la trace Grenoble-Aix, l'a été sous trois angles de prises de vue différents, deux visées étant obliques et une quasi verticale. Elle est équipée de 120 points-terrain environ. Chaque point a été observé dans chacun des 3 couples où il était visible. Le calcul global des 3 segments avec tous les points en appui sert de référence.

Les 3 couples de segments, de rapport base/hauteur respectifs 1,0, 0,6 et 0,3 ont été calculés indépendamment, chacun avec tous les points-terrain en appui.

Les résultats sont analogues à ceux de la recette en vol. La planimétrie se dégrade un peu avec la baisse du rapport B/H. L'altimétrie, en revanche, et comme prévu, y est beaucoup plus sensible.

ECARTS AU TERRAIN AUX POINTS D'APPUI

| *B/H* | *1,0* | *0,6* | *0,3* | *Réf.* |
|---|---|---|---|---|
| *XY* | 7,2 | 8,4 | 9,2 | 7,6 |
| *Z* | 3,7 | 5,3 | 7,1 | 4,5 |

Ecarts moyens quadratiques en mètres
Calculs sur un couple de segments, appuyés sur 100 points environ.

Les autres essais concernent le polygone dans son entier.

## RÉSULTATS DU CALCUL GLOBAL

La précision des points est évaluée par un calcul global où tous les points-terrain sont en appui. L'écart moyen quadratique est de 5,4 m en *X* et en *Y* et 3,9 m en *Z*.

Ce calcul, qui est appuyé sur tous les points connus, fournit le résultat le plus précis qu'on puisse obtenir avec ce jeu de données, et servira de référence par la suite. Afin d'estimer l'influence sur le calcul du bloc de telle ou telle configuration d'appui, on pourra s'intéresser aux écarts de positionnement des points entre le bloc étudié et le calcul de référence.

## EFFET D'UNE CONFIGURATION D'APPUI ALLÉGÉE

Afin d'illustrer ce qu'apporte une compensation de bloc, deux calculs ont été retenus.

Dans les deux cas, 6 points (doublés ou triplés pour éliminer les biais) servent à appuyer le bloc. Ils sont situés sur les limites Est et Ouest, et pour l'un (A) sur les scènes centrales, pour l'autre (B) sur les scènes Sud. La figure II les localise plus précisément.

La qualité des calculs est mesurée par les écarts aux points de vérification, dont le nombre dépasse 500. La dégradation par rapport au calcul de référence (Ø) est très faible.

ECARTS AU TERRAIN AUX POINTS DE

| | *Vérification* | | *Appui* |
|---|---|---|---|
| | (A) | (B) | (Ø) |
| *XY* | 7,9 | 8,8 | 7,9 |
| *Z* | 4,3 | 5,7 | 3,9 |

Ecarts moyens quadratiques en mètres
Calcul sur l'ensemble du polygone, avec plus de 500 points

Ces chiffres, moins de 10 m en planimétrie et moins de 5 m en altimétrie, permettent de réaliser des produits cartographiques géométriquement réguliers à partir d'images SPOT, avec un équipement-terrain réellement peu important. Pour chiffrer la réduction d'équipement-terrain, principalement altimérique, qu'apporte l'utilisation d'un bloc de photographies aériennes, on peut dire que, grâce à la stabilité d'orbite du satellite, la moitié des points suffisent (à nombre égal de clichés et de scènes). Une scène SPOT couvrant environ 36 clichés au 1/50 000, le rapport de canevas d'appui altimétrique, canevas SPOT/canevas aérien, est de 1/70. Ceci ne reste qu'un ordre de grandeur.

L'équipement-terrain minimum d'un tel bloc ne devra cependant pas être aussi léger que ces deux exemples tendent à le montrer. Il serait souhaitable de disposer d'autant de points de vérification que de points d'appui.

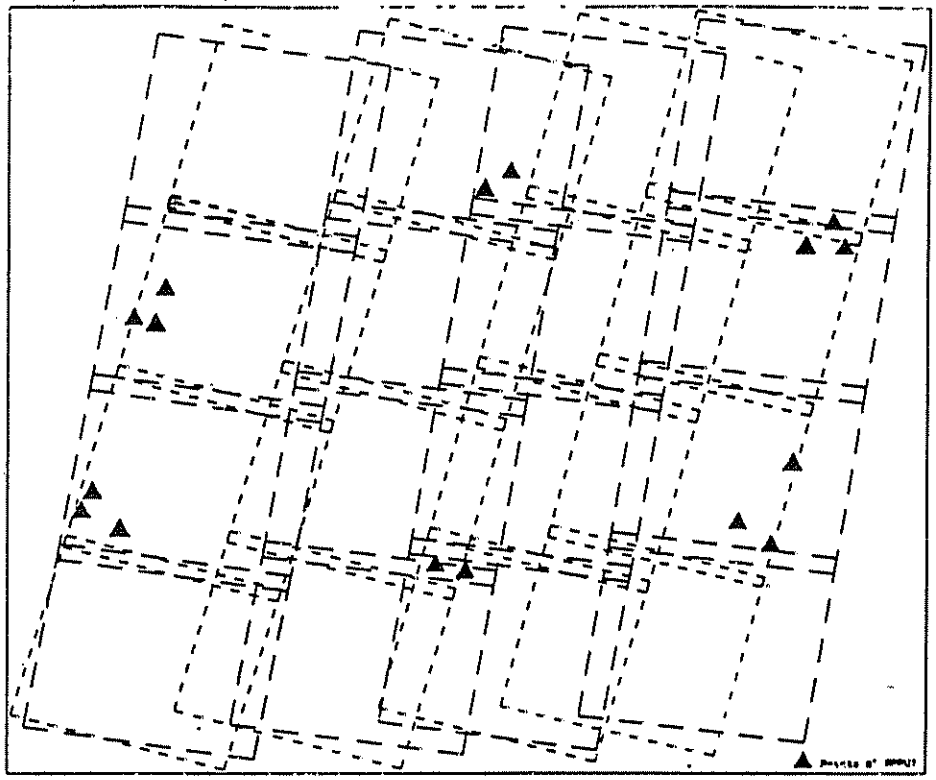
## POUR CONCLURE

*Suite à donner*

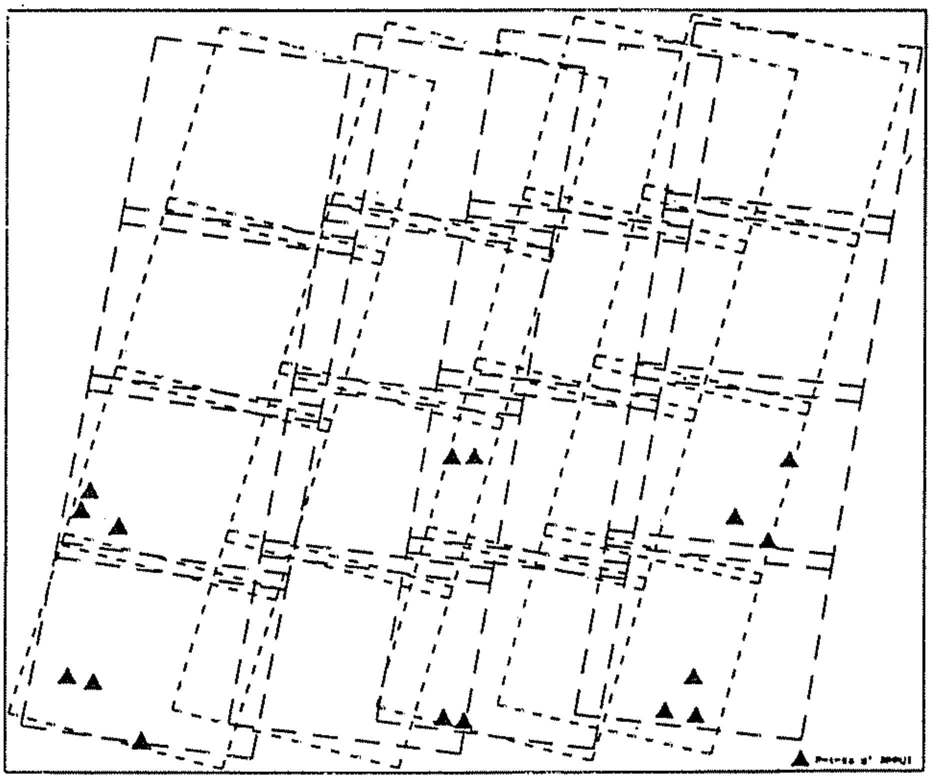
Ces données ADEF permettront la poursuite des évaluations de spatiotriangulation, concernant d'une part le

**Figure II. Structure du bloc d'essai**

STRUCTURE DU BLOC D'ESSAI (A)



STRUCTURE DU BLOC D'ESSAI (B)



*Source : Bull. Inf. I.G.N.*, 8913

choix de la modélisation la plus stable à adopter, permettant l'élimination d'erreurs et le calcul de blocs sous-équipés, et d'autre part, les possibilités d'extrapolation de la méthode.

Quant à la qualité des points, aux critères de sélection de ceux-ci, mieux vaut travailler en paysage destiné à ne faire l'objet que d'une restitution. En effet, une cartographie régulière à partir d'images SPOT nécessite malheureusement des travaux de complètement plus lourds que si des photographies aériennes étaient exploitées. Elle n'est pas adaptée aux paysages trop denses en détails

*Un chantier réel a déjà pu être traité*

Cette technique développée sur les données ADEF a pu être employée sur un chantier de production, comme phase préliminaire à la restitution commandée.

Un premier chantier de cartographie nouvelle, à base d'images SPOT, couvrant l'ensemble du territoire de Djibouti, est actuellement en cours d'exécution. Il s'agit, dans un premier temps, d'un projet de cartographie classique, mais pour lequel l'utilisation des images SPOT était économiquement envisageable.

Etant données les conditions de choix de points d'appui, un calcul de spatiotriangulation a permis d'assurer l'homogénéité de l'ensemble des 16 couples.

Sur ce travail, un calcul appuyé sur 6 des 26 points-terrains connus a donné des résultats analogues à ceux du calcul appuyé sur tous ces points connus; ceci confirme les essais ADEF et permettra, à l'avenir, d'alléger davantage encore le canevas d'appui.

*Les applications non stéréoscopiques*

La spatiotriangulation a pour principal objectif de réduire les travaux de terrain en phase de stéréopréparation dans le cadre d'un processus de cartographie utilisant les images SPOT.

Ce principe peut aussi bien être employé pour le prétraitement géométrique nécessaire à la fabrication de mosaïques d'images SPOT sur de larges zones peu pourvues en points de calage.

## PREPARATION OF THE NATIONAL ATLAS OF JAPAN, REVISED EDITION*

*Paper submitted by Japan*

### RÉSUMÉ

Le projet quinquennal entrepris par l'Institut géographique en 1986 afin de réviser l'*Atlas national du Japon* s'est achevé avec la publication en novembre 1990 de l'édition révisée de cet atlas. Dans le présent document, on décrit les grandes lignes du projet, ses caractéristiques essentielles, la politique de rédaction, etc.

Upon publication of the first edition of *The National Atlas of Japan*, it was put to practical use in many fields, such as government, local government, private companies and educational organizations. Today, after 10 years, economic and social situations have changed greatly. In the "international age", so to speak, relationships with foreign countries have become more significant, and along with recent progress in exchange of information, map information has risen in importance. For these reasons, all of the thematic maps included in the first edition had to be renewed.

*The National Atlas of Japan, Revised Edition,* contains a total of 235 thematic maps and their explanations, based on every kind of reliable data. These maps cover 14 subjects, such as physical features, climate, land development and conservation, population, social conditions, education and culture.

### OUTLINE OF THE PROJECT

The basic policies of the project were the following:

(*a*) Reduction of labour and promotion of efficiency by compilation of photo-engraving film and graphics with the introduction of a computerized mapping system;

(*b*) Comparison with the first edition;

(*c*) Investigation of the scale of the base map, and the expression;

(*d*) In order to meet the time schedule, reconsideration of maps found in the first edition and addition of new thematic maps and statistical graphs.

The planned working period was 5 years (from 1986 to 1990).

The format of the *Atlas* is:

*Size:* A2 size (60 × 46 cm)

*Pages:* 218 pages

*Scale:* 1:2,500,000 ~ 1:16,000,000

*Colours:* 5~12 colours (average 7 colours)

*Languages:* Japanese and English versions

The breakdown of thematic maps is shown in the table.

| *Map themes* | *The National Atlas of Japan 1977 edition Number of thematic maps (number of pages)* | *The National Atlas of Japan, Revised edition, 1990 Number of thematic maps (number of pages)* |
|---|---|---|
| General | 2 (4) | 2 (4) |
| Physical features | 30 (40) | 28 (32) |
| Climate | 29 (28) | 29 (20) |
| Land development and conservation | 15 (20) | 11 (16) |
| Population | 21 (28) | 27 (20) |
| Agriculture, forestry and fisheries | 31 (44) | 27 (20) |
| Mining, manufacturing and construction | 26 (38) | 23 (20) |
| Transport and communications | 29 (40) | 16 (16) |
| Foreign trade and flow of goods | 10 (12) | 4 (4) |
| Commerce, banking and insurance | 12 (16) | 11 (8) |
| Politics and finance | 8 (8) | 10 (8) |
| Social conditions | 26 (28) | 22 (20) |
| Education and culture | 29 (32) | 24 (20) |
| Regional maps | 7 (10) | |
| Administrative | 1 (3) | 1 (3) |

*The original text of this paper appeared as document E/CONF 83/L 12.

### Circumstances leading to preparation

The Geographical Survey Institute of Japan had compiled, at scale 1:8,000,000, geographical maps that could be considered as the offshoot of a national atlas of Japan from 1946 through 1960. However, they were not bound as an atlas. In 1948, the atlas *Japan* was published. It was a booklet consisting of maps at 1:2,000,000 scale, with geographical notes. The booklet turned out to be the product of elementary research work oriented toward the compilation of a genuine national atlas.

In 1971, the programme for the compilation of a national atlas of Japan was approved as an official project endorsed with a national budget. It was started as a five-year programme based on deliberations by the Committee for the National Atlas of Japan

In March 1977 *The National Atlas of Japan* was published. This was an A2-sized atlas of 351 pages containing 276 thematic maps and their descriptions in 15 different fields, such as physical features, development and land conservation, social condition and culture. It has been utilized as basic data for a true understanding of the territory of Japan ever since. Later, in the process of revising the thematic maps contained in *The National Atlas of Japan*, the Geographical Survey Institute and the Committee proposed the creation of a thematic atlas containing maps on particular themes. A new project with regional planning as its theme was started in 1979. This atlas was completed in September 1984 and published under the title of *The Atlas for Regional Planning—Actual Conditions and Changing Aspects of the National Land in Japan*.

Before the actual revisional work, the principal policy with regard to the whole plan was presented through discussion in the Committee for the *National Atlas*. In November 1990, it was named *The National Atlas of Japan, Revised Edition* and published.

### Compilation of the Atlas

The work of compiling the *Atlas* proceeded step by step, as follows.

1. *Establishment of the Committee for the National Atlas of Japan.* The revisional work was conducted under the Committee in order both to smooth the progress of the project and substantiate its content. The Committee divided itself into two parts: one a committee which discussed the project plan and the state of progress, and the other a special committee which examined each theme separately. The Under-secretary of Construction was the Chairman, and the membership consisted of scholars and special members of 20 related government agencies. They decided on the basic policy of revision work based on the discussions.

2. *Data collection.* Before the compilation of the thematic maps, most data collections were conducted by many public enterprises such as agencies of the central Government and public corporations. Such surveys were done directly by the researchers, who often transcribed or took a copy of necessary data collected, according to circumstances. In surveys relating to subjects that required special technical knowledge, they were orally helped by scholars or experts in the particular fields.

3. *Data analysis.* The data acquired were then analysed. Analysis consisted of judgements on whether the data could be made available or not and estimation of whether it was possible to indicate analysed data in an accepted method. Workers were then advised about the calculation process etc.

4. *Editorial rules.* After ratio calculation of each area to compile a choropleth map, various editorial rules for compiling the maps were decided upon, for example, statistical class mark derived by investigating the frequency of statistical values while exchanging views with the Committee for the National Atlas.

5. *Editorial work, cartography and film making.* The process of compiling the map, using products from former steps, was carried out mainly by computer operation. On the other hand, thematic maps compiled with traditional techniques were related to nature or climate, which were comparatively difficult to deal with by computer process.

6. *Test printing.* The actual maps were checked, mainly concerning colour design.

7. *Printing/Bookbinding.*

### Thematic map compiling by CCPS

In compiling the *National Atlas of Japan, Revised Edition*, by The Computer-aided Cartographic Processing System (CCPS), presentation was first discussed. It was finally decided that 60 per cent of the atlas should consist of statistical graphic charts, such as choropleth, circle symbol, and formation of unit symbol, or maps representing distribution of themes with scope demarcated, such as the climate chart. Therefore existing softwares were used for easy presentations. Meanwhile, software has been added or replaced, corresponding to the compiling of the *National Atlas*.

#### *Input/edit*

1. *Compiling of base map.* In compiling work, every scale was kept in repair with due regard to frequency of utilization. The working process is as follows:

(*a*) Paste up base map film on drum scanner, scan it by sampling pitch 50 μm. 4 revolutions/minute.

(*b*) The figures are recognized as lines (raster data), therefore vectorize and thin them;

(*c*) Process data that are displayed on the cathode ray tube (CRT) by dialogue operation; for example line correction, attribute bestowal, formalization and so on;

(*d*) In compiling the choropleth map, convert the file made at (c) to polygon data, and put code of administrative districts;

(*e*) Lay out base map in A2 size unit to avoid extra work when it is output.

2. *Compiling of choropleth map.* Statistical data were input from the keyboard or magnetic tape, analysed and ranked and a ranking file was made for the choropleth map. It was then matched to the polygon data file maintained in the compiling process of the base map, and a choropleth map for municipals of prefectures was compiled.

3. *Compiling map with circle graph.* The map with circle graphs was made by inputting statistical data, and then, by calculation and analysis, the compiling was done. The working process was as follows;

(*a*) Using the vector data compiled in the background map (base map), the centre of each prefecture was indicated by a cursor on the CRT, and then the file for the centre position (X,Y) of the circles was generated;

(*b*) By matching the parameter file (which includes the formula of the radius and the number of items) and the data necessary for drawing the circle graph, and also the centre position file compiled at (*a*) above, the circle graph was drawn on the CRT. If one circle should fall on another, they can be moved to a suitable position, so that the map with circle graphs are laid out appropriately and can be compiled.

4. *Compiling of maps representing the distribution theme, with its scope demarcated.* This map is compiled by a computer process where the original picture drawn by a scanner is input. There are several methods of input: by indication of colour points, by region-painting, by symbol recognition and so on. They are different in recognition of colours in closed regions. The method of indication of colour point is as follows;

(*a*) Trace out necessary boundary line on a polyester film from original pictures. Put colour in the centre of the closed region, which is contained by boundary line;

(*b*) Input pictures made at (a) by using scanner and distinguish the colours automatically: 16 colours can be distinguished on a personal computer system;

(*c*) Closed regions that cannot be distinguished by colour because of small area were corrected by dialogue operation.

5. *Compilation of distribution map.* The distribution maps, which, for example, show positions of public facilities, were compiled from partly processed or corrected existing data, such as digital national land information, and were output by laser printer etc. In such maps, if it became complicated because of the large number of points for its scale, we introduced manual editing, and drafted a map that indicated the positions output from X-Y plotters.

### *Regulation of files*

In cases where input and edit were performed on a computer system, many data files were generated; therefore the *National Atlas of Japan, Revised Edition* files are classified into base maps, legends, circle graphs, choropleths and final products. Furthermore, we regulated each thematic map.

### *Output*

Data output to ink jet printer, electrostatic plotter, laser plotter etc. are limited to raster form. So vector data must be converted to raster form. Though data inspection is unnecessary on CRT, vector data designated ranking and colour directly so as to be able to output without the image of raster data. In this case, the file for output can be stored, and we have introduced this method.

About the time spent in the compiling process: it took about 2 hours to compile file for output in sampling pitch 50 $\mu$m and Al-sized both base map and thematic map. Two and one half hours is needed to draw on film by a laser plotter.

## FUTURE VIEW AND PROBLEMS

### *Technical problems in CCPS utilization*

For the *National Atlas Revised Edition*, 60 per cent of the thematic maps were compiled by CCPS utilization, including manual work. The results confirmed the simplification of the working process and shortening of working time and cost reduction as compared to the traditional manual techniques. This will have a major impact on the technical level when it comes to doing the same type of work in other projects. Although the thematic maps dealt with in the *National Atlas* are numerous and varied, few technical and accuracy problems arose in the processing; thus, it was easier to carry out the work. However, there remain problems of computerization of the whole work which need to be resolved.

The maps compiled by CCPS are mainly present with choropleth and circle graph. For the thematic maps, which are comparatively hard to handle with a computer system, we will have to think of a better method to compile them smoothly.

The computer-assisted process is performed by a "dialogue" operation with the computer system. For the future, we think that study is necessary to compile fully automatically.

### *Modification plan of thematic map*

As for revision of the *National Atlas*, the whole atlas was traditionally revised. But now, social needs demand that new information be offered quickly in every thematic map. From now on, we will plan to be able to modify main thematic maps speedily. That plan will include designating statistics (whose data are cyclically replaced) that are especially in demand, and renewing thematic maps in good time, so that the latest information is offered to users promptly.

### *Conversion to electronic medium*

Recently in Japan, various kinds of new media have been developed and goods are available at low cost. In former days, computerized information was mainly used by enterprises. Now, it is necessary to offer information and pay serious attention to individual usage, such as with personal computers, word processors etc. Therefore the Geographical Survey Institute has promised a new electronic *National Atlas* in fiscal 1990. Actual work has begun on a plan to offer electronic map data with software that enables processing and editing of the original data.

### *Direction of the* National Atlas

In compiling an atlas, it is necessary to discuss an actual counterplan based on what atlas users will further expect. To immediately accommodate this information-oriented society, we think it is necessary to combine all data belonging to each government agency, with the online information processing system, and to offer the latest information in map form or in an electronic information form to users.

# AGENDA ITEM 7

## Cartographic data retrieval, analysis, depiction, presentation and product generation

### (a) *Map and chart reproduction, publishing and printing*

## DIRECT PRINTING OF DIGITAL IMAGERY*

*Paper submitted by Australia*


### RÉSUMÉ

Au cours des deux dernières années, l'Australie a mis au point une nouvelle technique de reproduction cartographique de grande qualité pour la production de copies multiples de données vidéo numériques rehaussées.

Conçue à l'origine grâce aux images fournies par le satellite SPOT pour cartographier des régions isolées de l'Antarctique, cette technique est désormais appliquée à de nombreux autres produits cartographiques en Australie, tels que l'établissement de cartes géologiques, les études de surveillance de l'environnement et les informations de base servant aux cartes touristiques des parcs nationaux, et l'on procède actuellement à des essais afin de l'utiliser dans l'aviation comme base des cartes d'approche à vue dans les aéroports australiens.


### CONVENTIONAL CARTOGRAPHIC PRODUCT GENERATION

Digital satellite imagery can be linearly and spectrally enhanced on many image analysis systems, but a problem arises when there is the requirement to produce quality copies of the displayed digital data.

Some common methods available are:

(*a*) Photograph the screen display and make enlargements;

(*b*) Use a film writer to produce a small negative or positive transparency;

(*c*) Inkjet plots;

(*d*) Electrostatic plots.

However, each of these methods has inherent disadvantages and is not suitable for producing thousands of copies of a high quality product to a uniform standard.

The traditional cartography technique is to print multiple copies by photolithography techniques. This involves scanning photographic enlargements from transparencies produced on a film writer device. These conventional techniques were used by the Australian Survey and Land Information Group (AUSLIG) to produce full colour satellite image maps of Antarctica from SPOT imagery (Lindsay and Manning, 1989). The maps produced were:

| | |
|---|---|
| Larsemann Hills | 1:25,000 (1st. ed., 1988) |
| Windmill Islands | 1:50,000 (1989) |
| Framnes Mountains | 1:100,000 (1989) |

The information on these maps was quite good and they provided an adequate solution for urgently needed cartography in remote areas. However the image resolution had been degraded during the cartographic and printing processes when compared with the detail visible on the computer screen display of the original imagery. This is a common problem encountered with the output of enhanced imagery from a computer.

### THE SIMAP PROCESS

To overcome this problem AUSLIG, in conjunction with two private sector Australian firms, developed a direct printing digital process. This technique eliminates much of the degradation associated with rescanning of photographic enlargements used in the conventional cartographic technique.

In this process the digital satellite imagery is corrected geometrically and fitted to ground control, where available. The information on the image is then spectrally enhanced by computer techniques to highlight the required features. The digital data is then reformatted to expand or reduce the grey scale increments and to be suitable for subsequent transfer to a graphics art scanner/plotter computer system.

In this raster system the colour balance is customized, then film repromat is produced at publication scale by the laser plotter output device. Printing is undertaken using a dot screen between 175-200 dots per inch after combining manually produced surround and vector information.

This process has the registered trademark name of SIMAP (Satellite Image Mapping). The improvement in detail and resolution quality achieved by the process is quite significant. Not only is the resolution better on the SIMAP products but the colours have been carefully controlled to highlight important features.

Quality improvement can be readily seen in the two newer satellite image maps of Antarctica:

| | |
|---|---|
| Larsemann Hills | 1:25,000 (2nd ed., 1990) |
| Beaver Lake | 1:100,000 (1990) |

*The original text of this paper appeared as document E/CONF 83/INF 9

On the Beaver Lake sheet the success of this process in penetrating the long shadows produced by high peaks and low sun angle is also apparent.

In Australia, AUSLIG has subsequently entered into a joint development agreement with the two Sydney based firms, Lasergraphics and Beaver Press, to undertake mapping projects for clients, using the SIMAP process.

Following the successful application to areas of Antarctica other client projects have been:

Geological mapping in Cape York

Environmental mapping in the Murray/Darling Basin

Aviation mapping for visual approach charts to major airports

At present, names, highlighted features and map surround are incorporated with the image at the final printing stage with conventional fair-drawn repromat, but further developments are being examined to input this data digitally from mapping systems.

### Potential applications of SIMAP

The SIMAP technique can be applied to the cartographic reproduction of all digital satellite imagery or digitized colour aerial photography. It is an economical process as it eliminates several production stages in the photo lithographic process.

The method provides a quick response since multiple copies of a quality, up-to-date satellite map can be produced within days of satellite data acquisition. This has obvious application in producing up-to-date land-use information or providing low-cost topographic maps in developing countries.

Further information on the application of this technique to cartographic or mapping projects is available through AUSLIG, Canberra P.O. Box 2, Belconnen, ACT 2617. Telephone Australia (06) 252 7595.

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### References


Lindsay, G. K., and J. Manning (1989). *Satellite Imagery Mapping of the Larsemann Hills, Antarctica*

International Cartographic Association. *Proceedings of the 14th World Cartographic Conference, Budapest, August 17-24*


# MAPPING AND MAP PUBLICATION IN CHINA*

*Paper submitted by People's Republic of China*

## RÉSUMÉ


Ce document présente les principales activités menées en Chine entre 1987 et 1990 dans les domaines suivants : levés et établissement de cartes topographiques; révision des cartes topographiques à 1/50 000; production de cartes illustrées; préparation et réalisation de cartes thématiques; préparation d'atlas nationaux; élaboration de cartes tactiles; recherche sur les nouvelles techniques cartographiques et application de ces techniques.


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### Topographic mapping

#### *Large-scale topographic mapping*

In China, large-scale topographic maps are considered to be those at scales being equal to or greater than 1:10,000. Such maps are generally made by aerophotogrammetric methods.

Large-scale topographic maps are produced mainly for meeting the needs of urban planning and municipal and engineering construction. In past years, for expressways, pipe lines, factories, mines and other engineering works in over 150 cities, surveying and mapping organizations have produced over 40,000 sheets of topographic maps at scales 1:500, 1:1,000 and 1:2,000, covering an area of about 10,000 sq km; 1,000 sheets of topographic maps at scale 1:5,000, covering about 7,000 sq km; 30,000 sheets of topographic maps at scale 1:10,000, covering about 750,000 sq km. Until 1990, 165,000 topographic map sheets at scale 1:10,000 have been produced covering over 4,000,000 sq km.

#### *Medium-scale topographic mapping*

Medium-scale topographic maps are considered in China as those at scales 1:25,000, 1:50,000 and 1:100,000. The maps are made by aerophotogrammetric methods except those at 1:100,000 scale, which are obtained by cartographic compilation.

Medium-scale topographic maps are the important fundamental charts and documents on which the Government bases urban planning, land resource investigation and construction for agriculture, forestry, hydraulic engineering and electrical engineering. In the past few years, Chinese surveying and mapping organizations have produced over 1,000 sheets of topographic maps at scale 1:25,000, covering an area of 100,000 sq km for some large and medium-scale engineering construction projects such as Gezhouba Dam, Yinluan Rujin (diverting water from Luanhe River to Tianjin city), and Yinhuang Jiwei (to supply Weihe River with water of the Yellow River).

Most of China's territory had already been covered by topographic maps at scale 1:50,000. In these years, some filling-in measurements and updating works were performed in some parts of the country, and over 900 new map sheets were produced.

In China, topographic maps at scale 1:100,000 are mainly used for land consolidation of large areas, for planning of agricultural capital construction, for studying flood control conditions, and for new traffic lines selection etc. Before 1980, there were about 600 topographic map sheets (first generation) at scale 1:100,000; since then, with the new

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cartographic symbols standard and specifications, over 100 topographic map sheets (second generation) have been revised and updated in provinces and autonomous regions of Shandong, Jiangsu, Zhejiang, Jiangxi, Fujian, Hebei, Inner Mongolia, Gansu, Yunnan and Xinjiang.

*Small-scale topographic mapping*

Small-scale topographic maps are commonly considered as maps at 1:250,000, 1:500,000 and 1:1,000,000 scales. All are compiled from maps of larger scales.

Topographic maps at scale 1:250,000 are mainly used by economic departments for national and regional planning, reconaissance planning, natural resources investigation, development and application.

There was no topographic map at 1:250,000 scale in China before 1984. 1,675 map sheets at 1:200,000 scale were produced in the 1970s. Such maps had the disadvantage of small format, many sheets and inconvenience in use. To overcome these weak points, the Government decided in 1984 to transfer these maps into 1:250,000 scale and more than 10 surveying and mapping units were organized for compilation. So far, the 1:250,000-scale topographic maps, covering all parts of China with over 800 map sheets, have been published.

Topographic maps at 1:500,000 scale are the basic maps, comprehensively reflecting the general conditions of regional physical geography and social economy in rather large areas. They are mainly used by economic departments for regional overall planning.

The 1:500,000-scale maps with 227 sheets had already covered the whole of China's territory in 1973. To improve their usefulness, in 1988 the Government decided to recompile the maps at 1:500,000 scale by using the new version of 1:250,000 topographic maps as the basis. Most of the new maps at 1:500,000 scale have already been compiled in 1990, and they will be published soon.

Topographic maps at 1:1,000,000 scale are important materials for studying regional physical geo-conditions and the economic situation. They are mainly used by economic departments for overall construction planning and industrial and agriculture distribution, etc. Compilation of the second generation topographic maps at scale 1:1,000,000 was completed in 1982. In recent years, along with the development of surveying and mapping and economic reform, on the basis of latest larger-scale topographic maps, the simplified Pinyin edition of topographic maps at 1:1,000,000 scale were compiled, and will be published in succession.

In total, from 1987 to 1990, more than 80,000 sheets of topographic maps were produced in China.

## Revision of 1:50,000 topographic maps

1:50,000 topographic maps have been revised three times. More than ten years have passed since the last revision in 1977. Therefore, the National Bureau of Surveying and Mapping made a decision: from 1990, the fourth revision of the 1:50,000 topographic maps would be conducted and the economic map series at that scale would be created in the meantime. The new series consists of five editions: maps, image maps, landform-type maps, land-use status maps and maps of international cooperation.

For this revision, different measures will be adopted in accordance with different conditions in different areas and the original mapping time. For the areas where there are few changes in land features and new larger-scale topographic maps are available, the office compilation method will be adopted; where there are many changes in land features and new larger-scale topographic maps are available, the office compilation method would be also adopted; where there are only some partial changes on the map elements but no new larger-scale topographic maps are available, the partial revision method would be adopted; where there are many changes on the map elements and no new larger-scale topographic maps are available, the method of overall revision or remeasurement would be adopted; where there are no 1:50,000 topographic maps and no new larger-scale topographic maps are available, the new mapping on the scale of 1:50,000 would be conducted at this time.

## Image map production

Research and experiment on image maps started in China in 1958 and became a new map product in 1977. After 1978, many departments of resource investigation and economy started to produce medium- and small-scale image maps by using multispectral satellite images, for example, the *Colour Satellite Image Map on National Land-Use* (1:2,000,000); the *Colour Satellite Image Relief Map* and the *Multispectral Ortho-Image Map* (1:1,000,000), produced by the Research Institute of Surveying and Mapping of NBSM; the *Colour Satellite Image Maps with International Nomenclature* (1:500,000), produced by the Military Bureau of Surveying and Mapping; and the *Colour Aerial Image Maps of Tengchong Areas*, produced by the Research Institute of Remote Sensing of the Academia Sinica. Over 300 aerial image maps of the Tangshan-Tianjin region at large and medium scale were produced by NBSM for the earthquake rescue in Tangshan.

In past years, China has produced many aerial-image maps at large scale. Over 30,000 aerial-image maps of Henan, Yunnan, Sha'anxi, Heilongjiang and other provinces, regions and cities have been produced for land planning and resource investigation, agriculture division.

## Cadastral surveying and mapping

Cadastral maps and their related documents and materials are the surveying results reflecting land ownership and data and are an important legal basis for land administration and land-use taxation.

Cadastral surveying and mapping in New China was started when the "Provisional Regulations on Land-Use Taxation in Cities and Towns" were promulgated by the China State Council in 1988. It was calculated that cadastral maps covering 40,000 sq km at scale 1:500-1:2,000 were needed for cadastral tasks of 447 cities, 1,936 county towns and 11,481 towns in China. According to the statistics in 1987-1990, over 9,000 cadastral maps for Shanghai, Tianjin and other large and medium-sized cities and some small cities and towns were produced. Taking the scale of 1:1,000 as an average, these maps cover an area of 1,800 sq km, which is 4.5 per cent of the total task of cadastral surveying and mapping in China.

## Thematic map compilation

Over 1,000 kinds of thematic maps have been compiled and published in China since 1987. Some typical ones of better quality are:

*Physical maps*

1. General physical maps, such as *National Physical Atlas of the People's Republic of China*; *Physical Atlas of Shanxi Province*; *Atlas of Natural Conservation of the Peo-*

*ple's Republic of China*; *Atlas of Environment Protection of Second Songhuajiang River*; *Atlas of Conservation and Research in Baiyangdian*; *Atlas of Pollution Prevention Research in Huanghai Sea and Bohal Sea*; *Atlas of Environment Quality in Tianjin*; and *Atlas of Ecological Environment in Beijing-Tianjin Area*.

2. Geological maps, such as *Geological Map of Qinghai-Tibet Plateau and the Adjacent Areas*; *Lithosphere Atlas of China*; and provincial and regional geological maps.

3. Marine maps, such as *Comprehensive Atlas of Resource Investigation of Coastal Zones and Sea Beach Ridges of China*; *Atlas of Geographical Names in Islands of China*.

4. Soil maps, such as *Soil Atlas of the People's Republic of China*.

### *Maps on Social Phenomenon*

1. Population maps, such as *Population Atlas of the People's Republic of China*.

2. *Economic maps*, such as *Atlas of National Economy of the People's Republic of China*; *Atlas of National Agriculture of the People's Republic of China*; *Atlas of Industrial Distribution of the People's Republic of China*; *Atlas of Investment Environment in the Coastal Areas of China*; *Atlas of Administrative Units, Enterprises, Institutions in Beijing*; *Atlas of Land Use of the People's Republic of China;* and atlases of provinces and cities on the topics of economy, land resources, city industry and business.

3. Historical maps, such as *Historical Atlas of the People's Republic of China*; *Atlas of Historical Earthquakes in the Qing Dynasty of China*; *Historical Atlas of Beijing*; *Atlas of Chinese Historical Relics*.

4. Other thematic maps, such as *Atlas of Post Codes of China*; *Atlas of Drinking Water in the People's Republic of China; Atlas of Schistosomiasis of Local Diseases in the People's Republic of China*; and maps of Chinese herbs, etc.

## Compilation of the National Atlas

The *National Atlas of China* was compiled twice. The first compilation was started in 1958 and completed in 1969; the second compilation was started in 1981 and is still in the process of compilation.

The second edition of the *National Atlas*, quarto size, consists of five volumes: *General Atlas, Physical Atlas, Agriculture Atlas, Economic Atlas* and *History Atlas*.

The *General Atlas* is chiefly compiled by the National Bureau of Surveying and Mapping and consists of four map groups: prefatory; provincial; regional; and city maps. So far, atlas compilation has been fully completed and the fair-drawing and scribing is nearly finished. The atlas will be published in the near future.

The *Agriculture Atlas* is chiefly compiled by the Nanjing Research Institute of Geography and Lakes and the Research Institute of Geography of Academia Sinica. Containing 161 pages of maps, this atlas consists of the following map groups: prefatory; agri-natural conditions and resources; agri-socio-economic conditions and technical levels; distribution features and productivities of agricultural units; and agricultural land use. The atlas was published in 1989 by China Cartographic.

The *Physical Atlas* is chiefly compiled by the Research Institute of Geography of Academia Sinica. Containing over 200 maps, this atlas consists of the following map groups: geology and geophysics; geomorphology; climate; land hydrography; soil; vegetation; animals; seas; natural conservation; and utilization and reform. The *Economic Atlas* is also chiefly compiled by the Research Institute of Geography of Academia Sinica. Containing 146 maps, this atlas consists of the following map groups: prefactory; resources; agriculture; industry; traffic; transportation and tele-communications; building industry; urban construction and environment protection; commercial business; foreign trade; tourism; finance and banking; education; sciences; sports and health, regional comprehensive economy. The *History Atlas* is chiefly compiled by the Academy of Social Sciences of China. Containing 1,147 maps, this atlas consists of the following map groups: primary society relics; ancient history in legend, Shang and Xizhou dynasties; territories and political divisions; climate; vegetation; geomorphology; deserts; animals and plants; natural disasters; agriculture and animal husbandry; industry and mining; traffic and travel notes; population; nationalities; capitals; city construction; culture; religion; wars, battles and military strategic towns; and People's Revolutionary Struggles after the 4 May Movement (1919).

The *Physical Atlas*, *Economic Atlas* and *History Atlas* are now being compiled.

## Tactile maps compilation

There are about 7,000,000 blind and weak-sighted persons and 53 schools for the blind, with about 3,000 students, in China. At present there are no specific organizations or institutions in China for producing tactile maps for blind and weak-sighted people. In teaching history and geography, self-made teaching aids and tactile maps in blind schools are not unified in content, which impairs teaching quality. Map publications for the blind are not available on the market, which causes blind persons inconvenience in work, study and living. Therefore, in 1987 at the request of NBSM, the Research Institute of Surveying and Mapping began research and compilation of the *Tactile Atlas of China*. After three years of compilation, this atlas will soon be published.

With 325 maps, the *Tactile Atlas of China* consists of five map groups: the world; China; regions; geographic regions; and provinces; as well as expanded maps, involving geology, geomorphology, earthquakes, climate, hydrography, population, nationalities, agriculture, forestry, animal husbandry and sideline production, mine deposits, industry and traffic in China and in the world. In the atlas, the locations and distributions of the individual elements are represented by about 60 dot-shaped tactile symbols. The objects in a line or in strip distribution are represented by about 20 line-shaped tactile symbols. Natural phenomena, social sciences and economy, which occupy larger areas and ranges in practice, are represented by 10 area tactile symbols.

The production of tactile maps in China is in its initial stage. The publication of the *Tactile Atlas of China* will fill the gap in maps published for the blind.

## Mapping and cartographic technologies

Besides the conventional methods of aerophotogrammetry, plane-tabling, engraving and litho film reprography still adopted in mapping and cartographic work, research and trial productions applying new techniques have been conducted in the past years as follows:

(*a*) Digital mapping techniques have been adopted in the Institutes of Surveying and Mapping in Shanghai and Beijing;

(*b*) Computer-assisted cartography has been introduced in map production;

(*c*) A national digital terrain model (DTM) database, at scale 1:1,000,000, was established;

(*d*) Digital terrain model (DTM) data together with place-names, were applied in flood control and prevention;

(*e*) Close-range photogrammetry was used in building distortion observation, historical relics preservation and depiction of cell molecular structures, and beneficial results were achieved;

(*f*) The geographic information system (GIS) at scale 1:250,000 in Liaoning Province and the digital cartographic database at 1:50,000 scale in Hainan Province were established or are under development;

(*g*) A technical reform scheme on digital photogrammetry and its pilot project were in progress.

## IMAGE PROCESSING TECHNIQUES FOR DIGITAL ORTHOPHOTOQUAD PRODUCTION*

*Paper submitted by the United States of America*

### RÉSUMÉ

L'on connaît de longue date l'utilité des orthophotographies en tant que complément ou substitut des cartes ordinaires. Le Geological Survey des Etats-Unis produit des orthophotographies sous forme de feuilles cartographiques à partir de divers appareils de redressement qui permettent tous de corriger les distorsions engendrées par les procédés photographiques de façon à obtenir une projection orthogonale. L'on peut ajuster l'échelle en réduisant ou agrandissant le cliché et restituer l'orientation par rotation de l'image et à l'aide d'un prisme de Dove.

Si les orthophotographies ainsi obtenues sont de très haute qualité, leurs applications sont limitées du fait qu'il s'agit de photographies. Le développement de la cartographie numérique a conduit le Geological Survey à mettre au point des techniques permettant de produire des orthophotographies numériques à haute résolution spatiale à partir d'un balayage des photographies aériennes et de la modélisation numérique des cotes d'élévation.

La numérisation d'une photographie aérienne aboutit à créer un fichier numérique qui représente la gamme de gris de l'image balayée. Des techniques de redressement faisant appel à la modélisation numérique des cotes sont alors appliquées à l'image numérique pour éliminer les distorsions dues à la non-verticalité de l'appareil et au relief du terrain et obtenir une orthophotographie numérique.

L'un des intérêts de l'orthophotographie numérique est que les techniques de traitement de l'image (mosaïque numérique, amélioration de l'image, fusion de données, etc.) peuvent contribuer à renforcer l'utilité des données. La possibilité de traiter par mosaïques les orthophotographies numériques permet non seulement de faire coïncider des images sur une même feuille mais encore de faire coïncider des feuilles adjacentes.

L'on s'attache actuellement à perfectionner ces techniques et à mettre en place un système de production. S'il reste encore beaucoup à faire, l'orthophotographie numérique est potentiellement extrêmement utile à la cartographie assistée par ordinateur.

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Orthophotographs have long been recognized for their value as supplements or alternatives to standard maps. The United States Geological Survey produces orthophotographs in quadrangle format from a variety of orthophoto instruments, all of which differentially transform a central perspective photograph to an orthogonal projection. With such instruments, scale correction is achieved by adjusting the optical magnification, and direction correction is achieved by image rotation with Dove prisms.

While these techniques produce orthophotographs of high quality, their applications are limited by their photographic form. Recent trends toward digital cartography have resulted in efforts to develop a digital orthophotoquad production system.

Digitizing an aerial photograph produces a digital file that represents the gray scale values of a scanned image. Rectification techniques applied to the digital image remove tilt and relief displacement, producing a digital orthophoto. A valuable aspect of a digital orthophoto is that image processing techniques, such as digital mosaicking, image enhancement, and data merging, can be applied. A number of experimental digital orthophotos for a variety of applications were produced from photographs of various scales. Final digital orthophoto products include:

| | |
|---|---|
| Fontana, CA | 1:12,000 (mosaic) |
| Orchards, OR | 1:4,800 |
| Orchards, OR | 1:6,000 |
| Portland, OR | 1:12,000 (mosaic) |
| McCall, ID | 1:24,000 (mosaic) |
| Dane County, WI | 1:12,000 (thirty-six quarter quadrangles) |

The Fontana, Orchards, and Portland orthophotos were produced as part of an experimental multipurpose cadastre project. Final products included political boundaries, con-

*The original text of this paper, prepared by Joy Hood Lyman Ladner and Richard Champion, United States Geological Survey, appeared as document E/CONF.83/L.34. Use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the United States Government.

tours lines, place names, and land use indicators either photographically embedded in the images or displayed as overlays. The McCall orthophoto was made from 1:80,000-scale National High Altitude Photography (NHAP) colour infrared photography, and the Dane County products were produced from 1:40,000-scale colour infrared photography.

## Previous research

The idea of a digital orthophoto is not new. Some of the mathematical models for restitution of scanner and scanned images were described by Konecny in 1976. Horton (1978) described a method for generating digital orthophotos through a hardware approach that made use of an image dissector tube to scan imagery non-orthogonally. Keating and Boston (1979) explained a software system to create an orthophoto from digital elevation models (DEM) and imagery scanned on a microdensitometer (an instrument that converts image density at any location to digital form). By 1979, Konecny was able to summarize experiences with digital image rectification software and display photographs of his results. His strategy acknowledged the significance of DEM resolution to the rectification problem and suggested one transformation for DEM cells and a simpler bilinear transformation for picture elements (pixels) within a cell. The present work builds upon that strategy.

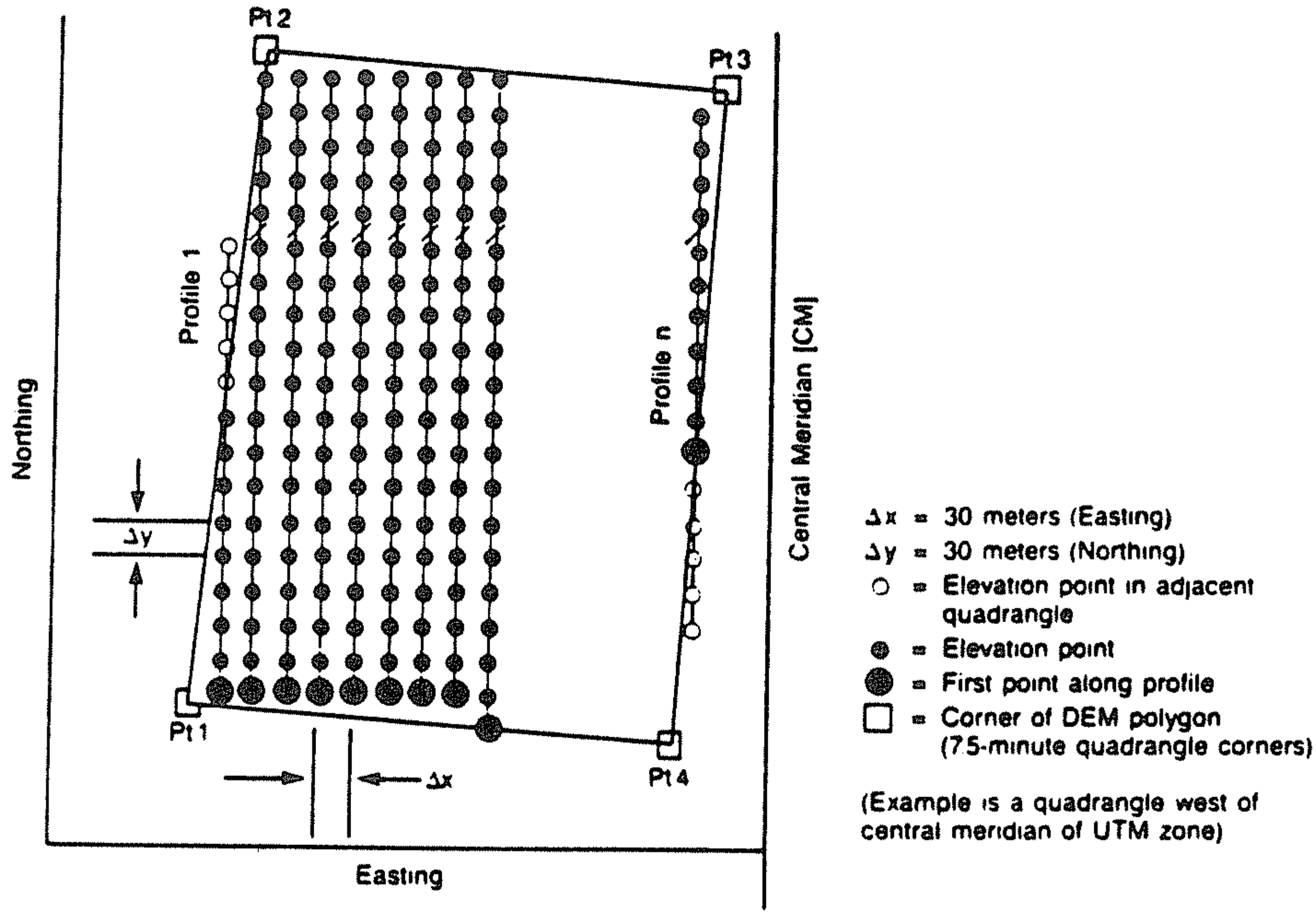
## Digital rectification

The rectification software was developed along the lines proposed by Keating and Boston (1979) and Olsen (1984). The two main sources of input data are a digitized aerial photograph and a DEM. The raster file results from scanning the photograph to be rectified on an Optronics C-4500 drum film scanner. The data of a standard 7.5-minute DEM have the following characteristics: (*a*) they consist of a regular array of elevations referenced in the Universal Transverse Mercator (UTM) coordinate system; (*b*) they are ordered from south to north in profiles that are ordered from west to east; (*c*) they are stored as profiles in which the spacing of the elevations along and between each profile is 30 m (figure 1).

In addition to the two main sources of information, several other data files are required. These files consist of ground coordinates of passpoints, photo coordinates of passpoints, camera calibration parameters, and photograph fiducial coordinates in the raster image system.

Initial input to the rectification process consisted of camera calibration parameters, ground coordinates, and photo coordinates of at least three passpoints of the photographs rectified. The exterior orientation of the photographs was solved using the familiar space resection (collinearity) equations (Wolf, 1974) (equation (1)). The six unknown orienta-

**Figure 1. Structure of a 7.5 minute digital elevation model**



tion parameters ($X_o$, $Y_o$, $Z_o$, $\omega$, $\phi$, $\kappa$) were determined by the solution of equation (1) for the photograph passpoints.

$$x = -f * \frac{m_{11}(X_p - X_o) + m_{12}(Y_p - Y_o) + m_{13}(Z_p - Z_o)}{m_{31}(X_p - X_o) + m_{32}(Y_p - Y_o) + m_{33}(Z_p - Z_o)}$$

$$y = -f * \frac{m_{21}(X_p - X_o) + m_{22}(Y_p - Y_o) + m_{23}(Z_p - Z_o)}{m_{31}(X_p - X_o) + m_{32}(Y_p - Y_o) + m_{33}(Z_p - Z_o)} \quad (1)$$

where:

$x$, $y$ are photo coordinates in the fiducial system;
$X_p$, $Y_p$, $Z_p$ are passpoint ground coordinates;
$X_o$, $Y_o$, $Z_o$ are camera station coordinates in ground system;
$m_{11}$, $m_{12}$, ..., $m_{33}$ are rotation matrix elements which are functions of $\omega$, $\phi$, and $\kappa$; and
$f$ is the known camera focal length

The coordinates (lines and samples) of the fiducials in the raster image were determined. These coordinates were found by measuring their location on an image display device. (This step is not necessary if the scanner is registered to the fiducials.)

The photo coordinates were referenced to the camera fiducial coordinate system using the linear conformal transformation equation (2).

$$x_c = ax_r - by_r + c$$
$$y_c = bx_r + ay_r + d \quad (2)$$

where:

$x_c$, $y_c$ are calibrated fiducial coordinates;
$x_r$, $y_r$ are fiducial coordinates in the raster image (line and sample); and
$a$, $b$, $c$, $d$ are linear transformation parameters.

The first two profiles of the DEM were input to form a profile pair of DEM cells. The photo coordinates of the corners of each DEM cell in the profile pair were calculated using the previously determined parameters of exterior orientation. This calculation determined the number of lines of image data that were required to rectify the area between profiles.

The microdensitometer coordinates of the cell corners were computed using the photo coordinates, the linear transformation parameters, and the linear conformal transformation equations. This step was completed for each DEM cell in the profile pair. The required number of lines of image data were then read into computer memory.

The cell was partitioned to the desired resolution. For a resolution of 2 m on the ground, the 30 m DEM cell was divided into 15 by 15 or 225 subdivisions. For NAPP imagery at 1:40,000 scale this gives a pixel size of 50 microns.

The elevation of the subdivisions were calculated from the surrounding area using bilinear interpolation. After interpolation the collinearity equations were again used with the previously calculated orientation parameters and the easting and northing of the ground point within the DEM cell were determined to compute the photo coordinates of the subdivision. Photo coordinates were computed in this manner for each subdivision within the DEM cell.

The photo coordinates were referenced to the camera fiducial coordinate system and so the linear transformation parameters used to compute the line and sample of the raster image correspond to the photo coordinate. For each cell subdivision the 8-bit binary gray scale value that corresponds to the image coordinate was assigned to the subdivision image coordinate. Choosing a gray scale value to be moved from the input image file to the output image file was accomplished by image resampling. Currently both nearest-neighbor resampling (using integer truncation to select the pixel) and cubic-convolution resampling (using a weighted average of neighboring pixels) are available.

The accuracy of the rectification process was measured by ascertaining the pixel coordinates of the passpoints appearing on the digital image and transforming them to their known positions. The passpoint locations in the orthophoto image were measured on a comparator, or image display device, and transformed to ground coordinates. The accuracy of the rectification was determined by comparing these measurements. A least-square fit of 33 test points measured for the McCall, Idaho, digital orthophotoquad showed the overall vector residual error to be 3.895 m, well within the map accuracy requirements for 1:24,000-scale mapping.

### DIGITAL MOSAICKING OF ORTHOPHOTOS

Aerial photographs acquired under the NAPP are quarterquad centred. To produce a digital orthophotoquad complementing the 1:24,000-scale map series, digital mosaicking techniques must be used to join the digital orthophotos. This process removes the geometric and brightness discontinuities along mosaic seams. Because the images have been geometrically rectified to the desired map projection, the goal of the mosaicking process is to retain the geometric accuracy obtained during rectification while removing the small, but esthetically objectionable, discontinuities along the mosaic seams.

Four basic concepts were involved in the development of the Large Area Mosaicking System (LAMS). The first concept involves the use of carefully defined polygons inside the border of each image. These polygons define the location of the mosaic seams, determine where the automatic correlation routine is applied to produce seam control points (points for which line and sample coordinates are known in two adjacent images), and limit processing to the portion of the scene included in the mosaic space. The second concept involves the adjustment of seam control points according to geographic control. Geographic control consists of points for which both the image line and sample and the geographic coordinates are known. The third concept involves the use of a compound geometric distortion model that corrects for lower spatial frequency distortions represented in the geographic control points, as well as the higher spatial frequency distortions represented by the seam control points. The fourth concept involves obtaining brightness correction information from the seam control points for use in adjusting brightness differences between adjacent images (Zobrist and others, 1983). Another very important aspect of LAMS is the use of a database system to manage the large amounts of tabular data generated in support of digital mosaicking. Digital mosaicking is divided into two general processes: the geometric correction process and the radiometric or brightness correction process.

#### *Geometric correction of rectified aerial photographs*

The first step in preparing a digital mosaic involves the selection of geographic control points. Because the individual digital orthophotos were geometrically rectified, the geographic control points are represented by a set of interior points used to hold the internal geometry of the images constant while removing the higher frequency geometric discontinuities along the mosaic seams. The passpoints used in the rectification process were used for geographic control points because they were well distributed throughout the images, and geographic and image coordinates were known.

The second step in the geometric correction process involves the selection of the polygonal boundaries for each image. As stated earlier, the polygons determine the location of the mosaic seams and seam control points while limiting processing to the portion of each image to be included in the final mosaic. The polygonal boundaries were manually selected using an image display device.

When working with digitally rectified aerial photographs, the selection of the polygonal boundaries is complicated by the spatial resolution of the data and the effects of look-angle. The polygons must be selected in such a way as to ensure that the effects of look-angle are minimized. For example, the polygon should not be selected through an area that is heavily shadowed in one image and not in the other.

Seam control points are located by applying a fast fourier transform (FFT) phase correlation along the polygonal boundaries. The correlation involves extracting image windows about the predicted seam control point from each image and running a phase correlation on the two image windows. The seam control point location in the second image is gradually changed until the best correlation value is found. To avoid false correlations, care must be taken in the selection of the correlation window sizes. The spatial resolution of the digitally rectified Portland photograph is approximately 1 m. Periodic features (more than one road intersection) frequently occur if the correlation windows are too large. For each successful correlation the line and sample locations for both images and the correlation values are stored in the respective control point files.

The seam control points are edited on the basis of a first-order fit of all points for a common overlap area (seam control for image one and two are edited separately from seam control for image one and four). The magnitudes of the acceptable residuals are based on the geometric accuracy of the digital orthophoto images as measured by the passpoints. In the case of the Portland mosaic residual errors as high as 4 pixels (4 m) were accepted.

After editing, the seam control points are adjusted to ensure an identical mapping to output line and sample in adjacent images. The adjustment process reconciles the differences in mapped line and sample of the seam control points by averaging. The geometric correction model for each image is based on the geographic and the seam control points.

Most geometric correction models designed for rectifying image data make use of polynomials or satellite spacecraft and sensor models, which are adequate for correcting single image distortions. When rectification is used to mosaic adjacent images, a surface interpolation method that is continuous, and yet can respond to the higher frequency distortions represented by the dense collection of seam control points, is required (Thormodsgard and Lillesand, 1987). The LAMS incorporates a triangulation technique developed by Manacher and Zobrist (1978) to combine the internal geographic control points and the seam control points in the creation of the surface interpolation model, known as the finite element technique. Zobrist and Manacher made use of the "greedy" triangulation technique in which edges are added to the triangular network based on their length. After ordering the edges from shortest to longest, edges are added to the triangulation network so long as they do not intersect existing edges in the network. Figure II(*a*) illustrates geometric and seam control points used for photo 14 of the Portland orthophotoquad. The resulting triangulation network is depicted in figure II(*b*). Because direct application of this faceted surface is far too inefficient and computer-time-consuming for large data sets, the faceted surface is gridded or sampled by placing an evenly spaced rectangular grid over the surface to reduce the computation time and optimize computer resources during image resampling (Zobrist, 1982).

During the resampling process, the input image space is mapped into the output image space. At each grid intersection this mapping is exact; at other locations bilinear interpolation within the grid cell is used to locate the input pixel. Currently a cubic convolution resampling algorithm is used for calculating the output pixel value. An assessment of the geometric accuracy of the transformed images verified that the goal of maintaining the accuracy of the digital ortho-

**Figure II (a). Geometric and seam control for photo 241**

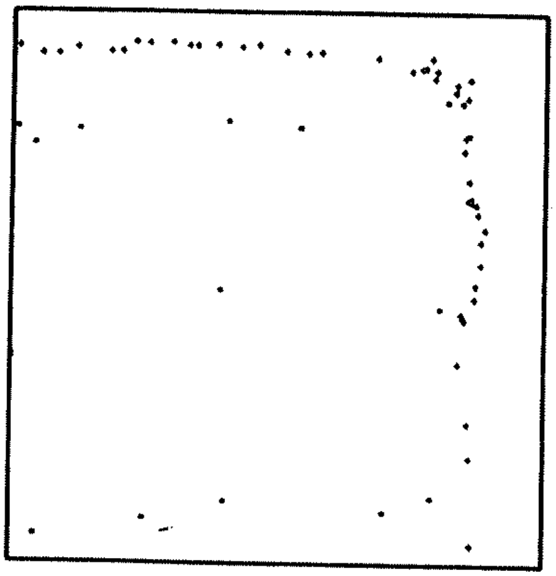
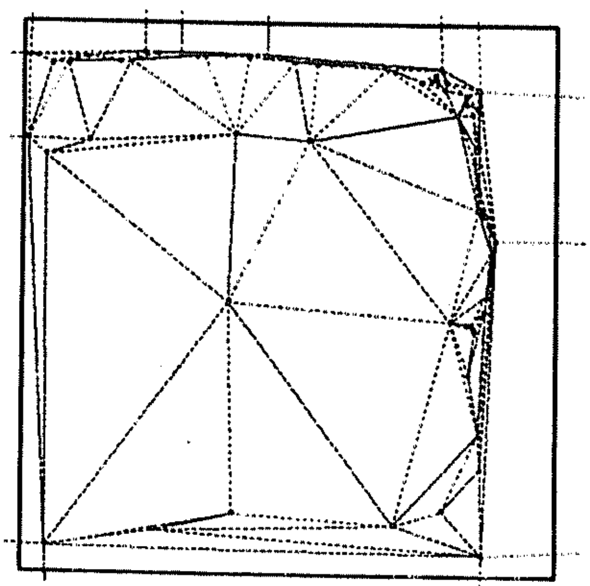


**Figure II (b). Faceted surface resulting from triangulation of geometric and seam control points**



photos was met. Table 1 shows the predicted and measured passpoint locations of photo 14 before and after image transformation for mosaicking.

### *Radiometric correction and mosaicking of rectified aerial photographs*

After all geometric corrections were applied and the geometric accuracy verified, the images were radiometrically matched and mosaicked. Working two images at a time, brightness correction information was collected along the polygonal seam boundary of the add-on image. The average pixel value for 10 by 10 pixel windows centred about the seam control points was computed for the reference and the add-on image and the information stored in tabular form. The average brightness difference between the two images was calculated. The remaining brightness differences were modelled using the gridded finite element technique discussed above. However, during radiometric correction the surface reflects the brightness adjustment to be applied at each vertex of the resulting triangles. At each grid intersection the brightness mapping is exact; at other locations bilinear interpolation within the grid cell was used to approximate the brightness adjustment to be applied to the input pixel. The corrected add-on image was cut precisely according to the polygonal boundary defined, and the two images were mosaicked. The process was repeated for all subsequent images in the mosaic where the previously created mosaic was used for the brightness reference image. Brightness correction and mosaicking were repeated for all bands.

## Enhancement of digital orthophotos

To improve the appearance of the digital mosaic, enhancement techniques such as spatial filtering and contrast enhancement were applied to the image. A spatial filter was used to increase the effectiveness of the subsequent contrast enhancement process (Chavez, 1984). To increase the high-frequency component and sharpen the image, an edge enhancement was applied to the data (Chavez and Berlin, 1984). This edge enhancement was accomplished by applying a small kernel (3 by 3 or 5 by 5) spatial filter to the image to increase the high-frequency spatial variation, thereby increasing the radiometric differences between pixels along edges. After filtering a multiple-point linear stretch was performed on each band. The cumulative histogram of each band was evaluated to determine the number and position of the breakpoints (Kidwell and McSweeney, 1984). The breakpoints were selected to provide a pleasing colour product.

## Future research

Additional research will be required to develop a digital orthophoto production system. Questions that must be answered include: DEM resolution for specific orthophoto scales, optimum image resampling, format of the digital data, distribution media, and optimum output medium.

Currently, the standard 30 m spacing of DEM is used during the rectification process of 1:80,000-scale NHAP and 1:40,000-scale NAPP images. For larger-scale photography the 30-m cell spacing of the DEM is questionable. Continuing research will address the requirements for higher resolution DEM's.

Research has recently been completed to develop a modulation transfer function (MTF) deconvolution kernel for digitized aerial photography scanned on an Optronics C-4500 film scanner (Schowengerdt, 1988). The resulting kernel is then used in a table-lookup resampling algorithm to simultaneously restore and resample the processed imagery (Schowengerdt, 1988).

While the Optronics (essentially a whisk broom scanner) is similar to the LANDSAT-MSS and TM and the AVHRR systems, operational differences dictated the decision to measure the MTF from special film targets scanned with standard instrument settings rather than attempting a detailed sensor model. Initial results suggest that MTF deconvolution can be applied to digitized aerial photographs resulting in significant visual enhancement; however, the results are limited by film granularity and film tightness during scanning. Research will address the implementation of this work in the digital rectification process.

Research will be required to determine the media best suited for storing data sets the size of digital orthophotoquads (NAPP photography scanned at 50 microns results in approximately a 4,000-line by 4,000-sample image.) The Geological Survey is experimenting with storing the digital orthophoto in encoded format on a CD ROM. In addition the issue of data format must be addressed. The digital orthophoto will require a header file containing such information as: type of photography, geographic coverage, type and quality of DEM data used, date produced, and accuracy assessment information.

## Applications

At present the Geological Survey is exploring the utility of large-scale orthophoto products as a base map component of a local multipurpose cadastre for city, county, and regional agencies. Pilot projects of the Fontana, California, and Portland, Oregon, areas have been started. In the Fontana project,

Table 1 Photo 14 passpoint locations after rectification and mosaicking

| Point number | *Predicted* Line | *Predicted* Sample | *After rectification* Line | *After rectification* Sample | *After transformation* Line | *After transformation* Sample |
|---|---|---|---|---|---|---|
| 10030 | 160 | 158 | 160 | 165 | 157 | 159 |
| 10032* | 1 959 | 526 | | | | |
| 10033 | 2 079 | 180 | 2 079 | 183 | 2 079 | 182 |
| 10040* | 168 | 158 | 167 | 1 967 | | |
| 10042 | 1 941 | 2 295 | 1 940 | 2 297 | 1 939 | 2 296 |
| 10050 | 467 | 3 844 | 470 | 3 846 | 469 | 3 847 |
| 10052 | 1 990 | 3 673 | 1 993 | 3 676 | 1 994 | 3 678 |
| 10401* | 1 733 | 3 500 | | | | |
| 10411* | 1 894 | 1 707 | | | | |
| 10421* | 1 946 | 41 | | | | |

*Point was unidentifiable due to image resampling as well as producing a 1:4,800-scale colour infrared digital orthophoto, four 1:12,000-scale digital orthophotos were produced from 1:20,000-scale photographs. The four orthophotos were then digitally mosaicked to form a 1:24,000-scale orthophoto. In the Portland pilot project, 1:21,000-scale photographs were digitally rectified and mosaicked to create a 1:12,000-scale digital orthophoto. This orthophoto will be evaluated for use in field identification and classification, as well as for stereocompilation.

Other possible applications for digital orthophotoquads include: map revision, custom maps, and as a base layer in a geographic information system (GIS) environment. Once contours have been captured for a quadrangle, incorporation of stereoinstruments in the mapping process is limited to the need to view new imagery in stereo for correct planimetric placement of new features. With the capability to produce digitized orthophotos, interpretation of new imagery can take place on image display devices rather than on a stereoplotter. New features could be captured in digital form directly and incorporated into the National Digital Cartographic Data Base. The capability to digitally rectify and mosaic aerial photographs makes the production of customized maps possible. Customized image processing techniques can be applied to enhance features of interest to various disciplines, such as geology, hydrology, and resource management. The digital orthophoto in a GIS environment can be overlayed with vector data, such as boundary, hydrography, and vegetation indexes, and used for a broad range of analysis.

### Conclusions

The Geological Survey has developed the capability to produce digital orthophotos with high spatial resolution from scanned aerial photographs and DEM data. The accuracy is primarily limited by the quality of the DEM data used.

Once rectified, digital image processing techniques, such as mosaicking, contrast enhancement, and filtering, can be applied to improve the usefulness of the data. The capability to mosaic digital orthophotos provides the means to join not only images within a quadrangle but also to join adjacent quadrangles. Attention is being directed toward improving the efficiency of the techniques and designing a production system. Although much work remains, the digital orthophoto offers great potential to computer-aided cartography.

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## (b) *Digital databases*

## DÉVELOPPEMENT DES BASES DE DONNÉES CARTOGRAPHIQUES*

*Document présenté par la France*

### SUMMARY


This paper is based on the premise that the development of cartographic databases refers to a whole range of activities leading to the creation of a database of geographical information covering a specific area. This applies both to the gathering and to the utilization of data. The first chapter describes the context in which a database of this type is established and utilized, while the next five chapters deal with the research that must be undertaken to ensure that such databases are developed more efficiently. Chapter seven covers the important subject of "orgware": organizing human resources in order to ensure the success of a database. The final chapter contains conclusions.


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Le principal postulat de cette communication est de considérer l'expression "développement des bases de données cartographiques" comme l'ensemble des actions conduisant à l'édification d'une base de données traitant de l'information géographique couvrant une zone précise. Y est considéré le recueil des données ainsi que leur exploitation. Le premier chapitre décrit le contexte conduisant à la constitution et à l'exploitation d'une telle base de données. Les cinq chapitres suivants concernent la recherche devant être entreprise afin d'obtenir un développement plus efficace des bases de données. Le chapitre sept traite du sujet important de l'orgware : l'organisation des ressources humaines visant au succès d'une base de données. Le dernier chapitre présente les conclusions issues de la discussion.

Base de données géographiques ou cartographiques, telle est la première décision à prendre lors de la conception d'une base de données. L'information cartographique peut être considérée comme la description du monde réel visant à la production de cartes (structure superficielle). De cette façon, l'information liée à un objet cartographique se refère à sa description graphique, à savoir les éléments d'une légende : largeur, forme, couleur, etc., d'un trait, d'un modèle, etc., d'une zone, d'un symbole, etc., d'un point, etc. L'information géographique est une description sémantique du monde réel (structure profonde) où les objets géographiques sont représentés numériquement de telle façon que l'ordinateur sait ce qu'est une route, un pont, une rivière, etc., avec leurs attributs et liens (Moellering, 1990, ATKIS, 1990, Salgé, 1989, Morehouse, 1990). Dans le contexte de cette communication le sigle GDB signifie "geographic database ou cartographic database" (base de données géographiques ou cartographiques) avec des commentaires spéciaux s'ils sont considérés comme nécessaires. Ces bases de données sont généralement reconnues comme nationales.

Le développement d'une GDB implique tout d'abord la définition de sa portée. Seule une vue spécifique du monde réel doit être "cartographiée" dans la GDB : définition des objets géographiques, des attributs qui leurs sont propres et des liens qui les relient. Une phase de définition structurelle est alors entreprise à l'aide d'un modèle conceptuel de données (CDM) conduisant au schéma conceptuel de données (CDS) qui reflète la structure de l'information (Guptill, 1990, Salgé, 1989). Sources et processus, mode de stockage, d'extraction et d'utilisation des données doivent être précisés.

Du point de vue systémique, une GDB comprend 4 sous-systèmes. Ces systèmes, qui sont bien connus de la communauté des bases de données, sont : recueil, manipulation, traitement et édition (Gardarin, 1982, Pressense, 1987). Cependant, en ce qui concerne l'information géographique numérique, chacun de ces sous-systèmes peut être considéré comme un système complet.

Le système de recueil de données saisit les données devant être incorporées à la base de données, et les éléments servant à la mise à jour de l'information existante. D'une façon générale, il doit numériser l'information analogique. Le système de manipulation des données doit stocker, gérer et extraire l'information. Le système de traitement est chargé de l'analyse, de la contre-vérification et des calculs effectués à l'aide des données, en vue de tirer des déductions de l'information stockée et extraite. L'édition ou l'exploitation des données tente de fournir les résultats de l'analyse sous forme lisible, à savoir de cartes ou tracés (car la meilleure interface utilisateur en matière d'information géographique est la sortie graphique).

Comme il a été suggéré précédemment, une condition préalable au développement d'une GDB est la définition du contenu des données et une condition postérieure en est l'"orgware" et le fonctionnement du système (Aagenbrugg, 1987, Rhind, 1988). Comme une GDB (que l'on a décidé de définir en fonction de son utilisation jusqu'à extinction) peut durer plusieurs décennies, l'organisation humaine et la définition du processus standard sont les conditions clés d'un système réussi et utile. Les coûts peuvent être évalués à 20 % pour le logiciel et le matériel (10 % chacun), à 40 % pour les données et le reste, 40 %, pour l'"orgware" (Mari, 1990).

## PROGRAMME DE RECHERCHE EN MATIÈRE DE DÉFINITION DU CONTENU DES DONNÉES

Au cours des dernières années, l'évolution des GDB existantes a montré un important changement des besoins en données : d'un fichier défini par le producteur à un fichier défini par l'utilisateur. En même temps, les tâches pour lesquelles les données étaient utilisées devinrent de plus en plus diverses, exigeant des données qui n'avaient pas été conçues initialement pour cela, de répondre aux besoins en information (Guptill, 1990). Ce contexte a conduit les organismes producteurs à définir et concevoir de nouveaux modèles de données spatiales sur la base de caractéristiques nouvelles. Cette tendance signale une évolution dans la conception de bases de données spatiales et de GIS.

Les problèmes liés à la souplesse, la normalisation et la compatibilité exigent une modification du contenu des données, de la couverture géographique, de la précision, et de l'homogénéité des catégories de données. Cette modification a un impact sur la conception du modèle de données. Cinq niveaux peuvent servir de degrés à l'affinage d'une conception destinée à répondre à une série de besoins (Guptill, 1990, Moellering, 1984, Salgé, 1990).

1. La *réalité*, qui est le phénomène total tel qu'il existe actuellement;

2. La *réalité des données*, qui est une abstraction de la réalité qui ne comprend que les entités considérées comme répondant à des besoins futurs (portée des données);

3. Le *schéma conceptuel de données (DCS)*, qui précise les jeux de composantes et les relations entre les composantes appartenant aux phénomènes spécifiques définis par la réalité des données (systèmes et structures indépendants); ce DCS repose sur *un modèle conceptuel de données (DCM)*, qui est un cadre de modélisation permettant aux concepts d'être organisés sans tenir compte de la réalité des données à modéliser;

4. La *structure des données*, qui précise l'organisation logique des composantes d'un schéma conceptuel de données et la façon dont les relations entre les composantes doivent être explicitement définies dans le cadre d'un système informatique;

5. La *structure du fichier de données*, qui est l'organisation physique des données.

La réalité et la réalité des données n'intéressent pas la recherche. Elles s'imposent comme des secteurs où l'information géographique numérique peut s'appliquer ou pas. Seuls sont exigés une meilleure compréhension de la portée du domaine et le mode par lequel les phénomènes impliquent une interprétation géographique.

Le modèle conceptuel de données peut donner matière à une recherche approfondie. Les modèles tels qu'ils sont connus d'après l'environnement (relationnel, orienté vers l'objet, ) de la base de données montrent leur inefficacité en matière de gestion des données géographiques (Bernstein, *et al.*, 1988, David, 1990). Des concepts tels que la topologie, les objets, les classes, les attributs (et les valeurs), les liens, sont efficaces pour modéliser toutes sortes de données géographiques connues mais ils ont aussi quelques limites bien connues. Parmi celles-ci, les méthodes (opérateurs, contraintes d'intégrité, règles) ne peuvent être rattachées aux objets (Morehouse, 1990) et être considérées comme des méthodes (dans le sens de méthodes orientées vers l'objet), la qualité ne peut être rattachée aux entités comme information de qualité (le modèle ne les connaît que comme attributs), un modèle pur en 3 dimensions doit être trouvé car il n'existe que des modèles à 2,5 etc.

Des bases de données sans échelle et sans délimitation, tenant compte de l'histoire, seront possibles dans le futur (Guptill, 1989), et permettront, entre autres, au DCM de faire face à de multiples représentations géométriques de l'objet.

La définition d'un schéma conceptuel de données implique l'identification de la réalité des données telle que perçue pour un domaine donné. Cette identification correspond à la définition précise des classes d'objets, de leurs attributs et des liens qui les relient, avec, pour chacun d'entre eux, l'association d'informations telles que descriptions exactes (définition complète), conditions de qualité requises, etc. Ceci conduira à la rédaction des spécifications du modèle conceptuel de données qui est la bible des GDB (Salgé, 1988). Les outils destinés à aider le concepteur de bases de données, qui simplifient son travail et conduisent à de meilleures solutions, sont aussi matière à de futures recherches (Bouzeghoub, 1986). Des règles pourront être définies et l'utilisation de systèmes experts devra être envisagée. Comme le contexte international conduit à un échange de données entre nations, un schéma conceptuel international de données (plurilingue) sera établi et donnera lieu à une normalisation qui permettra de cartographier toute base nationale de données dans le cadre de ce schéma internationalement reconnu (Sowton, 1990, Smith, 1990, Salgé, 1990).

Comme les techniques employées pour la conception du DCM et du DCS deviennent de plus en plus complexes, les compétences du personnel devront être améliorées, et les systèmes et méthodes qui pourront éliminer cette complexité seront les bienvenus (Goodchild, 1990, Burns, 1989, Chorley, 1987).

### PROGRAMME DE RECHERCHE EN MATIÈRE DE RECUEIL DE DONNÉES

Comme il a été précédemment exposé, toute base de données repose sur des données qui ont été déjà numérisées. La somme de travail demandée pour le recueil des données est en elle-même une tâche d'importance. La mise à jour d'une base de données relève du producteur de données et l'utilisateur, comme la réalité, en raison des activités humaines, évolue. Le recueil des données et leur mise à jour (à savoir numérisation des données mises à jour) implique un travail manuel considérable car le problème primordial est de convertir l'information analogique en données numériques. Les bases de données existantes ont été nourries de données provenant de cartes (par numérisation ou exploration), de levés aériens (par stéréo-restitution), d'images spatiales (par traitement d'image, reconnaissance de forme, ou classification), de complètement sur le terrain (mesures numériques) et d'autres bases de données (incorporation de bases de données existantes).

Tous ces méthodes reposent sur des techniques où l'activité humaine est prédominante. Elles comprennent fondamentalement six phases :

1. Préparation des données et recueil d'informations supplémentaires;
2. Numérisation;
3. Vérification des données;
4. Correction des données (ces deux phases entrainent des itérations);
5. Contrôle définitif des données;
6. Intégration des données à la base de données. Le défi pour le futur est de rendre chacune de ces phases aussi automatiques que possible. (DMA, 1988).

Les phases 2 et 4 sont étroitement liées car elles impliquent des techniques similaires.

Les phases 3 et 5 sont également étroitement liées car la première est basée sur un plan d'assurance de qualité (une sorte de liste de contrôle à suivre au cours du processus de numérisation) et la seconde sur un plan de contrôle de qualité (une sorte de liste de contrôle définitive à appliquer, une sorte d'évaluation définitive de la qualité du fichier : ok ou à refaire).

En plus de ces six phases, quatre thèmes de recherche peuvent être définis. Comme les opérateurs ne sont pas nécessairement capables de comprendre entièrement la structure complète et complexe des données dans le DEMS, il y a défi à définir les structures des données orientées vers la saisie, qui sont des interfaces humaines à la structure des données, une interface "naturelle" et évidente à cette dernière. Ces schémas orientés vers la saisie sont nécessaires à l'obtention de méthodes opérationnelles réelles et un second défi est de les rendre invulnérables aux erreurs de l'opérateur. Ce sont, en fait, des techniques impliquant une série de règles où une approche basée sur les connaissances pourrait être utile. Comme le point clé de la mise en place de telles techniques est l'efficacité, du point de vue de l'opérateur, des systèmes efficaces, basés sur les connaissances, doivent être développés, constituant de ce fait un troisième défi. Comme les six phases précédemment définies sont fonctionnellement très proches de celles des GIS, l'on peut imaginer l'utilisation d'un GIS existant pour saisir les données (Goodchild, 1990, Salgé, 1990). Le quatrième défi est le suivant : comme les GIS existants ne peuvent être exploités par des opérateurs non experts, même si un langage de quatrième génération y est associé, un système efficace pour recueillir une information sémantique est nécessaire.

La phase 1 ne peut guère être automatisée car le recueil et la préparation des données semble reposer, dans une certaine mesure, sur des tracés existants. Comme notre société a tendance à s'informatiser peu à peu complètement, il existera des bases de données qui comprendront des éléments utiles pour la mise à jour d'une GDB : par exemple, de nouvelles autoroutes ou de nouveaux échangeurs sont conçus à l'aide des systèmes CAD/CAM, et le défi est ici d'insérer ces données dans la GDB.

Les phases 2 et 4 s'automatisent peu à peu. Le défi est ici de définir un procédé automatique d'extraction des informations provenant de levés aériens, de données télédétectées, et de cartes maillées (Ilg, 1990, NCGIA, 1989). Les techniques à utiliser sont des méthodes spécifiques d'analyse d'image, celles de reconnaissance de forme n'étant pas assez efficaces. Le problème à résoudre est celui de "l'extraction d'objets géographiques des images numériques du monde réel''. Pouvons-nous rêver d'extraction d'objets entièrement automatique à partir de levés aériens numériques vers 2010 ? Une alternative serait d'utiliser le GPS motorisé, ce qui permettrait d'effectuer la mise à jour d'une GDB à l'aide d'un système motorisé. (Des méthodes efficaces de saisie de données mises à jour doivent être trouvées : via levés aériens numériques, au moyen de dispositifs GPS, en réutilisant des données provenant de systèmes de ''conception''. Des objets flous (ceux dont les limites ne sont pas bien définies) posent encore des problèmes car il y a peu de techniques pour les saisir et les définir.

Les phases 3 et 5 se rapportent aux plans d'assurance de qualité et de contrôle de qualité. Pendant toute la durée de la numérisation, depuis les données d'entrée jusqu'à l'information devant être envoyée au système de gestion de la base de données, une méthode graduelle de contrôle de qualité doit être établie et les mesures de qualité définitives doivent être effectuées. Même si ces méthodes ont été, dans le passé, mises en œuvre avec un certain succès, il reste à élaborer la définition numérique de la qualité (Chrisman, 1989, Bickmore, 1989, Drummond, 1989). Quels sont les critères de qualité à mesurer et comment les mesurer et les exprimer ?

## PROGRAMME DE RECHERCHE EN MATIÈRE DE MANIPULATION ET DE GESTION DES DONNÉES

La manipulation des données dans le contexte d'un système de gestion d'une base de données, quel qu'il soit, est basée sur trois sortes de schémas (Gardarin, 1982).

1. Les schémas conceptuels expriment les schémas conceptuels des données de la GDB d'une façon compréhensible pour le DBMS. Ils traduisent les DCS à l'aide des outils et suivant le modèle sur lesquels repose le système. L'actuel DBMS montre leur inefficacité en tenant compte du fait que la GDB traite des données spatiales. On peut suivre trois orientations : *a*) base de données relationnelles étendue ; *b*) base de données orientées vers l'objet (Kemp, 1990); *c*) ''générateur de DMBS'' (David, 1990). Pour chacune de ces orientations l'on peut essayer d'évaluer leur capacité à traiter les données spatiales (quel type de données, quel algorithme) et leur efficacité en matière de stockage et d'extraction. Les données métriques, topologiques et sémantiques doivent être traitées dans un système intégré.

2. Les schémas externes expriment l'idée que l'utilisateur a des données. A une utilisation spécifique en vue d'une application spécifique correspond une demande spécifique de données spécifiques. Les schémas externes reflètent ces spécificités. Deux problèmes se posent : comment ces schémas externes peuvent-ils être projetés dans le schéma conceptuel, afin de transformer une vue spécifique en schéma général ? et comment l'utilisateur peut-il formuler des demandes relatives aux schémas externes (Raper, 1990) ? Dans une certaine mesure, l'utilisateur préférerait ne pas savoir comment le DBMS travaille et aussi être capable de formuler des demandes dans son propre langage.

En ce qui concerne les GBD à portée nationale, seul le recueil d'une quantité d'informations thématiquement et géographiquement restreinte est demandée (Bickmore, 1989, Salgé, 1988). Le fichier résultant est alors transféré à un système spécifique où un dialogue interactif avec les données géographiques s'établit.

3. Le schéma interne indique, du point de vue de l'ordinateur, l'endroit où les données doivent être stockées et la nature du logiciel afin de pouvoir y accéder. Le problème principal soulevé à propos du type de logiciel est de savoir comment améliorer l'efficacité de l'extraction des données. Des recherches supplémentaires seront alors nécessaires pour choisir et mettre en œuvre le mode le plus efficace de stockage des données dans une GDB (Goodchild, 1989). Y a-t-il un algorithme de parallélisme qui produisé une extraction plus rapide des données (clés géométriques)?

Les GDB, en raison de leur caractère national, soulèvent d'autres problèmes qui n'ont pas encore été entièrement résolus. L'énorme quantité de données, (100 G bits de données hautement structurées sont actuellement cités) donne lieu à des sujets de recherche que les informaticiens doivent étudier (Rhind, 1988). Faisant partie du patrimoine historique d'un pays, les GDB nationales doivent refléter l'évolution du pays dans le temps et donner une idée plus abstraite d'une tranche de l'histoire. La prochaine génération de DBMS devra alors faire face aux multiples représentations d'objets géographiques dans le temps et l'espace (Guptill, 1990, Langran, 1989, Salgé, 1990). Dans le futur ces types de GDB devront être capables de répondre à des questions telles que ''quelles données étaient disponibles au temps t1 sur une zone donnée au temps t2 ? ou quelle était l'évolution générale d'une zone donnée entre le temps t3 et le temps t4 ?'' Avant que les DBMS puissent répondre à de telles questions, ils devront être capables de résoudre le problème de la mise à jour d'une GDB, à savoir d'intégrer des connaissances mises à jour, décrivant une zone donnée; les objets qui font partie de la vue sémantique des informations géographiques numériques (DGI) doivent être correctement identifiés et des identificateurs sans équivoque devront être trouvés.

Comme les informations et les données de qualité sur les objets géographiques flous seront peu à peu saisies, les futurs DBMS devront être capables de les traiter et de les extraire.

Dans le futur, les objets du monde réel, appelés détails caractéristiques dans la terminologie SDTS, (ACSM, 1988) seront décrits à travers les textes et les images. Comme la prochaine génération de GDB sera dans une certaine mesure orientée vers l'objet, les DBMS traiteront en mode intégré les textes, images et informations géographiques. (Boursier, 1990) ! Tel est le concept de la base de données intelligente qui intègre diverses technologies (orientées vers l'objet, systèmes experts, hypersupports... (Bennis, 1990).

## PROGRAMME DE RECHERCHE EN MATIÈRE DE POST-TRAITEMENT DES DONNÉES

Les données provenant d'une GDB nationale seront disponibles pour les utilisateurs qui peuvent ne pas appartenir à l'organisme du producteur. Les besoins des utilisateurs seront divers et impliqueront dans une certaine mesure une personnalisation du fichier. Deux sortes de personnalisations auront lieu : interne et externe.

1. La personnalisation interne pour un fichier donné comprend des calculs ou une analyse à l'intérieur du fichier lui-même sans que des données extérieures soient impliquées. Parmi ces opérations figure le traitement de la topologie interne. L'on peut définir une topologie géométrique là où les données sont considérées comme immergées dans un plan Euclidien et une topologie sémantique là où les objets sont reliés selon un réseau spécifique d'organisation = graphiques de traitement, graphiques de manipulation et algorithmes sur graphiques doivent être réinventés par rapport aux caractéristiques spatiales des DGI (Raper, 1990, Pressensé, 1987). Les fichiers

d'une GDB peuvent devoir être intégrés verticalement et horizontalement : des couches distinctes devront être combinées en respectant leur structure profonde. D'autre part, comme l'extraction thématique des données d'une GDB peut définir des artefacts dus à la projection du schéma conceptuel en schéma externe, des algorithmes purificateurs seront nécessaires pour les effacer. La combinaison de couches de données d'une GDB est également possible et permettra d'extraire des informations combinées, par exemple : courbes de niveau + hydrographie en montagne et en vallée (Guptill, 1989, Falcidieno, 1990). Une analyse, basée sur les connaissances, de données recueillies dans une base de données nationale peut conduire à des bases de données dérivées qui répondent aux besoins de l'utilisateur.

Les informations de qualité doivent être également utilisées et leur visualisation et utilisation dans les calculs font aussi partie de la personnalisation des données. De la même façon les données de temps seront utilisées pour l'analyse de l'évolution (Mari, 1990).

2. La personnalisation externe signifie que les données externes peuvent fusionner avec les données d'une GDB, en vue des mêmes types d'utilisation. Ainsi les problèmes de cadrage devront être résolus et les "systèmes experts" seront utiles pour surmonter le manque de conscience de ces problèmes montré par l'utilisateur.

### Programme de recherche en matière d'exploitation des données

L'exploitation des données a trait à l'intégration des données dans la GDB. Cet aspect inclut les sorties graphiques et cartographiques (sur papier comme sur écran) et la génération de "fichiers" à échanger; ceci appellera une discussion sur les aspects juridiques de l'échange des données, un motif de recherche qui n'est pas du ressort des géographes (le législateur devra peut-être envisager cet aspect) [CHORLEY, 1988].

Selon la définition d'une carte dans une matrice, où la visibilité directe et indirecte constitue les colonnes et la sortie sur papier et la visualisation sur écran constituent les lignes, les sorties graphiques et cartographiques appartiennent à la carte réelle et à la carte virtuelle de type 1 alors que l'échange des données se rapporte à la carte virtuelle de type 3 (et dans une certaine mesure à la carte virtuelle de type 2). Ces deux types de problèmes soulèvent différentes questions (Moellering, 1984).

En tant que sortie d'une GDB nationale, les cartes réelles demeureront un problème spécifique. En général, les GDB sont conçues pour répondre à des besoins à des échelles spécifiques. Ici, les échelles ne se rapportent à aucun rapport graphique, mais elles expriment le niveau d'abstraction auquel le monde est décrit. Par exemple, une GDB conçue pour le 1/25 000 permet le tracé de cartes topographiques de 1/10 000 à 1/50 000 en n'utilisant que quelques procédés spécifiques. Cependant personne ne peut trouver de méthodes réalistes pour en dériver des sorties cartographiques au 1/100 000 ou 1/200 000. (Muller, 1990). Cette opération est fortement reliée à la généralisation qui est une technique bien connue en cartographie. La façon classique de procéder à une telle opération repose sur un ensemble de règles qui n'ont pas été totalement établies car elles ont été transmises oralement par une génération de dessinateurs. La généralisation est basée sur trois principes fondamentaux (Pernot, 1988) :

1. Sélection des objets pertinents devant être caractérisés et de leurs attributs.

2. Définition des objets à généraliser car ils sont liés dans une certaine mesure à un litige spécifique concernant la bonne compréhension de la carte à dessiner.

3. Réalisation de la généralisation qui n'est pas seulement un déplacement géométrique mais aussi une transformation formelle avec exagération caractéristique et la caricature de quelques séries d'objets.

La première recherche à effectuer sera d'établir des normes de sélection d'objets pour une cartographie donnée, en supposant que la légende afférente a été précédemment définie, (un "système expert" pour la conception cartographique doit être développé) [Pressense, 1987]. L'ensemble des règles (plus de 3 000) doivent être définies et peuvent être isolées par l'analyse des questions spécifiques posées aux experts cartographes et l'étude des cartes et de celles dont elles dérivent (Muller, 1990). Les caractéristiques importantes de cette technique font que toutes les composantes de la carte doivent être considérées et traitées simultanément et que la méthode utilisée pour une carte donnée ne sera pas directement applicable à la carte suivante. C'est un secteur de recherche où les systèmes experts ou les réseaux neuronaux peuvent s'appliquer. L'on peut également relier à cette question la méthode de placement automatique des toponymes et l'édification de bases de données cartographiques qui suivent l'entier processus de cartographie à partir d'une GDB.

La carte virtuelle de type 2 (visualisation sur une CRT) soulève des problèmes similaires car la possibilité de faire un zoom (vers gros plan et vers plan général) et un panneautage pourrait être comparée dans une certaine mesure à la technique de généralisation. Pendant ce temps, d'autres thèmes doivent être considérés qui profitent de la capacité des ordinateurs à afficher des images rapides, versatiles et volatiles sur un CRT. Malheureusement, les progrès techniques en matériel graphique dépassent de loin les développements de la compréhension des mécanismes cognitifs et perceptuels au moyen desquels les formes spatiales sont identifiées et interprétées (Buttenfield, 1990). Comme la sémiologie graphique de Bertin s'applique au dessin cartographique (Bertin, 1983), il est nécessaire d'appliquer cette théorie aux affichages sur CRT. D'autres types de représentation devront être tirés d'une GDB tels que vues perspectives, combinaison des éléments linéaires tirés d'une GDB avec des images (spatiocartes), simulations (évolution de phénomènes donnés)... Les liens entre les GIS et les systèmes de synthèse d'image devront également être établis et développés (Salge, 1989).

Qualité est souvent synonyme de certitude. Cependant, la qualité des données fausse l'interprétation des images écran (carte réelle ou carte virtuelle type 2). La visualisation de la qualité d'une carte dérivée est un problème important car elle permet de connaître la pertinence de l'information visualisée. La qualité d'une décision dépend de la qualité de la carte utilisée et la visualisation de l'information de qualité peut minimiser les erreurs dans le processus décisionnel (Mari, 1990, NCGIA, 1989). Il y a une autre question importante : comment communiquer l'information de qualité à l'utilisateur afin qu'il puisse utiliser les données convenablement ?

En tant que sortie d'une GDB nationale, les cartes virtuelles de type 3 devront être échangées. Un de leurs buts principaux est de diffuser des données géographiques numériques. Lorsqu'un ensemble de données sera extrait d'une GDB, il devra être formaté en vue d'un échange. En supposant que les normes du format d'échange aient été définies, reste le problème du passage du format basé sur le schéma conceptuel des données de la GDB au format de la norme et de son modèle conceptuel. La première étape consiste à interfacer les modèles avant d'interfacer les données elles-mêmes. Après la livraison au client d'un fichier donné, la GDB poursuivra son processus de mise à jour et en définitive le problème de la livraison des versions mises à jour, au même client, se posera. Comme il aura probablement ajouté des données spécifiques au premier fichier, il sera important de livrer des versions mises à jour liées aux précédentes. Ce sera alors un autre défi de pouvoir réaliser différentes versions en un laps de temps donné. Ajouter des méthodes aux objets ou livrer des fichiers uniquement modifiables sont des solutions à explorer (Moellering, 1990, Sowton, 1990, Salgé, 1990).

L'échange normalisé de messages afin que le consommateur puisse mettre à jour sa propre base de données est une autre solution qui implique de profiter des derniers progrès faits dans l'échange électronique des données (EDI) [Fingis, 1989].

### PROGRAMME DE RECHERCHE EN MATIÈRE D'ORGWARE ET D'APTITUDE OPÉRATIONNELLE

Comme il a été précédemment exposé, l'orgware et l'aptitude opérationnelle comptent pour 40 % dans les coûts relatifs au développement d'une base de données nationale. Ceci conduit à des techniques qui doivent être aussi faciles que possible à utiliser. Cela pose le problème général de l'interface humaine. (NCGIA, 1989). Compte tenu du fait que la meilleure interface utilisateur est celle qui repose sur les habitudes des opérateurs, l'on peut essayer d'étudier leurs connaissances et leur conduite. Néanmoins, une approche pragmatique doit être faite ; les GIS et autres outils utilisés pour le développement des bases de données devront fournir quelques jeux d'outils permettant au programmeur d'adapter l'interface opérateur au savoir-faire des futurs opérateurs (Goodchild, 1990, Burns, 1989). Une recherche approfondie sur la métaphore n'est pas pertinente en ce qui concerne ce problème car le point important est de construire des systèmes opérationnels même s'ils ne devraient pas l'être et non de construire des systèmes non opérationnels même s'ils devraient l'être.

Comme, pour différentes raisons, les différents formats utilisés pour le développement d'une GDB ne peuvent être acquis auprès d'un seul fabricant, et comme l'on doit faire connecter différents systèmes, ce qui rend possible l'échange de données sans dégradation, l'on peut définir un format d'échange "interne". Le mécanisme doit fonctionner dans le but d'être aussi rapide que possible, et avec l'obligation de conserver toutes les informations métriques, topologiques et sémantiques dans n'importe quel fichier. Le problème d'interfacer les diverses composantes d'un Système de GDB est légèrement différent du problème général des normes d'échange car les divers sous-systèmes sont bien définis dans le premier cas et l'interface peut être ainsi spécifiée (Scalfer, 1990).

Les aspects organisationnels concernent aussi la définition de la configuration qui permet à la GDB d'exister et la seule recherche possible est alors de suivre la recherche informatique et d'essayer de tirer profit de ses résultats.

Les aspects organisationnels concernent aussi la capacité humaine à faire face aux nouveaux aspects de l'information géographique numérique. Le développement d'une base de données nationale est si coûteux qu'il ne peut être effectué par une seule personne ! Des équipes d'une centaine de personnes sont souvent mentionnées et donc toutes les opérations devront reposer sur le personnel d'encadrement. Cela signifie que la formation de ces opérateurs est un problème à considérer et qu'une méthode de formation devra être mise au point. (NCGIA, 1989).

Comme le développement d'une GDB nationale vise à satisfaire, dans une certaine mesure, les futurs besoins des utilisateurs, un autre défi sera de leur faire prendre conscience de ce qui est faisable. La formation des utilisateurs est un problème important auquel doit faire face tout fabricant et la recherche en la matière permettra d'améliorer ces aspects éducatifs (Guptill, S, 1990).

### CONCLUSION

Les producteurs d'informations géographiques sont généralement des organismes. Ils étaient principalement responsables de la production de cartes. Ils entrèrent dans le monde de l'information géographique numérique par le biais de la cartographie numérique. La dernière décennie les a poussés vers le concept de bases de données et leur a fait prendre conscience que leur travail était de livrer des données cartographiques ainsi que des données géographiques numériques. Peu à peu la structure sémantique des données s'impose comme un problème clé pour répondre aux besoins des utilisateurs. Pour ces derniers, c'est une évolution qui ressemble à une révolution !

En admettant que cette tendance vers des produits définis par l'utilisateur soit assimilée par ces institutions, la prochaine décennie sera en définitive celle de la souplesse et le programme de recherche en matière de développement des bases de données géographiques vise à y ajouter cette souplesse. La recherche conduisant à une meilleure automatisation de toutes les techniques entourant la base de données, de la saisie des données à leur utilisation, doit être entreprise dans le but de faire travailler ces systèmes par un opérateur ne disposant que d'un bagage scientifique limité.

Les GIS et par conséquent les GDB ont une base de connaissances scientifiques considérables et cette tendance semble s'amplifier avec le progrès de la recherche. Cependant, la plupart de ces connaissances doivent être cachées aux utilisateurs, même si ce sont des opérateurs ou des ingénieurs qui utilisent un GIS ou une GDB pour accomplir leur travail.

#### *Sommaire destiné à l'homme de l'art*

Les réalisations actuelles permettent aux organismes cartographiques de construire des bases de données nationales. Sauf quelques exceptions, ces bases de données sont plutôt cartographiques, même si un grand nombre de pays étudient et projettent de réelles bases de données géographiques. Elles ont des échelles car elles sont construites autour d'une échelle "pivot" spécifique (c'est-à-dire pour un étroit éventail d'échelles). L'on ne peut guère dire qu'il existe des GDB sans échelle.

Saisie et traitement des données sont mis en place et reposent principalement sur des équipes d'opérateurs. Le coût de l'automatisation est tel que les programmes de cartographie numérique sont des programmes à long terme ou sous-traités (et donc coûteux). Des solutions pour augmenter le rythme actuel de fonctionnement sont peu à peu mises en place avec une attention spécifique donnée à la qualité. Aucun mécanisme opérationnel convenable n'existe pour la mise à jour des bases de données nationales.

Les GDB nationales existantes sont construites sur des logiciels spécifiques qui essayent de tirer le meilleur des DBMS existants. Pendant ce temps l'on ne peut guère dire que les systèmes de manipulation et de gestion des données soient normalisés et que leur efficacité ne soit pas si grande.

Les mécanismes d'exploitation et de post-traitement des données sont jusqu'ici plutôt orientés vers le producteur et la personnalisation de l'information, pour un utilisateur spécifique, est souvent limitée à une simple extraction de données disponibles pour un jeu de "feuilles".

Une des préoccupations principales est de faire prendre conscience à l'utilisateur s'il est possible ou non d'utiliser les données de la GDB. L'éducation et la formation de l'opérateur sont des problèmes qui sont résolus actuellement de façon pragmatique.

Le mécanisme d'échange fonctionne irrégulièrement car peu de normes nationales sont opérationnelles. Les formats de transfert nationaux s'utilisent progressivement et aboutiront à une technique organisée et normalisée d'échange des données géographiques.

*Sommaire prospectif*

Ce sommaire prospectif prend la forme d'un programme de recherche clairement détaillé, classé par priorités décroissantes conformément à la logique qui précède.

Définition du contenu des données :

Modèle conceptuel de données
*Outils adaptés aux concepteurs de données en vue de la rédaction des spécifications*
*Conception du modèle de données spatiales basées sur les détails caractéristiques*
*Schéma conceptuel international de données*
*Bases de données sans échelles et sans limites et historique*
*Systèmes et méthodes cachant la complexité de la conception des DCM/DCS*

Saisie des données et des données mises à jour :

*Problèmes de qualité*
*Méthodes opérationnelles et sûres de saisie des données*
*Extraction automatique des données géographiques à partir d'images numériques (cartes explorées, images spatiales, levés aériens numériques...)*
*Saisie d'informations sémantiques basée sur GIS (avec règles)*
*Structures des données orientées vers la saisie*
*Utilisation de GPS pour les bases de données géographiques*
*Systèmes efficaces basés sur les connaissances utilisées pour la saisie des données*

Manipulation et gestion des données :

*DBMS efficaces pour les bases de données géographiques*
*Projection du schéma externe (interrogation de l'utilisateur) dans le schéma conceptuel*
*Méthode efficace de stockage des données*
*Manipulation d'une énorme quantité de données et de données relatives au temps*
*Mise à jour intelligente des GDB*
*Bases de données intelligentes*

Post-traitement des données :

*Algorithmes purificateurs*
*Bases de données clarifiées et déductions à partir des bases de données*
*Traitement des informations de qualité*
*Intégration horizontale et verticale*
*Opérateurs topologiques efficaces*
*Systèmes experts pour le cadrage des données hétérogènes*

Exploitation des données :

*Tracé de cartes réelles : symbolisation, généralisation, toponymie*
*Conception de cartes réelles d'après GDB*
*Utilisation de réseaux neuronaux pour production de cartes*
*Sémiologie graphique sur affichage CRT, synthèse des images cartographiques*
*Communication aux utilisateurs de la qualité estimée*
*Mécanismes d'échange : modifications seules, méthodes reliées aux objets*

Orgware et aptitude opérationnelle :

*Interface humaine adaptée à la compétence de l'opérateur*
*Mécanismes d'échange interne de données : connexion avec ceux des GIS*
*Outils pour la formation et l'organisation des opérateurs*
*Outils pour la formation des utilisateurs*

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## DIGITAL MAPPING AND TOPOGRAPHIC DATABASES: ASPECTS OF THE DEVELOPMENT OF SPATIAL INFORMATION SYSTEMS IN INDONESIA*

*Paper submitted by Indonesia*


## RÉSUMÉ

En Indonésie, la demande croissante de données géographiques sous forme numérique pour l'analyse des données spatiales et les applications du système d'information géographique (SIG) a amené l'agence BAKOSURTANAL à prendre conscience qu'il fallait non plus recueillir ces données au coup par coup mais créer une base de données numériques consultable en permanence par tous. Les diverses mesures prises pour atteindre cet objectif sont brièvement décrites dans le présent document, qui insiste en particulier sur les aspects suivants :

*a*) Conception du modèle de donnés à adopter pour organiser les informations topographiques de terrain et les informations de relief de manière à faciliter les applications du SIG;

*b*) Densification des détails dans la base de données et possibilité de structurer les données sur plusieurs niveaux afin de stocker dans une même base de données des informations de terrain à divers niveaux de précision, de résolution, d'abstraction des données, etc.;

*c*) Réflexion en vue d'intégrer le système à la production de données numèriques;

*d*) Elaboration des caractéristiques techniques du système.


### THE ROLE OF BAKOSURTANAL FROM THE INFORMATION PERSPECTIVE

Economic growth in Indonesia, as in many developing countries, is dependent on the proper utilization of its natural resources. Specialists involved in the inventory of natural resources are therefore under pressure to make use of the technological advances achieved in the last two decades in the area of spatial data analysis. These advances create the possibility of achieving new tasks as well as providing new ways and alternatives to carry out existing ones. Consequently, the number of spatial information systems, i.e., geographic and land information systems (GIS/LIS), already developed or still under development, in various disciplines in Indonesia, is increasing (Rais and Suharto, 1989).

Among many organizational and technical components, the availability of digitally encoded maps in these systems, with specified format, content and data structure, is a prerequisite in providing the base on which a series of GIS operations can be performed. With special reference to the ongoing Land Resource Evaluation and Planning Project (LREP), the present phase was directed towards the acquisition of digital data on resource potentials and environmental conditions, including coastlines, hydrography, roads, administrative boundaries, land systems, land status, land use and height information. As a result, the map-making industry in Indonesia began to redefine its objectives from the perspective of information, and digital map data started to have value by themselves, beside being the data source for traditional printed maps.

Digital mapping techniques were introduced at the national coordination agency for survey and mapping (BAKOSURTANAL) in the mid-1970s and were used as a means of speeding up map production, particularly for the determination of geodetic and photogrammetric control, photogrammetric compilation and cartographic fair-drawing (Suharto and others, 1988). However, the growing need for geo-referenced data in digital form for other disciplines, had created an awareness at the agency about the need to change

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its working procedures and its organizational structure in order to allow the expansion of its mission from conventional map making towards support of the decision-making process in the National Development Plan, in general, and the Natural Resources Inventory Programme of LREP in particular.

The creation of a National Digital Topographic Database has been emphasized at BAKOSURTANAL. Its objectives are:

(*a*) Support for the map-updating activities;

(*b*) Improvement of response to demands for topographic information in digital form;

(*c*) Provision of the base upon which a series of spatial analysis and GIS operations can be performed, with emphasis on the ongoing LREP project.

Measures currently being undertaken by BAKOSURTANAL in order to achieve this goal include:

(*a*) Establishment of an efficient mechanism in order to provide awareness of potential users and determine the realistic information requirements of these users and the nature of spatial processes in which they are involved;

(*b*) Establishment of digital mapping standards for data collection, data structure and organizational data storage, data quality model and data exchange format;

(*c*) Conversion of existing maps and any available data that have been produced in the past, into the required data structure. This includes the design of "interfaces" for the integration of data collection from various sources of spatial data (ground surveys, aerial surveys, digitization of graphic documents, remote sensing and image processing systems, as well as other spatial databases available at various geo-information producers);

(*d*) Upgrading of its hardware and software capabilities as well as staff knowledge and skill;

(*e*) Shift from collection of digital topographic data on an ad hoc basis, under the constraints imposed by specific project requirements and available funds, towards the systematic creation and updating of a topographic database that can be used continuously by all potential users;

(*f*) Institutional structure and its organization and the introduction of the necessary changes in its working procedures (both technical and managerial).

## STRATEGIC OBJECTIVES: SHORT- AND LONG-TERM POLICIES

The intended geographic information system, which will support the spatial information analysis necessary for planning and decision-making in the LREP programme, is basically a geographic grid cell reference system based on the 1:250,000 National Topographic Map series (Pranoto, 1978 and 1982). Each grid cell is of 1/2 × 1/2 minute in size. All phenomena existing or occurring in the grid area will be digitized or recorded in the individual cell to which they belong. The data can be later retrieved on single or composite entities and be presented cell-by-cell or in any other format. Due to restrictions imposed by the availability of topographic maps, the LREP, Phase I (1986-1991) has restricted its activities to the Island of Sumatera (Rais and Suharto, 1989). Mass digitizing activities took place at BAKOSURTANAL in 1989-1990 in order to convert the existing maps to a digital form, using the ARC/INFO system. The data required for the project was mainly collected from the 1:250,000 *National Topographic Map* series whenever available and up-to-date, otherwise the most recently produced 1:50,000 *Base Map* series are used. Recent remotely sensed images were also used for the updating of topographic features and the extraction of thematic information, such as land suitability, land use and recommended areas for development etc. This information has been prepared under the ongoing Regional Physical Planning Programme for Transmigration maps. The collected data are assembled together in order to form "geographic units" equivalent to the 1:250,000-scale maps. Considering the need for rapid availability of digital data for the LREP project, it is recognized that the most practical approach is to extend current activities to other major islands in Indonesia.

The next phases on the LREP project, starting from 1991, will be directed towards the collection of geo-referenced information at higher resolution. While the current Phase I is directed to the locating of most potential areas for agricultural activities, Phase II will consist of semi-detailed surveys of verified potential areas.

Although the immediate needs of the LREP programme enforce data collection on an ad hoc basis, according to priorities set by the National Land Resources policy, BAKOSURTANAL strategy is to make use of whatever data are available and to initiate the systematic creation and updating of the collected digital coverage.

The short-term policy is to continue with the nationwide 1:250,000 digital coverage. Such coverage can serve as a starting point towards the establishment of the BAKOSURTANAL Digital Topographic Database, (Suharto and others, 1988; Stefanovic and others, 1988). As long-term policy, however, data entry into this database (for the purpose of updating and further densification of details for specific information theme(s) in a particular geographic region), is to be at larger scales (1:50,000 and 1:25,000), using photogrammetric stereo compilation in connection with the next base mapping programme starting in the year 1991, digitization of the newly produced base maps, use of SPOT images etc. How much can be achieved in this direction will depend on the available funds and the possibility of upgrading the technical and human resources of the BAKOSURTANAL Mapping Division as well as the domestic mapping contractors.

## DATABASE DESIGN CONSIDERATIONS

A topographic database is a special type of database capable of handling terrain entities, their descriptors (positional and attributes) and the relationships (topological and functional) among them. These entities can be presented at various levels of abstraction, starting from primitive elements (point, line, area elements, as offered by the existing methods for data collection from various sources of geo-referenced data) up to objects of higher-order meaning for specific applications and to which users can assign information. Accordingly, information modelling in a topographic database should be able to handle these various levels of terrain representation and data organization, as will be seen later.

In the course of current activities at BAKOSURTANAL in this field, we tried to address the following aspects, (Radwan, 1989; Radwan and Suharto, 1990).

(*a*) Data structuring in the topographic database;

(*b*) Data updating and densification of details;

(*c*) Concept of integration in production environment;

(*d*) System specifications standards for the production of digital geo-data.

### *Data structuring in topographic databases: the object-oriented concept*

Under the current working procedure, the collected data are archived on map-sheet basis and stored in computer data files, where one file represents one theme (information layer) for one map sheet. These files have the ARC/INFO file structure and data format. The management of these files is taken care of by the File Management Utilities of the VAX-VMS operating system. The user of any geo-referenced database likes, however, to view terrain information logically as a global set and on an "object" basis, rather than being segmented according to the traditional map-sheet separates (map overlays). Further, all inherent relationships among terrain elements, such as topological, proximity, functional and phenomenological relationships, must be explicitly presented. The map-sheet file base may however continue to be used as a base for data collection, data maintenance, as well as an internal data filing system.

On the user level, the database will be managed on an object level, which can be viewed at various levels of abstraction:

(*a*) Primitive objects (in vector environment: points, lines, polygons; and in raster environment: area element/pixel);

(*b*) Simple objects of equivalence to terrain entities such as road, river, house etc.;

(*c*) Complex objects of higher-order meaning, in view of specific applications such as road network, watershed, residential block etc.

These objects can be collected from objects of lower logical levels in the data hierarchy, according to user freely defined criteria, for example:

(*a*) Grouping of chained vectors or polygons which have adjacency, connectivity or contiguity relations between them;

(*b*) Grouping of objects which have certain characteristics in common;

(*c*) Grouping of objects which participate in a certain functional relation.

User's freely defined descriptors can be assigned to these objects, either by direct data-entry to such a database or transferred from other related databases.

Information modelling in the object-oriented topographic database deals with various levels of data abstraction:

(*a*) Data collection level: geared to the capabilities of the available data collection subsystems, specifications and methods of data collection and feature extraction;

(*b*) Database level: the general "conceptual" information model, which is able to accommodate the various views of the user community and the applications for which the database is created;

(*c*) Data structure supporting this model: it is not necessarily that in which the data will be collected or finally supplied to the user. In the background of such a level, there is a "standard" database management system, which handles information storage in computer files and its mapping to the database's conceptual information model.

(*d*) User level: the "tailored" models, which support specific requests of individual user groups.

The interaction between these levels of terrain feature abstraction is shown in figure I.

The implementation of an object-oriented database requires (Radwan and Suharto, 1990):

(*a*) Design of an information model and the supporting data structure for each of these levels of data abstraction. These models will define information content, its organization and descriptors. More details are given later under "system specifications";

(*b*) Design of "interface", which interfaces between these various levels and allows the "mapping" of the collected data files under one level into the data structure required by another one in this data hierarchy.

These interfaces include:

(*a*) Conversion of the collected data, which are organized and structured in the way offered by the data collection system, into the required data structure of the database's conceptual model;

(*b*) Mapping of the conceptual model's data structure to the "logical" data structure of the existing database management system in order to store data in the computer system;

(*c*) Functional models for the extraction of "tailored" data model, which supports user's view on the stored data sets and his application computer packages.

These interfaces are introduced as a set of operators/commands which will operate on the data stored in one level of abstraction and convert them into the form required by the other level. These operators can carry out various operations such as:

(*a*) Reformatting and reorganization of data in digital files produced by a digital mapping system into the file format of another system;

(*b*) Reclassification and coding;

(*c*) Aggregation of a set of elements into one element and forming objects of higher order meaning from elements at lower order in the data hierarchy, using pre-set rules and criteria;

(*d*) Introducing spatial and non-spatial relationships among the stored elements;

(*e*) Overlaying of elements stored in separate information themes into a composite presentation for which the user can assign a new set of descriptors;

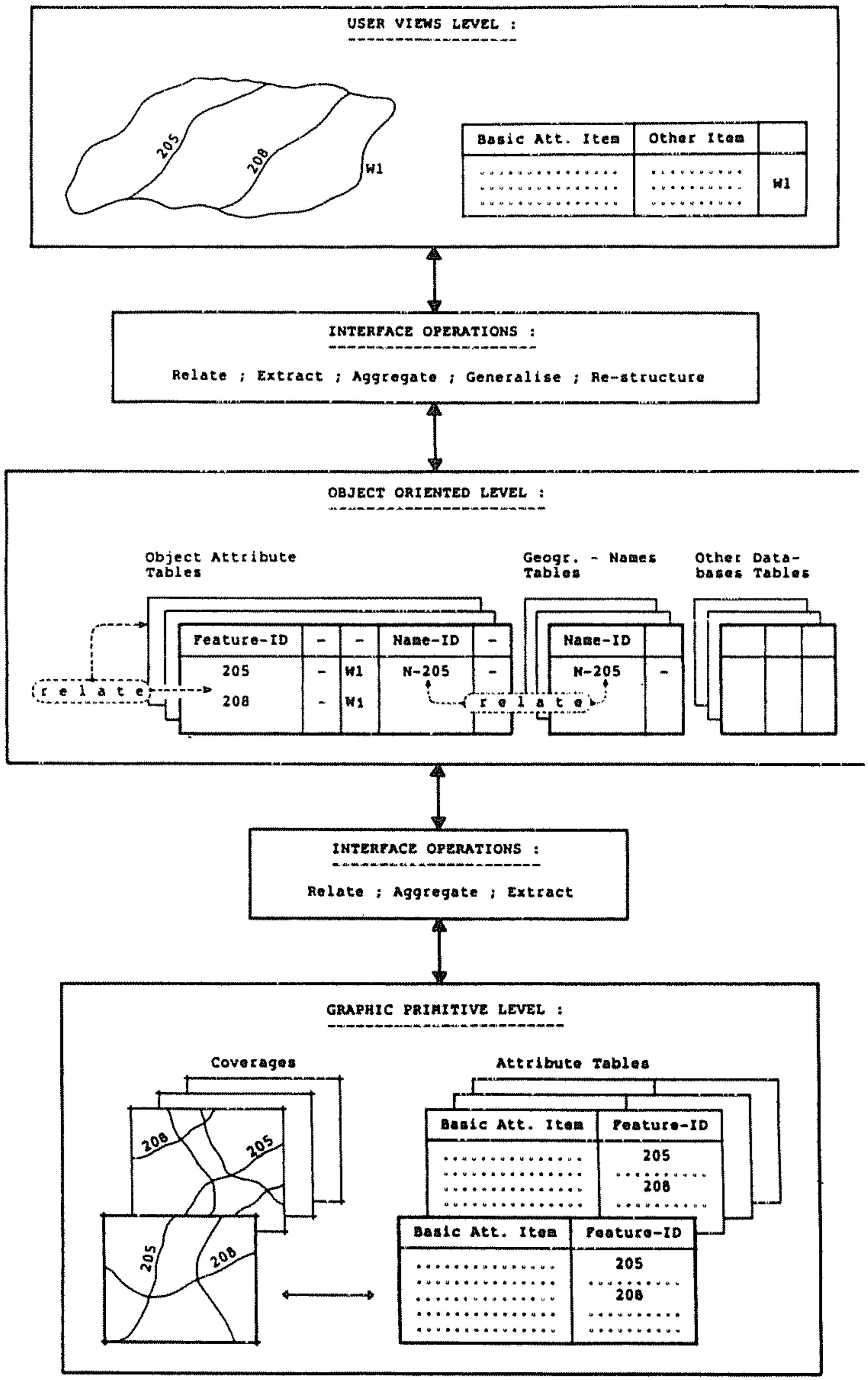
(*f*) Presentation of information (digital/graphical) in a certain data format and pre-specified cartographic standards.

Operations involved for the implementation of this concept are given in detail later in this text, with special reference to the use of the ARC/INFO system for this purpose.

### *Densification of the database contents: the multilevel structuring concept*

Decision on the level of resolution and positional accuracy and details of descriptors of the stored data is an essential aspect to be considered in the design of a georeferenced database. Following the conventional approach in the base mapping programmes, i.e., creating various databases where each is equivalent to a map-scale and is meant to serve a specific user group, will result in redundancy of information, a slow and costly data collection procedure and large computer overhead. After careful examination of user requirements for topographic information in various disciplines, however, one will recognize that not all feature types in various geographic regions are needed at the same level of accuracy, resolution and classification detail. Accordingly, the multilevel structuring concept was adapted, which allows the terrain features to be stored in the same database, at levels with varying positional accuracy, resolution and descriptor lists. Each of these levels and/or

Figure I. Object-oriented database



their combination are meant to satisfy the needs of a specific user group (Radwan and others, under preparation).

Accordingly, the future densification of the existing database from larger map-scales and other relevant data sources will incorporate only those terrain elements, of specific theme(s) in certain geographical regions, with the accuracy, resolution and descriptors that are relevant to users requiring further details than are available. This approach should lead to:

(*a*) Saving in time and costs in the data collection phase, by specifying the most appropriate data source(s) and data extraction techniques for the specific feature class and associate product specifications;

(*b*) Avoiding redundancy of information and unnecessary computer overhead for individual users.

Such an approach requires careful identification of potential users and their requirements, through well established communication channels between geo-information producers and consumers. Based on this, users will be categorized in homogeneous user-groups sharing similar context objectives, similar means of spatial data handling and fields of activities. Each of these groups has a specific "view" on the database contents, i.e.:

Information layer(s) of interest

Classification scheme for features in each layer

Quality parameters for each layer (resolution/scale, positional accuracy, temporal validity)

List of descriptors (spatial, functional) for various feature classes in each layer

List of relationships (topological, functional) among features in the same layer as well as across layers

Layers which might be at various levels of abstraction and resolution

Form of representation for individual feature classes

After analysing the various requirements (referred to as data models) of the individual user groups, the system designer should be able to adapt the multilevel data structuring approach as follows:

(*a*) *On the database internal level:* Classification of its contents into:

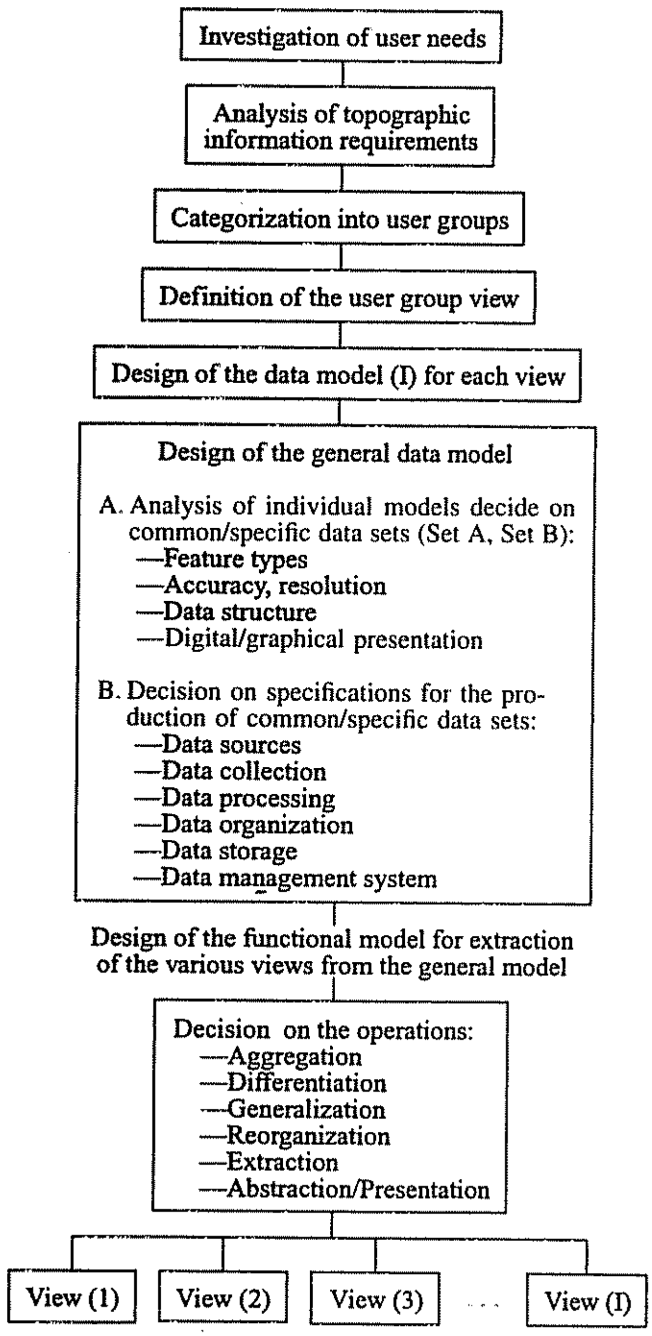
(i) General set: for all user community;

(ii) Specific set: additional information (with various resolution and accuracy levels) for specific user groups;

(*b*) *On the user external level:* Definition of the user view and the operations necessary for the derivation and abstraction of information from the various resolution levels.

The phases involved in the design of a database based on this concept are outlined in figure II.

**Figure II. Phases for defining of user requirement**




*Integrated production system*

The commonly applied concept of integration in many production institutions is usually restricted to hardware interface (a sort of computer networking) and data transfer from one unit to another in the production flow via a specialized software for data reformatting and recording. High-level integration should aim, however, at overall optimization and allow the production systems for geo-information to be able to:

(*a*) Extract information from various sources, such as existing graphic documents, aerial photographs, remotely sensed data (satellite images, radar data), field surveys, alphanumeric reports, information extracted from existing information systems in related disciplines, etc.;

(*b*) Provide alternatives for data acquisition, data processing and information presentation;

(*c*) Provide the possibility for bi-directional data flow between various processing units in the system and the integration of different data format (vector, raster) and different data organization;

(*d*) Integrate operations which have similar tasks and sharing in the various production lines.

This level of integration includes the interfacing and compatibility of the various components for information gathering, processing and analysis and presentation, (Makarovec, 1988). These components can be:

(*a*) Hardware: computers and computer peripherals (mainframe, mini, personal computers, intelligent workstations), computer communications and networks, photogrammetric plotters (analytical and computer supported), graphic digitizers (manual, semi-automatic, automatic scanners), computer graphic workstations, graphic plotting devices, ground surveying systems (total stations for the survey of details, GPS for point determination), digital image processing workstations, film read/write devices, etc.;

(*b*) Software: computer program packages in order to support various operations involved in information processing;

(*c*) Information and data (with various levels of abstraction, classification, and processing level);

(*d*) Knowledge and procedures for various tasks involved in production lines;

(*e*) Support and quality control components;

(*f*) Communication among various components: user-to-system interface, operator-to-machine interface, interfacing various input data sources (photogrammetric plotters, digitization of maps, processing of digital images, archived data files), information flow between various operations, etc.

The integration of these components implies optimization, with the following objectives:

(*a*) Development of production lines that provide optimal use of resources (hardware, software, humanware);

(*b*) Versatility in producing outputs of various forms;

(*c*) Increasing system capabilities in terms of production rate, quality of end product and quality check procedures, compatibility and flexibility in changing production mode and working procedures.

Among the current activities at BAKOSURTANAL, a special working group was set up in order to address various issues related to the subject of integration in various production lines. This included the identification of all requirements for hardware and software, knowledge and human skills; operations involved and their tasks; data type; format; volume and rate of flow; and the possibility of integrating the operations of common tasks, sharing similar data type and quality control procedures etc. Figure III outlines the BAKOSURTANAL integrated digital mapping and GIS system.

### *System specifications*

The establishment of standards (conventions) for the various aspects necessary for system implementation, is an essential phase of system design. In addition to conventional mapping standards, further specifications are necessary in order to define methods of data collection in digital mapping systems, design of information models for various levels of data abstraction (as defined above), methods of quality control and the design of quality models, and specifications for hardware and software support etc.

A special working group was set up in order to address the various aspects related to this subject. This group will make use of specifications published by many mapping institutions around the world such as the Canadian CCSM National Standards for the Exchange of Digital Topographic Data, United States Geographical Survey Digital Cartographic Data Standards, United Kingdom National Standards for the Transfer of Digital Data (see specifications references). The group has the task of setting up rules and standards for the various operations involved in current activities, with emphasis on those described below.

*Definition of data models*

The database system has to deal with various levels of data extraction. System specifications should provide a definition of the data model which supports each of these levels. Such a model defines:

Feature type (what object level to be considered)

Feature definition (commonly referred to as "Dictionary of Terms")

Criteria and rules of operations (functional model) for the extraction of objects at a certain level from elements of lower logical level in the data hierarchy

Feature classification scheme

Feature codes, reflecting feature class, source of data collection, quality etc.

Spatial descriptors (position, orientation, geometry)

Functional descriptors (attribute list)

Quality parameters (measures for positional accuracy, resolution level, cultural validity, classification reliability)

Topological organization of elements and method of representation in the database

Functional relationships

Rules, methods and standards for digital/graphical presentation (presentation model)

*Data collection methods*

The establishment of methods involves specifying the appropriate data source for various data sets and the method of data acquisition. The design of conventions (rules) for feature extraction includes the following:

Tracing of feature boundaries

Representation of individual features in terms of graphic primitives (point, line, area element)

Enhancement of data source (documents/digital data)

Handling of common features between various information layers

The design of conventions (rules) for data editing and verification includes:

Data verification within individual layer, e.g. correction of gaps, overshoot, polygon misclosures, connectivity among topologically related features, etc.

Consistency between layers, e.g. consistency among features having common boundaries, or are logically related

Edge matching between mapping units

*Design of quality model*

Quality parameters are set out in a list which will help system users to assess the quality of the data they intended to use. These parameters provide information about:

Source and method of data collection

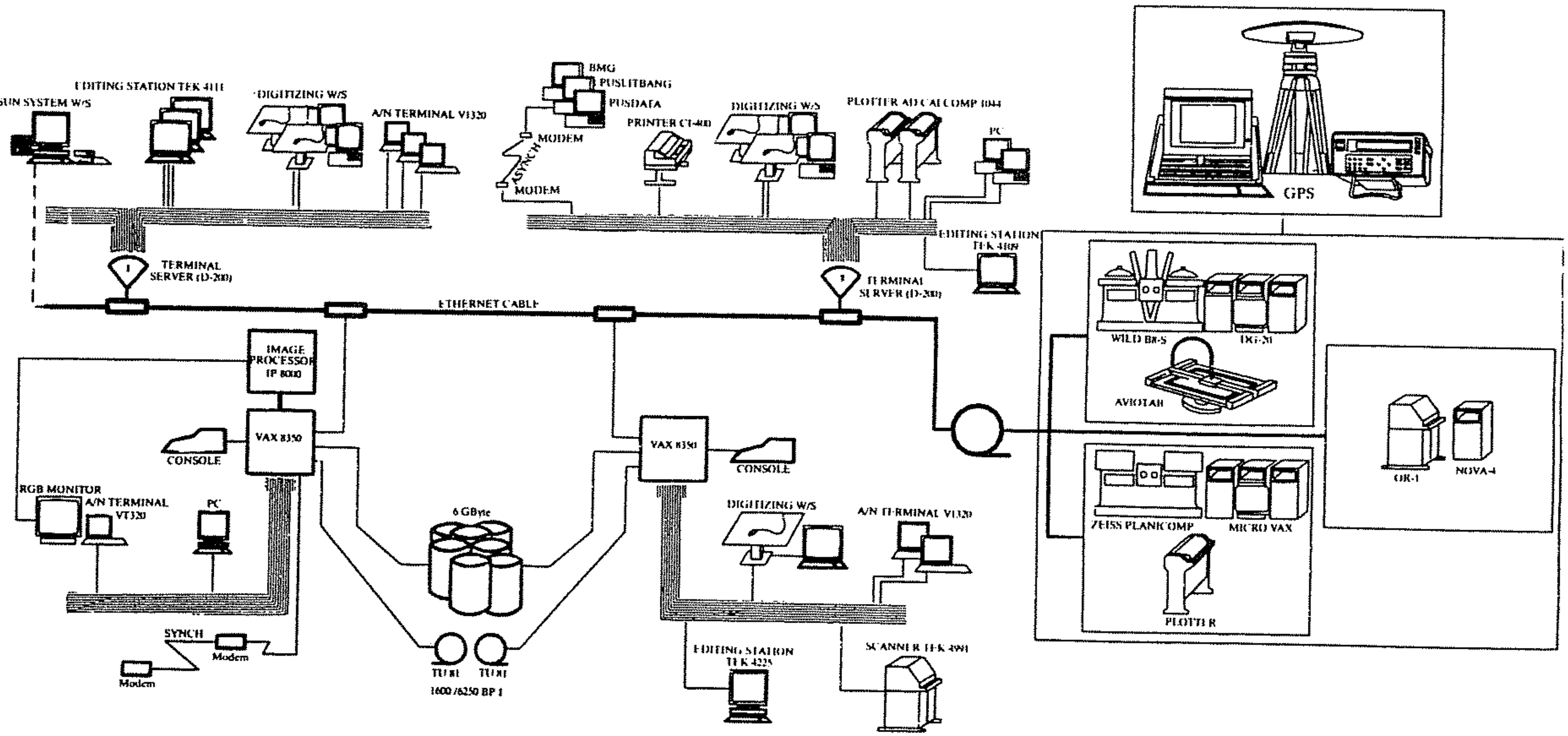
Completeness (intended data model with its feature classification scheme, list of feature classes actually in existence, list of available features, indicator for changes as reported by the database Quality Assessment Group and System Users)

Up-to-dateness (cultural validity)—decay rate of its geometric and thematic characteristics, period of attribute validity

Quantified measure for the positional accuracy and reliability of its geometry

Classification reliability

**Figure III. Integrated geo-information production system**



Resolution (conformity with the base map specifications for the representation of terrain features)

Factors affecting data quality are analysed (e.g. factors affecting positional accuracy, interpretation and extraction of features, etc.) at the various processes in the production line. This should include the possibility of quantifying these factors in a mathematical model.

A coding system is designed for the database entities in order to express quality parameters (as will be shown later in this text).

A data history report is designed (product quality report).

*Data exchange format*

Specifications for the data exchange format provide a mechanism for the transfer of geo-referenced data between agencies involved in the production of geo-information and/or its uses. These agencies are not necessarily using the same computer system. Setting these specifications is an attempt to unify measures for data quality, coordinate systems, definition and classification of terrain elements, and to provide a "standard" data organic model. These specifications will also provide interfaces allowing the conversion of the user-oriented data model to the standard data exchange format and vice versa. The definition of these terms was given earlier in this text.

The data in this standard form will be exchanged, via standard magnetic tapes or diskettes, as standard ASCII data files with well defined structure and data format. A special working group was set up at BAKOSURTANAL, with the participation of other specialists from related organizations. Further details about the activities of this group will be published later in 1991 as a separate report.

## Implementation of the object-oriented database concept on the ARC/INFO system

In the following section, current activities are reviewed that were conducted at BAKOSURTANAL under the ITC (NL) Consulting Services, TAT Project (Radwan, 1989), in order to address the-various issues raised above and their implementation on the existing ARC/INFO system.

The ARC/INFO system is a set of tools for creating, analysing, displaying and managing spatial data. It has two components (ARC/INFO Manual):

(*a*) ARC, with its topological data structure for managing the spatial component of the data model (location of terrain elements and topological relationships among them);

(*b*) INFO, with its relational tabular structure for managing the non-spatial component of the data model (functional descriptors and non-spatial relationships among terrain entities).

ARC/INFO organizes its data files in a hierarchical directory structure. It uses two basic storage units, coverage and workspace. A coverage corresponds to a single information layer, e.g., a map separate, and is implemented as a sub-directory of data files containing coordinates and topological information about one feature class and its feature attributes (ATTRIBUTE TABLES). A workspace is a directory (or sub-directory) containing a group of related coverages (sub-directories) covering a geographic area/map-sheet and the attribute data on the coverage level (i.e. global characteristics of the information layer).

The ARC/INFO MAPLIBRARY system is used as a database management system which allows users to view the database logically as a global data set rather than a set of archived data files (coverages, map-sheet based). This tool is used to organize coverages and associate attributes by location (into spatial location scheme, referred to as the TILE structure of regular or irregular shapes, as shown in figure IV or by subject into information layers. It also allows data extraction, control access rights to various data sets and organize data insertion and data updating. The digitized terrain elements coverages, and their associate attribute tables, after being verified and topologically structured, are "segmented" according to the MAPLIBRARY indexing system (TILE Structure) and are archived in directories referred to as "TILE Directories".

With respect to the requirements mentioned above, the following items were specially considered in our implementation.

Implementation of the object-oriented database concept is outlined in figure I, showing:

(*a*) Interaction between various levels in the database structure, i.e. (object-primitive element levels), (object-to-object levels), (layer-to-layer levels), (object and other database levels);

(*b*) Implementation of the multi-level data structuring approach, which allows various levels of densification (various resolution levels/different map-scales) and different levels of abstraction and organization;

(*c*) Implementation of the user-view concept, which allows user interaction on freely spatial as well as thematic bases and with a "tailored" data model for information manipulation and presentation.

While ARC/INFO has a variety of tools for graphic and attribute manipulation in a straightforward way, a series of adaptations were made and several command procedures were developed (using ARC/INFO AML Micro-Programming Language) in order to implement the required concept. These adaptations, as outlined in figure IV and given in detail in Radwan, 1989, can be summarized as shown below.

### *Spatial indexing to database contents*

Two types of indexing are used:

(*a*) MAIN-INDEX. A regular tile structure based on the basemap-sheet layout with tiles of equivalent size to the smallest map-sheet size that is frequently used as base for data collection and data updating;

(*b*) AUXILIARY-INDEX. One or more indexing systems are prepared per user-group with its tiles defined by the boundaries of the "land units" which represent the user's spatial view of the data.

The interaction between these two indexing systems is outlined in figure V.

### *Layer information*

In addition to the LAYER table in the MAPLIBRARY system (which provides the list of layers in the system, layer types (point/line/area) and feature attribute items to be used as standards for checking consistency of inserted data), two extra tables are created:

LAYER-GLOBAL-ATTRIBUTES TABLES

LAYER-TO-LAYER RELATE TABLE

Their creation and the operations on these tables are supported by the Database Management System INFO. They are:

(*a*) LAYER-GLOBAL-ATTRIBUTES TABLES. A global set of characteristics for each layer is provided, such as

SOURCE CODE (main source of data collection)

Figure IV. Database structure

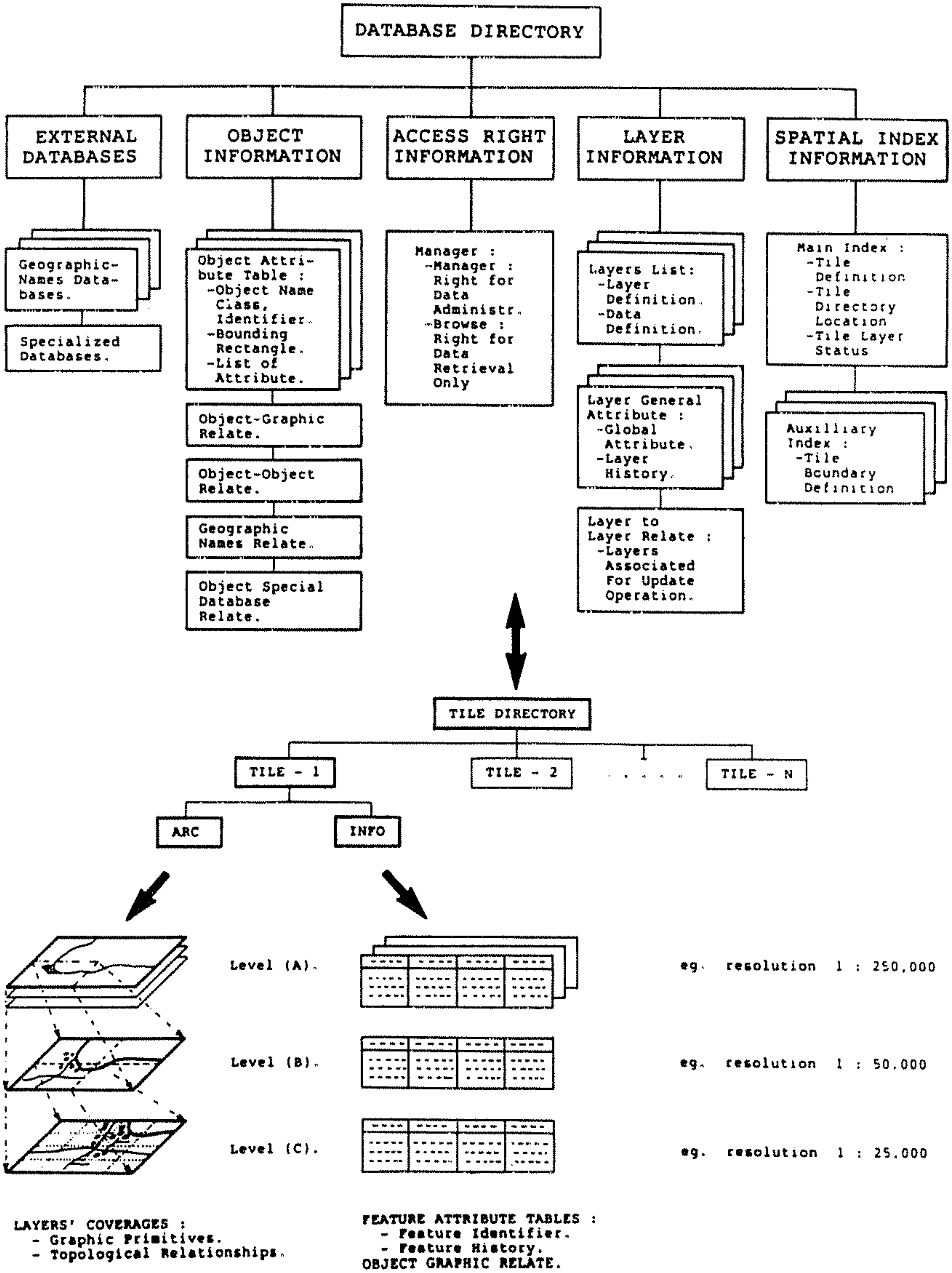
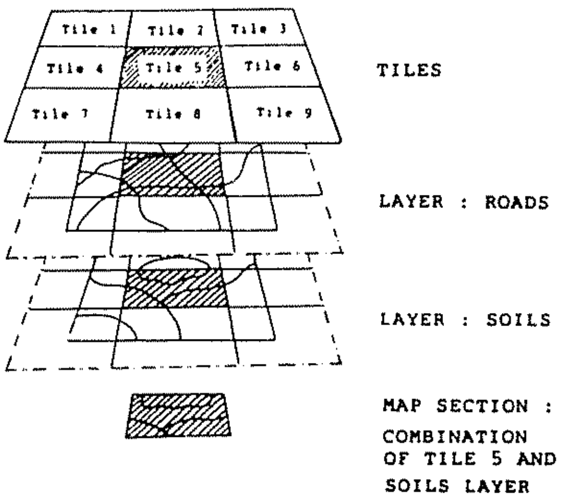


Figure V. MAP LIBRARY tile structure




RESOLUTION CODE (conformity with map scales)

RELIABILITY CODE (reliability and decay rate for its geometric and semantic characteristics)

UP-TO-DATENESS CODE (an approximate date related to validity)

GENERAL ATTRIBUTE LIST

(*b*) LAYER-TO-LAYER RELATE TABLE. Its objective is to provide awareness to the Database Administrator about layers which are related in data updating operations. Such layers have to be considered together in any future update in order to insure consistency among their common features.

*OBJECT DATABASE*

This database is built on the primitive element level, the TILE directories as shown in figures I and IV, and forms the base upon which users will perform their queries. It provides (in a tabular form) a list of features of interest and their relevant characteristics (spatial and semantic descriptors) and relationships among them. This list is obtained from the GEOGRAPHIC NAMES DATABASE, which was independently prepared by the Cartography Division at BAKOSURTANAL with the task of providing the correct names and a "quick" reference (via the location of a feature point in a particular map-sheet) for terrain features in Indonesia. The use of the GEOGRAPHIC NAMES DATABASE for the assignment of the correct names for the digitized terrain elements and the extraction of the feature list involves a series of ARC/INFO operations using its buffering and overlaying capabilities in order to find correspondence between feature-points in the GEOGRAPHIC NAMES DATABASE and the digitized terrain elements in the ARC/INFO coverages.

The OBJECT DATABASE contains the following tables:

OBJECT-ATTRIBUTE TABLES

OBJECT-TO-OBJECT RELATIONS

RELATION TABLES

The creation of and the operations performed on these tables are supported by the Database Management System INFO and specially designed "functional" models (using ARC/INFO AML Macro-Programming Language) in order to support user queries (user views). The contents of these tables are:

(*a*) OBJECT-ATTRIBUTE TABLES. A set of tables, one table per layer, in order to provide a list of features of interest in such layers:

FEATURE IDENTIFIER (for "internal" referencing between an object and its terrain elements stored in the coverages under TILE directories)

FEATURE CLASS CODE (to provide feature class, feature category and feature attribute classification, according to a pre-specified classification system);

FEATURE GEOGRAPHIC NAME

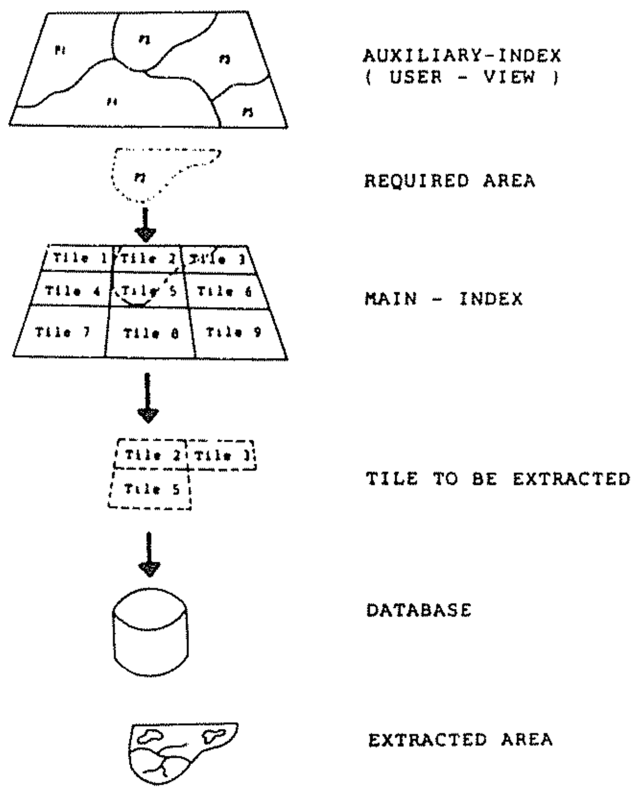
NAME IDENTIFIER (for referencing between this table and the GEOGRAPHIC NAMES DATABASE)

BOUNDING RECTANGLE (it acts as a window to access the object's primitive/graphic components which might be spread over many coverages) as shown in figure VI. The determination of this rectangle and its assignment to the object's FEATURE IDENTIFIER are done through successive ARC/INFO operations during the loading of the graphic coverages in the system

ATTRIBUTE LIST (assigned to individual objects either by direct entry to these tables or transferred from external databases using INFO export tools)

(*b*) OBJECT-TO-OBJECT TABLES. A set of tables describing all possible relations (spatial such as proximity, overlay, crossing, etc. and functional relations) that might exist between objects in the same layer as well as across layers. Each table has a name (RELATION NAME) and includes FEATURE IDENTIFIER of objects participating in such a relation and the items describing the nature of the relation;

Figure VI. Interaction between user's view and LIBRARY INDEX System



(*c*) RELATION TABLES. The OBJECT DATABASE should keep track (list) of all possible relations in which these objects are involved. The name and description of each relation (i.e. name of the two tables involved and the "relate" item between them) will be stored in RELATION TABLES as part of the database (using ARC/INFO RELATE operation).

Relations of interest are:

(i) OBJECT-TO-OBJECT RELATE. It ensures correspondence between records in the OBJECT-ATTRIBUTE TABLES where the corresponding objects are part of OBJECT-TO-OBJECT relations;

(ii) OBJECT-GRAPHIC RELATE. It ensures correspondence between records in the OBJECT-ATTRIBUTE TABLE belonging to a specific layer and the corresponding records in the coverage's ATTRIBUTE TABLES. This will provide a reference between the object and its graphic/primitive components;

(iii) OBJECT-TO-OTHER DATABASES RELATE. It ensures correspondence between records in the OBJECT-ATTRIBUTE TABLES and the corresponding records in the table of interest in other related databases (e.g., GEOGRAPHIC NAMES DATABASE, LANDUSE DATABASE etc.). This can be used in order to access additional attributes in the other databases which are of interest to topo-information users.

*Interaction between object and graphic databases*

The means of interaction between object and graphic (primitive elements) levels should be explicitly established in the DATABASE directory in order to allow association between these two levels. This interaction will serve data retrieval operations, such as:

(*a*) In the user environment:

(i) When a query operation is on the object level, it is required to derive the object's graphic elements and its topology from the GRAPHIC DATABASE (TILE Directories);

(ii) When a query is on the graphic level, it is required to retrieve further object descriptors from tables in the OBJECT DATABASE;

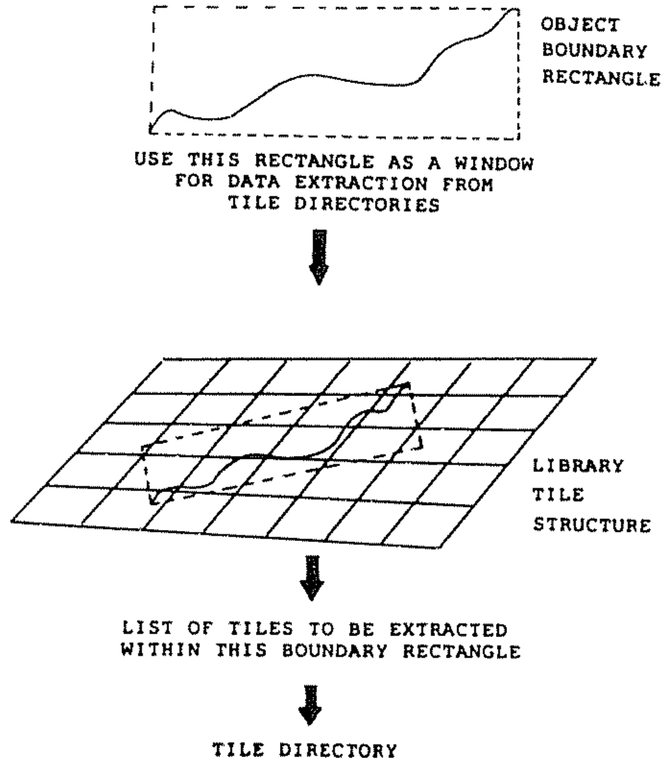
(*b*) In the DATABASE Administrator environment:

When it is required to assign values for items in an attribute table in one level from values included in tables in the other level.

The interaction between object and graphic levels is a type of one-to-many relation, i.e. one object and many graphic elements which might be spread over many coverages (map-sheets) in the TILE directories.

In such a situation, the FEATURE IDENTIFIER in the attribute tables in both levels allows easy reference between a graphic element in a special coverage (in a TILE directory) to the corresponding object in the OBJECT-ATTRIBUTE TABLE in the OBJECT DATABASE. The opposite however is not true as for a particular object (in the OBJECT-ATTRIBUTE TABLE) it is not known to which coverage (i.e. which TILE directory) the reference should be made. For this reason, we adopt the concept of the BOUNDARY RECTANGLE in the OBJECT-ATTRIBUTE TABLE, in order to be used as "window" in the data extraction operation in the MAPLIBRARY module. The extracted coverage will include all graphic information for such an object, as shown in figure VII.

**Figure VII. Using object's boundary rectangle for extraction of its graphic elements**




*Quality model*

As mentioned above, this quality model is an important part of a database and its purpose is to provide system users with the "quality parameters" that will help them to assess the quality of data they intend to use. Reference is made to various levels of terrain-feature abstractions, i.e. graphic and object levels, as well as layer (global) levels in a specific region (map-sheet base); these parameters are given at all these levels in order to provide "quality information", referred to as a Data History Report, ranging from an overview summary up to a detailed description for the quality of individual objects.

For this reason, the following adaptations were made:

(*a*) On the layer level in the OBJECT DATABASE, the LAYER-GLOBAL-ATTRIBUTE TABLE, as shown above, provides a set of quality parameters for a global assessment of layer contents;

(*b*) On the graphic level in the TILE directories (map-sheet base), the coverage's attribute tables are extended to include:

History Report (a global one) on the coverage level,

Individual features coded with a code number consisting of: Cl, C2, C3, C4 and C5,

where Cl, C2, C3 and C4 are used for feature classification (class, category, feature and attribute codes),

and C5 is a quality indicator consisting of three parts:

Dl (indicator for the data source and the positional accuracy);

D2 (indicator for the resolution level and its map scale equivalence);

D3 (reliability indicator for the object's geometry and its classification and their decay rate).

A specially designed programme was developed (using ARC/INFO AML Macros) in order to present these parameters (i.e. History Report) on both global as well as individual feature levels.

### RELIEF REPRESENTATION IN THE TOPO-DATABASE: THE UNIFIED APPROACH TO TERRAIN MODELLING

Terrain relief modelling should incorporate information about elevation, morphological features, such as terrain peaks, pits and points at slope interrupts, local minimum, local maximum, ridge lines, streams and valley lines, water bodies, terraces etc. Data needed for the extraction of this information might have been explicitly collected for elevation representation, such as contours, height profiles, ridge lines etc. or collected as part of other information layers such as water-streams, terraces of agricultural land etc.

The selected model for relief representation should be able to accommodate this information and have the ability to adapt to changes in terrain roughness and areas of differing relief complexity, without much computer data storage or data redundancy. The triangular irregular network (TIN) as offered by the ARC/INFO system, offers an appropriate data structure from this view. The TIN package has the capability to analyse the given relief data and extract the surface's most significant points for terrain relief presentation. These points are presented in the form of a network of triangles which fit the terrain surface. In our implementation (Radwan and Suharto, 1990), this TIN 3D structure is further converted to and stored in the ARC/INFO system as 2D polygon coverage, i.e. a coverage of non-overlapping triangles, where its node's elevation data and its geomorphological significance are stored in the coverage's ATTRIBUTE TABLES. We refer to this coverage as the digital terrain model (DTM) coverage. Such coverage will have the same data structure as any other layer coverage in the ARC/INFO environment and can be treated in the same way for data storage, archiving and retrieval in the Topo-Database.

Data extracted from the DTM coverage can be converted back to 3D TIN structure for the purpose of generating other relief models (such as grid, profiles, slopes etc.) and various DTM applications.

This unified approach to handling various data sets in the same database, as shown in figure VIII, allows us to set a unified strategy for the collection and management of terrain information.

#### *Multilevel structuring of the database contents*

In order to implement the multilevel data structuring concept, as outlined earlier, the data management capabilities of the existing ARC/INFO were adapted in order to allow storage of the various accuracy and resolution levels in the same database under the ARC/INFO MAPLIBRARY system for data archiving and management, as shown in figure IV, and to allow the user to "zoom" from one resolution level into a higher or lower one in the same database.

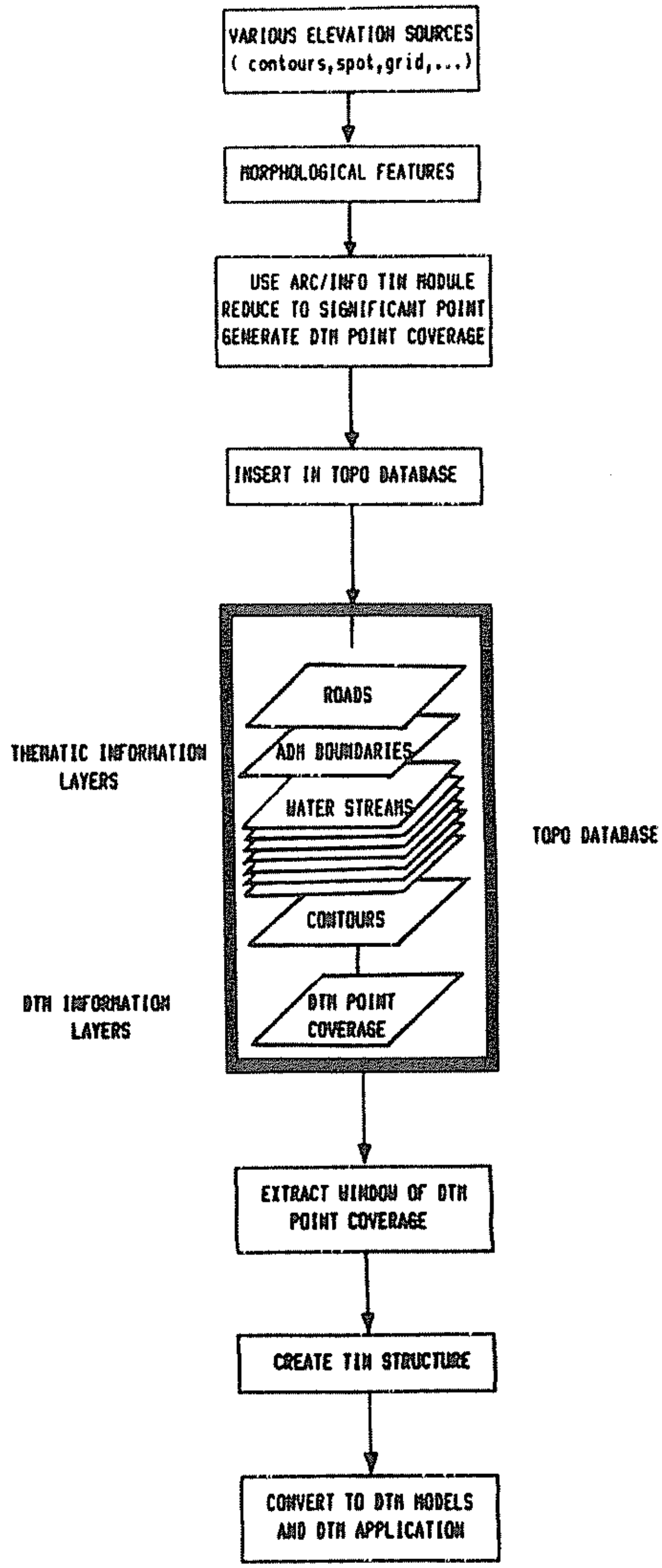
On the user level, a special user-interface model will be designed for each user group in order to:

(*a*) Define the user view on the stored data set (i.e., elements of interest, accuracy and resolution levels for each, and its organization and data structuring);

(*b*) Define the various operations necessary to support these views (such as extraction, aggregation, differentiation, generalization, reorganization, representation etc.).

In our implementation, these various data sets (with various accuracy and resolution levels) are stored in the various data storage levels (Sub-directories) in the TILE directories

Figure VIII. BAKOSURTANAL DTM Concept



with each level having its own data content, quality parameters and list of descriptors.

A special program package was developed in ARC/INFO Macros Language (AML), in order to handle these various data storage levels (its graphics and attribute components), to provide information about the database status in each accuracy and resolution level and to allow users to "zoom" from one storage level to another for visual and analytical operations.

## CONCLUSION

The object of this study is to set up guidelines for the design and implementation of the intended topographic database, using existing resources. Real data from the LREP Project, covering one province in the Island of Sumatera, was used. The rest of the collected data will be loaded in the ARC/INFO system following the experience gained and procedures adapted in this study and the necessary enhancement implemented.

In parallel, further activities have been activated for:

(*a*) Identification and analysis of the requirements of potential users via the various communication channels between geo-information producers and consumers, and design of an appropriate "interview" method;

(*b*) Analysing the suitability of existing data for satisfying those requirements;

(*c*) Investigating the suitability of various data sources and methods of information extraction for the future densification of the existing database and of the multilevel structuring approach as outlined in this study for satisfying the requirements of potential users.

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# STANDARD PROCEDURE AND DATA FORMAT FOR DIGITAL MAPPING*

*Paper submitted by Japan*

## RÉSUMÉ


En 1984, l'Institut géographique japonais a réuni la plupart des sociétés japonaises de photogrammétrie aérienne participant à l'établissement de cartes par ordinateur afin de mettre au point une norme japonaise. Depuis lors, l'Institut a mis en place un comité composé de scientifiques et d'experts pour discuter de cette norme. En mars 1988, l'Institut et le comité ont proposé un projet de norme axé sur l'application de la photogrammétrie à l'établissement par ordinateur de cartes à grande échelle.

La norme vise à obtenir des positions exactes sans procéder à aucune substitution ou suppression, à faire en sorte que les données répondent aux besoins des utilisateurs et qu'elles soient présentées de façon suffisamment simple pour être applicables dans tout système d'utilisation et pour que la série de renseignements cartographiques généraux soit complète.


Computer mapping technology, including computer assisted map-making, digital cartographic data creation and geographical information management, has become more and more favoured in Japan in these few years. "Digital mapping" technology, especially the creation of digital cartographic data through photogrammetric processes, has rapidly become the centre of attention of local governments and public utility enterprises, because of its high accuracy and usefulness in true position data.

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In order to take full advantage of this technology and to bring it into wider use, it is essential to standardize the procedure and data format. In this regard, the Geographical Survey Institute (GSI) gathered most of the Japanese aerosurvey companies involved or interested in research and the business of digital mapping technology to establish a Japanese standard in 1984. In the meantime, GSI set up a committee composed of scholars and experts in the fields of photogrammetry, computer mapping and municipal administration to discuss and investigate the standard.

Through one year of preparatory study and three years of investigation, GSI and the committee made the draft standard in March 1988, which is now in process of authorization.

This paper describes the principles and substance of the standard.

## CURRENT SITUATION OF DIGITAL MAPPING IN JAPAN

The world of computer mapping can be divided into three stages, namely, data creation, circulation of data set and data utilization. The data creation stage can be subdivided into two different techniques: the digitization of printed maps and digital mapping.

In Japan, medium-scale maps of 1:25,000 have been prepared by the GSI, covering all of Japan as the national base maps. They are revised every three to ten years. Digital cartographic data corresponding to medium scales are expected to be prepared by map digitization method, rather than by digital mapping, and maps have been partially digitized by GSI and other organizations.

On the other hand, larger-scale mapping of 1:500, 1:1,000, 1:2,500, 1:5,000 or others are mainly prepared by local governments for urban planning, public works inventory, utility management and so on. Digitization of those maps are much focused on the geographic information system (GIS). Because of the requirement of high accuracy and data freshness, digital mapping technology is thought to be very suitable for the creation of digital cartographic data at those scales.

The procedure and specification of digital mapping should be standardized in order to guarantee data accuracy and compatibility so that the data can be utilized by other parties as well. The GSI considered that it was its responsibility to help the digital mapping community to establish the Japanese standard for the procedure and compatible data format.

Before this study was started, some municipalities and public utility enterprises together with some leading aerosurvey companies prepared digital cartographic data with no compatibility, and this situation seemed to expand year by year. Therefore, in consideration of this urgency, the first draft was issued in March 1986 and the final draft was made in March 1988.

## PRINCIPLES OF THE STANDARD

Digital mapping technology is not only a method to create digital cartographic data; there is also photogrammetric surveying and mapping. In this regard, standardization is focused not only on data format and data code systems corresponding to each cartographic entity, but also on the procedure and the specification of digital photogrammetric processes. Regarding photogrammetric processes, attention was paid to assuring surveying accuracy according to prescribed rules and regulations for corresponding scale maps. On the other hand, data codes and formats are to be standardized from the viewpoint of data compatibility and data usability in various geographical information systems. The principles of standardization are as follows.

### *Purpose of digital mapping*

The main purpose of digital mapping is the creation of digital cartographic data for various geographical information systems. The digital data set obtained through digital mapping should meet the following requirements.

(*a*) Assured true position data without replacement or deletion such as arises from limitations of map-drawing capability;

(*b*) Data flexibility, enabling various user objectives to be met;

(*c*) Simplicity of data format to assure applicability to any user system;

(*d*) Completeness as to the general cartographic information set.

### *Documents of standards*

Contents of the standard were described in the following seven documents:

Standard procedure of digital mapping
Code system for digital cartographic information
Data format of standard exchange file
Manual of data acquisition specification
Recommended map drawing standard
Related file format and specification
Quality control manual of digital mapping

### *Standard exchange file*

Many files can be created and used in computer mapping; however, most of them are only temporary or unique to a specific application to which standardization is unnecessary and useless. Here, only the "true position data file" was strictly standardized in order to guarantee compatibility. In addition, recommended standards were shown for mapping (drawing) the data file and structurized data file.

## STANDARD PROCEDURE OF DIGITAL MAPPING

Standard processes are determined as follows:

Planning and preparation
Control point survey
Anti-airphoto signal setting
Aerial photographing
Pricking
Field affirmation
Aerial triangulation
Digital data acquisition through stereoplotting
Field terrain survey
Data edition and compilation
Supplemental field survey
Creation of standard exchange file
Revision of standard exchange file
Arrangement of results and products

The following processes are determined to be optional:

Creation of data management file
Drawing out maps
Creation of structurized data file

Processes from "Control point survey" to "Aerial triangulation" were standardized just as are conventional photogrammetric mapping processes. The process "Digital data acquisition through stereoplotter" is performed by using either analytical plotter or analog stereoplotter with encoding capability. Data should be monitored simultaneously by either a graphic display or drawing table during the data acquisition stage. Terrain information can be created by any of the following three methods: (*a*) obtaining digital contour line data; (*b*) obtaining grided digital elevation data; and (*c*) drawing contour lines on paper and then digitizing them.

### CODE SYSTEM FOR DIGITAL CARTOGRAPHIC INFORMATION

In order to identify each cartographic entity, 10-digit integers composed of a 2-digit "layer code", a 2-digit "data item code", a 2-digit "area code" and a 4-digit "information code" were prepared. The layer code and the data item code are strictly standardized, while the area code and the information code are optional. The area code is to be used to express locational or topological information. The information code is to be used to subdivide or dual-classify the data item code.

Standardized "layer codes" are as follows:

| *Code* | *Layer* | *Code* | *Layer* |
|---|---|---|---|
| 11 | boundary | 42 | other small objects |
| 21 | road | 51 | water front |
| 22 | road facility | 52 | water facility |
| 23 | railway | 61 | wall, fence etc. |
| 24 | railway facility | 62 | special field |
| 30 | unclassified building | 63 | vegetation |
| 31 | lower building | 71 | contour |
| 32 | higher building | 72 | scarp |
| 33 | building without wall | 73 | control point |
| 34 | building belongings | 75 | DEM |
| 35 | building use | 81 | text |
| 41 | public utility facility | | |

### DATA FORMAT OF STANDARD EXCHANGE FILE

**Hierarchical structure with any depth of level was adopted. There are six record types, all of fixed length of 84 bytes in ASCII/JIS characters. They are defined as follows:**

*Index record.* As a header of one complete digital cartographic data set, this record describes the information of contents and is recorded on an independent file.

*Map marginal unit record.* The data set is to be divided by appropriate units, usually corresponding to conventional map sheets, so as to avoid the decrease of usability caused by the huge quantity of data. Each unit is stored in one file. The map marginal unit record contains the information of each unit, such as the name of the area, geodetic coordinates of the unit origin, date of data creation, revision etc., recorded at the top of the file.

*Group header record.* In the hierarchical structure, each element corresponding to the individual cartographic entity can be grouped. Moreover, elements, groups of elements and groups of groups can be grouped. This group header record describes the information on how the group is composed.

*Grid header record.* Most of the digital mapping data are composed of points and sequence of points (so called vector data). Besides, there can be grided data as digital elevation model data. The grid header record is a record to describe the grid origin, interval, size, etc., followed by substantial grided data records.

*Element record.* This record is the lowest level header record corresponding to the individual cartographic entity, which is expressed by one type of substantial data record. This record is followed by substantial data records.

*Substantial data record.* This record describes real geocoordinates, text or attributes. There are five types of formats, corresponding to three-dimensional coordinates, two dimensional coordinates, text, attributes and grided data.

### PRINCIPLES OF MAP DRAWING

The main purpose of digital mapping is to create digital cartographic data for various geographical information systems. However, drawn or printed maps are often still used in many ways. In this study, map-drawing procedures and specifications were not to be strictly standardized, but recommendations were shown.

Since the standard exchange data file is composed of true position data, it would be rather difficult to read the map directly drawn from the data. In order to improve the readability of a drawn map, it is necessary to edit or compile the data from the viewpoint of map presentation capability. In this recommendation, most attention was paid to performance rather than to automatic editing or manual/interactive editing, to improve cost-benefit trade-off. This direction may reduce map quality. However, since map output is considered to be a secondary product in digital mapping this reduction of map quality may be allowed.

### STRUCTURIZED DATA FILE

The standard exchange data file contains digital cartographic data with classification code recorded on standard file format. However, for advanced utilization of data as in a geographical information system, it is necessary that some data are to be topologically structured. Structurized data are created for individual geographical information systems and are usually not expected to be exchanged between different systems. Therefore, the structurized data file was considered out of standardization, and only recommendations were shown.

In the recommendation five standard geometric models are proposed and twelve file formats are invented for structurizing all structural bodies. By combining five standard geometric models, any structural body can be structurized.

The standard geometric models are as follows:

Individual point model
Individual line model
Individual plane model
Network model
Area divided model

The twelve files are as follows:

Index file
Structurized file
Point file
Line file
Plane file
Plane definition file
Standard phase file
Extended phase file
External identifier file
Digital mapping attribute file
User attribute file
Correspondence file to standard exchange file

### Conclusion

Digital mapping is a relatively young technology and is still being developed. The GSI believes that standardization can help to further the development and popularizing of this new technology. However, standardization might also narrow the development of techniques and reduce incentives for new research. Taking into account this risk, GSI intends to continue to review the standard and continue research and development of this promising technology.

## DIGITAL MAP DATA: A COMPONENT OF GEOGRAPHIC AND LAND INFORMATION SYSTEMS*

*Paper submitted by United Kingdom of Great Britain and Northern Ireland*


### RÉSUMÉ

Toute carte représente fondamentalement une solution de compromis faisant intervenir trois éléments — échelle, contenu et description — en vue de représenter certaines caractéristiques du terrain ayant fait l'objet de levés, de tracés puis de reproduction. Les cartes topographiques répondent à des utilisations très variées des utilisateurs. Toute carte est en soi un système d'information comportant une multitude de données, lesquelles, à leur tour, sont transformées en information par le cerveau de l'utilisateur.

L'émergence des techniques de cartographie numérique, vers la fin des annés 60, a été perçue comme pouvant accélérer la production de cartes. L'on n'avait pas pensé alors que les données établies à cette fin pourraient trouver d'autres applications.

Dès les années 80, l'utilisation de ces données comme instrument de visualisation de l'information liée à la cartographie s'est rapidement propagée; toutefois, elles ne servaient que rarement de support à l'analyse.

La caractéristique fondamentale d'un système d'information géographique est de pouvoir connecter des données provenant de sources diverses grâce aux liaisons spatiales que comportent ces données. Si les données spatiales renferment suffisamment d'intelligence, elles peuvent permettre à un ordinateur d'effectuer le travail d'analyse et de procéder à des déductions logiques. C'est ce qu'a rendu possible l'amélioration du contenu des données cartographiques. Le présent document définit le système de documentation foncière comme étant un sous-ensemble du système d'information géographique.

On y trouvera des exemples d'application des données cartographiques numériques aux systèmes d'information géographique et de documentation foncière.


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A conventional map is a sophisticated information system which has been measured by the surveyor, drawn by the cartographer and printed by the printer. Each works to a specification which determines the accuracy, the content and the area covered.

The specification determines which features in the terrain are selected and how they are measured, fair drawn and printed. Early cartographers embellished their work with pictorial symbols which represented significant features but whose main purpose was to overcome limitations of accuracy and content. By using designs to fill the blank spaces surrounding the mapped area they produced an attractive result which was cartographically pleasing if metrically doubtful.

The scale of these early maps was determined to a great extent by the amount of detail to be shown and the positional accuracy of the survey had a lower significance than in modern cartography. Later, improvements in surveying techniques meant that more topographic detail could be measured and depicted accurately and the map scale took on more significance in the map design. As time passed the cartographer spent less time ornamenting his map and placed more emphasis on the correct depiction and placement of the topographic features.

As the ability of the surveyor to produce accurate positional surveys improved, the need for accurate large-scale maps could be met. The cartographer was now faced with a dilemma; there was too much detail and the accuracy was greater than necessary for some of the map scales. Thus the cartographer had to develop rules which he applied to reduce the content and downgrade the accurate coordinates provided by the surveyor in order to produce smaller-scale maps for specific purposes from larger-scale surveys. This process, known as generalization, is a compromise between the map scale, the content and the way in which detail is depicted. For any particular map, or more frequently map series, this compromise is arrived at by agreement between the map designers and the map users.

There is one further limitation imposed on the cartographic design and this is the sheet size. The sheet size is limited by the physical size that can be handled comfortably by the user, by storage considerations and to a limited extent by the size of the printing press. A number of standard printing sizes exist from which the map designer can select one which is suitable taking account of the effect upon ground coverage at the scale selected, sheet layout and design of the map series.

### A map is an information system

The information content of any map depends on the purpose for which the map has been created. Thus a map for

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motorists needs to be at a scale where the limitations of printing size will allow sufficient area to be shown without being unmanageable, and the content will include significant features for navigation and a selection of the road network. If this is not sufficiently detailed a larger-scale map has to be used but the penalty of less coverage and hence more map sheets has to be accepted. At the other end of the scale range are maps used for cadastral and planning purposes where scales sufficiently large to show street furniture such as lamp posts and manhole covers in their true position are used.

A map then is a representation of the real world where some selection of the content has taken place to service the needs of particular users, resulting in a specification which is a compromise between scale, content, accuracy, sheet-size and, finally, the way in which the map is drawn and symbolized.

In order to use a map to unlock the information contained within it some skill in map reading is needed, but once acquired it is a relatively simple process for questions such as: How far? Where is? What is the distance between? and How high is the ground at? to be answered; while questions such as: Can A be seen from B? What is the slope? and Which direction is the stream flowing? can also be answered with more practice and some additional knowledge about maps. What cannot be answered without access to additional information are questions about the features in the map, or related to them, such as: Who lives at? How high is the bridge? or What is the speed limit?, which are all simple examples of the kind of information contained in a Geographic Information System (GIS).

### *Thematic maps*

Between the topographic map and the GIS is a whole range of purpose-built thematic maps designed to portray information related to geographic positions, which are sometimes printed with the topographic map as a background. Examples of these are geological and soil maps. Demographic maps are often designed with symbols representing the quantitative information related to a geographic position, such as population to urban centres. This may be done using increasing symbol sizes. However, there is a drawback to this display as any breakdown of the information requires yet another map, so that to obtain information about the distribution of ethnic groups in the urban centres, or the relative numbers by age or sex, this becomes a cumbersome procedure. It is for this purpose that the GIS is so effective.

## Digital mapping

Before looking at GIS it is necessary to consider how a computer differs from a person when considering a map. People have a perception of maps that is affected by their knowledge of the real world, their experience and their intuition, which interacts with the information within the map giving its relationship to the real world such as scale, orientation, symbolization, projection and degree of generalization. The two latter items affect the perception by introducing degrees of distortion and displacement which complicate the way in which the map is interpreted. Finally, people have to contend with their preconceived ideas and even prejudices, which distort the perception. Nonetheless the human brain is extremely efficient at extracting information from the huge amount of detail available in a topographic map.

Questions about relative position, slope, size, distance, and connectivity are rapidly answered, whereas a computer would need to be given details which a person can rapidly infer, such as that there is no logical connection between a stream and a road even at a ford, or that a motorway only connects to other roads at specific junctions.

However, a computer programmed correctly and given the correct data can rapidly overcome differences which arise from projections and to some extent generalization, which many people fail to understand.

In order to do this the data must include information which the computer program uses to distinguish the various parts of the map: geometry, reference systems, feature codes, attributes and topology.

Before looking at the way in which these are used it is worth considering the way digital mapping at the Ordnance Survey (OS), the national mapping agency of Great Britain, developed.

In the late 1960s it was thought that if digital processes could be effectively introduced to produce maps automatically from stored data it would be possible not only to emulate the existing map specifications but also through software to produce generalized maps at a variety of scales from the same data. During these early investigations there were few demands for map data beyond the map making processes, so development concentrated almost entirely on using the data for map production.

Although some work was done at small scales, investigations concentrated on the production of digital data for the large-scale urban mapping and the associated generalization problems.

By the early 1980s a demand for digital map data was emerging for use as a background reference map for the display of information predominantly from the digitized records of cables or pipelines of public utilities. Data for this purpose did not require all the various coding that had been introduced for cartography and as a result, some reduction in content was introduced in order to make the data more acceptable. From about 1988 a demand for more sophisticated data has emerged partly to improve cartographic processes and more specifically to service GIS. However, the predominant use of digital data in Great Britain remains at large scale (1:1,250) for the recording of utility distribution networks, and at local government level where there is an increasing number of municipal authorities developing geographic and land information systems (GIS/LIS) for urban land management and physical planning, although investigations into the wide range of possible applications in GIS are beginning to create demands for data at other scales.

### *Geometry*

At the lowest level, a digital map is composed of the coordinates which define positions on the Earth's surface for all the features included in the data set. In its simplest form the coordinates representing these features are collected in any order and the resulting strings of coordinates provide the information which the computer needs to reproduce a map. At this level there is no intelligence in the data; thus, one coordinate string cannot be identified from another nor are the points where strings or lines cross specifically defined, unless the crossing point has been coordinated as a deliberate act.

### *Reference systems*

In order to introduce a relationship between coordinated points on the Earth's surface and their representation as a map, computers rely on various reference systems through which scale and projection are related to the real world in exactly the same way that a conventional map establishes these relationships. The difference is that the conventional map series has the scale and projection determined as part of the specification, whereas computers are capable of varying projection and scale rapidly and accurately. In practice a coordinate reference system is selected for a particular country and application, which here in Great Britain is the National Grid; but a system based on latitude and longitude or Universal Transverse Mercator could be used with equal effect. Provided there is a relationship which can be programmed into the computer system, transformation of coordinates between reference systems can be carried out. For a computer the concept of scale is not significant, since scale is dependent purely on the relationship between the screen display and the real world. What is of much greater importance is the resolution of the coordinates which have been captured, since coordinates captured to the nearest 5 metres may be quite adequate for a scale of 1:50,000 whereas at 1:1,000 they do not have sufficient accuracy for that resolution.

In addition to the coordinate reference system there are other ways of selecting locations in the digital data such as addresses and postcodes, but these are dependent on being included in the data set with suitable pointers to the coordinate system so that they can be recognized by the computer program.

### *Feature codes*

To unlock the relationship between a line in the data and a feature in the terrain the computer needs to be told what the coordinate strings represent, and this is the basis through which the digital data takes on a more coherent form. Each line in the data is assigned a feature code which identifies what it represents on the ground. Thus a building outline can be separated from the fences which bound the land parcel, and the edges of a road can be identified as being made up of a series of lines, coded building, fence, ditch etc. through linking them to the centre line, which acts as a pointer to the edges. In a similar way point objects can be coded so that the correct identification can be assigned and the correct symbol displayed.

### *Attributes*

Having located the lines through coordinates and identified what they represent, additional information can be assigned through seed points in the data. In a cartographic context these attributes would be the line styles, such as pecked lines for road curbs or line weights depending on the specification, and they would include road names and house numbers. Attributes can arise from a number of sources and, in a GIS, seed points in the map data are linked to non-spatial data in associated databases to give the geographic relationship to those data.

### *Topology*

In order to perform properly within a sophisticated information system, the data need to be structured in such a way that the computer can readily determine the logic in the data, while still relying on the geometry and the feature codes to define the features. In topologically structured data the component parts of the data are identified so that significant junctions are made into unique points called nodes, while the lines between the nodes regardless of whether sinuous or straight are termed links. Only where two links cross which have a significant connection in the real world are the links broken and a node created. Thus, where a power line crosses a fence the two links would cross without a node at the crossing point. In topology the data are formed into polygons and seed points are created so that attributes can be related to the objects formed by the polygons. This concept allows the inside and outside of a polygon to be separately identified and linked to separate attributes. It is now possible to identify objects in the data so that a collection of building polygons with a perimeter, and possibly separate but associated polygons, can be identified as a school. It is a short step from here to catchment analysis, given the school pattern and the location of the homes of school age children or even the planning of school bus routes to transport the children to school.

In addition to the polygons formed from the links, topology makes possible the identification of networks so that either river or road networks can be formed for analysis in relation to the attributes which can be attached to the links.

Finally, there are relationships which identify the connectivity so that the link passing under can be identified in its spatial position relative to the link passing over.

A prime example of a topological map is probably familiar to most people who visit London without realizing the significance of the diagram. The London Underground map has no geometric framework, it has variable scale and the positions of the stations give only very approximately their relationship to other stations, particularly those on another line. However, what is shown is the network and the connectivity which allows a route to be planned, but which, without some knowledge of the true shape of the layout in relation to the city streets, may not always result in the quickest journey. A GIS application could very simply be designed to produce such a result if journey times were attached to each link and coordinates were assigned to the stations to relate them to a suitable topographic map.

## Levels of use of digital data

There are three main levels of use for digital map data. In the early days of digital mapping, data increased in complexity from level 1 to level 3, but recent improvements in map production can only be achieved with data that satisfy many of the requirements of level 3.

*Level 1: Data for the production of maps and plans.* The use of digital map data makes it possible to produce maps to a variety of scales and content. The simplest form of data, which includes geometry and feature coding, is capable of map production to a specification which does not include symbols or ornamentation. However, fully automated production can be achieved through improvement of the data by using polygons containing seed points to indicate where symbols and ornamentation are to be included. Thus woodland, slopes and building stipples can now be plotted in their correct style and position automatically. These more versatile data make it possible to eliminate the constraints of sheet size, map layout and, within limits, scale. They also allow the map design to be changed through alteration of the symbols and the addition of colour, and with special software can carry out a certain degree of generalization automatically.

*Level 2: Background to user data.* Even using the simplest form of digital map data will allow information such as pipeline routes to be recorded against the digital map background. The result can be displayed on a screen or plotted as a composite document, but until additional intelligence is included in the map data it is only possible to analyse the associated user data to the level of intelligence in those data. Thus it would be possible to obtain information about the pipeline network such as pipe sizes, material flow etc., but any underlying information relating to the customers being supplied could not be accessed through the map data without a more sophisticated map data set with associated attributes which would be essential for GIS applications.

*Level 3: Component of a GIS/LIS.* Although level 2 is a simple GIS, in order to be used as a component of a GIS/LIS the map data would need to include sufficient topology to make the attachment of both graphic and nongraphic attributes possible. In such an application it would be possible to relate the digital map data to associated databases which would allow various separate sources of information to be related through the spatial reference system of the map data. In the case of utility records it would be possible to identify the house number or name, the occupier, consumption, billing details etc.

### *Geographic information systems (GIS)*

There are numerous definitions of GIS but all err on the side of brevity leaving out, as a result, many of the functions of GIS by not specifying exactly what it includes.

The essential nature of a GIS is that it should be capable of linking a variety of data through a common spatial reference system. A GIS allows the collection, updating and display of a number of unconnected data sets bringing them into a common reference system for spatial analysis from which relationships can be identified and decisions made. Through the structure in the data it is possible to link non-spatial data to the polygon seeds and to individual links in the map data and to manipulate the various data sets as a single data set.

A GIS is not concerned primarily with maps. While a map may be a way in which to access the data and simplify storage it is the spatial reference system which allows the analysis and integration of datasets to happen effectively. However when it comes to the display of results there is no better way in which to show location and relationship between sites or events than the digital map. When this is done it is important to produce a clear and concise map to a high quality which in turn adds credibility to the results. The structure and feature coding in the map data allow the data to be manipulated to produce maps which are suitable for display.

Finally the map has various components which, when attributes have been attached, can be used to provide analyses of polygons or networks. Special subsets of the map data can be used to create specialized data products to support specific GIS applications. When used in these ways the map data take on a high level of importance as a GIS component.

### *Land information systems (LIS)*

For the purpose of this paper a LIS is defined as a subset of GIS attributes, the principal difference being that a LIS uses large-scale digital map data as a base on which to overlay land-related digital information in a computer system for the specific purpose of managing land-related activities. This usually requires digital map data captured at large scales (1:1,000-1:10,000) in order to provide a topological base to show the relative position and relationship of buildings/land plots. The definitions given in the previous paragraph about GIS apply also to LIS.

## OS ACHIEVEMENTS WITH DIGITAL MAP DATA

By 31 March 1991, OS will have completed the digitizing of all published national plans at 1:1,250 scale (this scale of mapping covers urban centres with a population of more than 20,000). The digitizing of 1:2,500-scale mapping, covering the smaller towns and populated rural areas, is also proceeding rapidly, and is 20 per cent complete.

In order to make this structured digital data available to all potential users for their GIS/LIS use, OS has developed the national transfer format (NTF) which is capable of transferring data with a variety of complexity. Responsibility for NTF has recently been taken on by the Association for Geographic Information and is being made compatible with the International Standards Organization standard: ISO 8211.

Another important aspect of data for GIS/LIS is that they should be kept up-to-date. OS has created the digital field update system (DFUS) for updating vector data, which is now being further developed to incorporate the ability to maintain structured data. This equipment has been installed in 25 field offices and a further 14 offices will have the systems delivered in 1991. In order to support these systems, which are essentially office equipment, OS has developed a portable interactive edit station (PIES) to be carried in the field by the surveyor who enters his revision work directly into a copy of the digital data, which is in effect an electronic plane table. Data updated in PIES are then fed into the database through an interface with DFUS.

In addition to the extensive digital data availability at 1:1,250 and 1:2,500 scales, OS now has complete national digital data at 1:625,000 and 1:250,000 scales and investigations are in hand to create a data specification for GIS applications at 1:50,000 scale.

It is no exaggeration to say that OS is a world leader in digital map data collection and management and to this end is well qualified to provide consultancy advice and training to third world countries intending to develop national GIS/LIS.

## GIS APPLICATIONS IN THE UNITED KINGDOM

The use of GIS has recently been stimulated by the Economic and Social Research Council, which has established eight Regional Research Laboratories based at universities throughout the United Kingdom. At these centres of excellence a number of applications ranging from hazard or disaster planning to the best location of a Superstore are being studied, and clients are being urged to bring forward problems that can be solved using GIS technology to increase the public awareness of this extremely powerful tool for decision making.

Structured digital map data suitable for use in a GIS have been supplied by OS to a number of local authorities to allow GIS to be studied for various applications related to local government. For example, at Tameside Metropolitan Borough in Greater Manchester a number of applications of GIS are being studied:

(*a*) Urban renewal, where the analysis of ownership, state of repair, occupancy and other factors are linked using the OS map data;

(*b*) Scheduling buses for "special schools";

(*c*) Street lighting;

(*d*) Application of GIS to the Land Terrier (LIS activity).

As an example of GIS in a planning role the digital map of an area shows the field boundaries, road layout, buildings and some information about the land use such as woodland, orchards, marsh etc. If the pattern of land ownership is added, together with information about the existence or otherwise of planning permission, it is possible to determine the development potential and suitability of various sites on offer. The map background makes it possible to display the various analyses and also can provide details about access and parcel areas which, together with land values, would provide a good basis for making a decision about a development proposal. However simple it may appear the components of a GIS have to be collected and integrated into the GIS; thus, in this example unless the ownership of the land can be established as well as which parcels already have planning permission, the initial stage in the process must be data collection, and this should not be underestimated either in the time or cost required to do it.

The previous example has illustrated large-scale map data applications which show an overlap of GIS and LIS, but a GIS is equally suited to the consideration of problems over wider areas where factors affecting the environment can be studied in relation to their effect on the population. One such study by a Regional Research Laboratory is concerned with investigation of the reasons why clusters of cases of childhood leukaemia occur. For this study the map base needs to be of sufficient resolution to show the location of population centres significant to the study over the whole area and yet be suitable for display of smaller areas at larger scale.

The population census data being collected in 1991 for the United Kingdom will create the requirement for map displays based on the small-scale maps of the country combined with the ability to display data related to local government wards, census enumeration districts and possibly unit post codes in the urban areas. Thus the generalization inherent in the maps will have to be introduced into the nongraphic data to allow macro-spatial analysis to be carried out from the detailed data which the census will provide.

In a similar way data for in-car navigation are a combination of the macro-route network and the very detailed road systems in the urban areas. Attributes relating to the road network which include direction restrictions, speed limits, bridge heights, width restrictions etc. that are of a permanent nature or change infrequently, and those of an ephemeral nature such as lane restrictions, road works, accidents etc., are linked to relevant points in the map data to create a complete database of the road network that can be used for a variety of applications ranging from in-car navigation to route-planning. Clearly a database of this sort, combined with traffic patterns and volumes, would be able to answer questions such as: What happens if main interchanges on national highways are closed on national holidays?

### LIS applications in the United Kingdom

At the municipal level, the Milton Keynes Development Corporation has created a corporate land information system which is used to keep all the land transactions and associated records of occupancy, ownership, leasehold etc.

With reference to Land Title Registration, both H.M. Land Registry in England and Wales and the Registers of Scotland now have active programmes to transfer title records from the existing OS cadastral plans onto OS digital map data.

In Great Britain, because the national digital map data are both topographic (geographic) and cadastral (land) there is a tendency for GIS and LIS to overlap.

### Conclusion

The foregoing paper has given a very brief description of some of the considerations concerning digital mapping, its relationship to GIS/LIS and developments and applications in the United Kingdom. There are many other factors for which there is insufficient space and time to give a mention. It must be remembered that for a GIS/LIS to be effective it needs sufficient data for the investigation in hand and where data are not available their collection is a major consideration.

Not only are data a major resource but their management and maintenance are of prime importance. Out-of-date information will give flawed results but an out-of-date background map is of equal concern. Revision of the map base affects the whole GIS/LIS and it is absolutely vital that the way in which this is carried out is carefully considered as part of the GIS/LIS design.

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## ARC DIGITIZED RASTER GRAPHICS AND THEIR APPLICATION*

*Paper submitted by the United States of America*

## RÉSUMÉ


Les produits graphiques ARC numérisés par balayage (ADRG) sont des reproductions de cartes que la Defense Mapping Agency produit sur disques optiques compacts (CD-ROM) pour les diffuser. Le processus ADRG convertit les données et la projection de la source en norme du système géodésique mondial 1984 (WGS-84) et du système Equal ARC-Second Raster Chart/Map, ce qui permet d'établir une base de données ininterrompue à l'échelle mondiale pour les données de cartes à une échelle donnée.

Les produits actuellement concernés sont les suivants : cartes de navigation opérationnelles à l'échelle de 1/1 000 000, cartes de navigation tactique à l'échelle de 1/500 000, Joint operations graphics à l'échelle de 1/250 000, cartes vectorielles topo-


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graphiques à l'échelle de 1/50 000 et cartes de navigation pour les avions à réaction à l'échelle de 1/2 000 000. De nombreux CD-ROM de cartes à petite échelle sont en vente libre.

La meilleure utilisation des données ADRG est en tant que fond d'images obtenues par balayage pour les applications des systèmes d'information géographique. Au sein du Département de la défense des Etats-Unis, l'ADRG appuie actuellement le programme AV8B de la marine et le système de surveillance des manœuvres militaires.

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## Product description

ARC digitized raster graphics (ADRG) are digital images derived from printed maps and charts, distributed on CD-ROM. ADRG is comprised of a raster image of a paper map or chart supported by ancillary raster images of chart-specific marginalia and text data such as datum, projection, and accuracy information.

ADRG raster map images are generated by transforming a scanned map from its original datum and projection to the WGS 84 on the projection defined in the Equal ARC system. Production of ADRG on WGS 84 in the ARC system permits generation of a worldwide seamless image database for maps of the same scale. Currently, ADRG coverage includes jet navigation charts (JNCs) at 1:2,000,000, operational navigation charts (ONCs) at 1:1,000,000, tactical pilotage charts (TPCs) at 1:500,000, some joint operations graphics (JOGs) at 1:250,000 and topographic line maps (TLMs) at 1:50,000.

ADRG data are organized into distribution rectangles which are groups of one or more same-scale maps. Distribution rectangle size is limited by the amount of data that will fit on a CD-ROM; the typical size does not exceed 600 megabytes. As a rule, ONCs, TPCs, and JNCs are distributed one sheet per CD-ROM; six TLMs and four JOGs fit into a single distribution rectangle. On multi-sheet distribution rectangles, the joins between adjacent sheets are practically undetectable.

ADRG raster image data is collected as nominal 100-micron pixels in 24-bit red, green, and blue colour. During the ADRG product design phase, 24-bit colour was determined to be high enough resolution to withstand multiple resampling operations without significant image degradation.

For a given CD-ROM, top level data files include a text file describing the distribution rectangles that appear on the disk, as well as a colour patch image file to use for colour calibration on a user's display system. For a given distribution rectangle, there is a subdirectory containing text files of ancillary data that describe the ARC images, accuracy of the source map, and security/releasability information. The subdirectory also contains the ARC images themselves with the corresponding overview image.

The overview image, compressed from the actual 24-bit ARC image, is designed to fit in its entirety on a single screen display. It is the digital equivalent of a location diagram and provides a graphic index for rapid access to the full-resolution ARC image.

Each source map within a distribution rectangle also has its own complement of ancillary data files. These files include source-specific information such as map name, datum, essential aeronautical data, and map sheet boundary coordinates. Each source map within a distribution rectangle also has a set of one or more raster images of map-specific marginalia. Examples include landmark feature symbols and boundary diagrams.

ADRG design reflects the Defense Mapping Agency's emphasis on standard exchange formats. All ADRG data and file directories are formatted in compliance with the ISO 8211 standard. International Standards Organization (ISO) 8211 is a self-describing file format flexible enough to accommodate a variety of data formats and is completely independent of the exchange medium. ISO 9660 has been selected as the volume and file structure for the ADRG CD-ROMs.

### *ARC system*

The ARC system was designed for ease of computer display and for simple, direct computation of geographic coordinates from image pixel location.

As implemented in ADRG, ARC defines 16 non-polar bands called zones that lie between 80 degrees north and 80 degrees south latitude, plus two additional zones at each pole (figure 1). In the non-polar zones, ARC is based on an equirectangular projection (Snyder, 1987, p. 90); the spherical form of the azimuthal equidistant projection, polar aspect (Snyder, 1987, page 191) forms the projection basis for the ARC system over the poles. The number of zones defined in ARC minimizes distortion in a given zone to no more than 18 per cent maximum stretch or shrink. (The datum used for ARC in ADRG is WGS 84.)

Although the scale of any given application of the ARC system is dependent upon the scale of the map originally scanned, ARC has a simple relationship to angular distance for a given scale. Within a specified non-polar zone, any pixel represents the same angular distance in the east-west direction. Across zone boundaries in the north-south direction, each pixel represents the same angular distance in all non-polar zones.

ARC was also designed to support creation of seamless worldwide map image databases. As it is applied in ADRG, a 1,024-pixel overlap between ARC zones allows programming of image display software to scroll seamlessly from zone to zone.

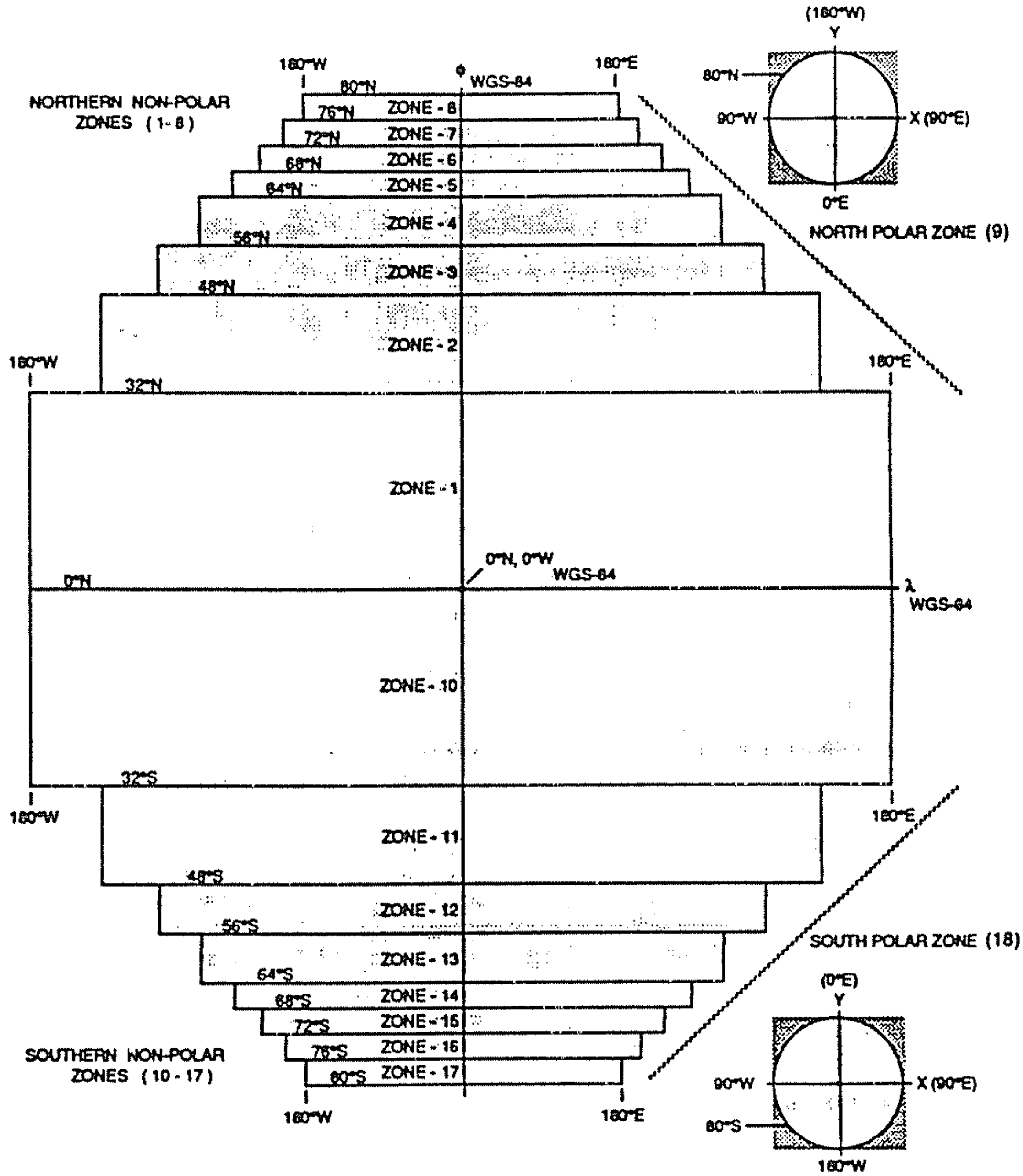
Pixels in ARC are organized into 128 × 128-pixel tiles. This tiling scheme, which is seamless across the worldwide ARC zones, permits development of optimized image data retrieval software that can access image data rapidly by tile.

## ADRG production process

### *Production system*

The ADRG production system consists of four 19" monitor colour graphics data preparation workstations, one 44" × 60" large format drum scanner with interface processor, five transformation batch processors running at 10 million instructions per second with three gigabytes of disk space and 117 megabytes of memory, and two 27" monitor colour graphics quality control workstations. All system components are connected to a dedicated network. Once input data is prepared for entry into the ADRG production system, data processing time for each CD-ROM ranges from five to seven

**Figure I. ARC system zone layout**



houses. Other signs are increasing congestion, air and water pollution, and deteriorating infrastructure. Simply put, rapid urbanization has outstripped many, if not most, Governments' ability to cope with even the most basic of services. As a consequence, the major international aid and lending organizations, and its borrowers, have to tackle the serious distortions that exist in the financial, land and housing markets (Holstein, 1989, and Williamson, 1990).

There are large inequities in most third world cities where, as a consequence of poor mapping and land administration systems, a large number of well developed properties are not paying essential taxes. If the city does not have an up-to-date record of property, does not know where it is, who owns it and what is its value, it is difficult to tax land and property equitably. At the same time, if a city does not know the location of all exisiting services, it is difficult to repair and upgrade them. Other consequences of poor land management include the inability to undertake any city planning or acquire land for public facilities. Land and geographic systems are seen as one method of helping to overcome these urgent problems. Examples of large metropolises in the third world which are developing various LIS/GIS systems as well as facility information systems (FIS) include Cairo (Leppanen, 1990), Mexico City (Reyes and others, 1990) and Bangkok.

The City of Bangkok is an excellent case study to examine the problems and strategies in developing an integrated land information system. First, the Bangkok Land Information System (BLIS) project builds on the success of the larger Land Titling Project (LTP), funded since 1983 by aid from the World Bank and Australia (see below). This project has the objective of upgrading the cadastral mapping base, improving the land titles records and improving the valuation base for the City. Secondly, the BLIS project is an ideal example of a strategy to develop a land information system in a large third world metropolis. One of the most important aspects of this project is the institutional arrangements for its establishment and management. The project exhibits an exceptionally high level of cooperation and collaboration between the key participating agencies, namely the Bangkok Metropolitan Administration (BMA), the Metropolitan Water Works Authority (MWA), the Metropolitan Electricity Authority (MEA), the Telephone Organization of Thailand (TOT) and the Department of Lands (DOL). Each of these organizations has invested money and people in the joint project. The project is also being supported by the Australian International Development Assistance Bureau (AIDAB).

There is often confusion with the terminology used in land and geographic information system projects; however, in this case it is quite clear. The overall project is called the Bangkok *Land Information System* (BLIS) project. This is justified since the project is primarily large scale (1:1,000) with a large parcel based component. BLIS is very much a dynamic land administration system. A major component of the project is a *digital mapping base* including both topographic and parcel information. An important component of the project will be the development of specific *facility information systems* for the major utilities involved. All the preceding activities will be at a nominal scale of 1:1,000.

## The City of Bangkok

Bangkok metropolis, the capital of Thailand, is located on a low flat plain of the Chao Phraya River extending to the Gulf of Thailand. Since established in 1782 as the new capital of Thailand by King Rama I, Bangkok has been promoted as the centre of commerce, industry, national culture, national and international transportation and most of the central Government administration. The total area of the Metropolis now covers 1,568 sq km.

### *Population*

After its establishment in 1782, Bangkok grew slowly until 1900, when the population was only 600,000. After the Second World War, the city experienced heavy public investment in national infrastructure and public utilities throughout the city. The rate of growth in population and urbanized area has steadily increased since then. Although an official figure from the household registrations in 1989 showed Bangkok's population at 5.8 million, it is generally recognized that with at least 30 per cent of persons not registered and the uncontrollable one-way migration from the rural areas, the actual population is now over 8 million, making it one of the world's largest cities.

### *Administration*

The Bangkok Metropolitan Administration (BMA) is the local administration authority in Bangkok with staff in excess of 40,000, and it is responsible for a wide range of services within the Metropolis such as flood protection, drainage and sewerage, city planning, public works and traffic control, medical and health services, social welfare and community development, education and public cleanliness and orderliness.

Other major utility services within Bangkok are provided by various State enterprises, such as those already mentioned, TOT, MWA and MEA.

### *Expansion of Bangkok and subsequent problems*

The Thailand economy is currently experiencing its third year of double-digit growth and it is expected to continue to grow at annual rates of around 8 per cent during the next ten years. In view of the economy's rapid growth and industrialization, the recent demand for public services and infrastructure has pushed the city government's ability to provide these services to the limit. Traffic congestion, water shortages, solid waste, and air, water and noise pollution problems have noticeably worsened in the last few years. These problems are now acute as nearly 75 per cent of Thailand's manufacturing is concentrated in the Bangkok area.

Bangkok's growth and the subsequent problems being experienced by the servicing authorities in their attempts to respond to the expansion in terms of planning and supply of services can be illustrated by the following examples.

#### *Water-supply shortage*

The MWA, for example, which is responsible for the pipe water supplied in Bangkok and its surrounding towns, has experienced an increased demand for its water of approximately 8 per cent per annum over the past decade. Despite considerable expansion of its distribution system, the MWA is able to supply only 43 per cent of the area and 66 per cent of the population under its responsibility. The rest is met by ground water pumping.

Assuming an average growth rate of approximately 7 per cent and proportional water use, the demand for water should double in 10 years and more than triple in 16 years, outpacing a supply which faces limited raw water allocation, water pollution and rising supply costs.

In addition, in the industrial province of Samut Prakarn and other areas of the Bangkok metropolitan region, excessive ground water pumping, to supplement pipe water has led to land subsidence of 5-10 centimetres per year, affecting established on 1 June 1990. The Terms of Reference of the Centre are herewith attached as annex I. The operational procedures, systems and formats, supporting the banking of bathymetric data at the Centre, have yet to be established by the NGDC.

In order to be successful, it is important that all echo-sounding data collected by all survey and research vessels operated by national and commercial organizations should be forwarded to the IHO Data Centre for Digital Bathymetry, either directly to the NGDC at Boulder, or via the VHOs. It is also desirable that bathymetric data should be collected as a matter of routine during all oceanographic cruises.

It should be noted that provision of digital bathymetric data to all IHO member States is free of charge (annex I, para. (2)), regardless of the amount of data which they may have individually contributed, provided their request is made through the IHB. Other potential customers may order data directly from the NGDC.

For information, the total number of individual soundings (greater than 100 metres) in the data bank have now exceeded 20 million.

### ANNEX I

**Services to be provided by the IHO data for digital bathymetry**

Services to be provided by the United States National Geophysical Data Center (NGDC) on behalf of the IHO will include, but not be limited to:

1. Operation of the data Centre with a focus of activity on oceanic regions with depths greater than 100 metres.

2. Provision, free of charge, to IHO for use by its member States, the data needed for their national or international projects. The IHO member States will submit their requests for data through the International Hydrographic Bureau (IHB). IHO member States' Hydrographic Offices (HOs) will provide the Centre with digital bathymetric data collected by their nations' institutions in oceanic regions.

3. Maintenance of a quality control facility whereby data provided to the Centre are subjected to at least simple checks for violation of physical principles (instantaneous changes in position, impossibly high ship speeds etc.) and completeness of labelling, referring detected obvious errors back to suppliers of data for possible correction. Member states' Hydrographic Offices may be requested to assist in resolving matters of quality control concerning data originated by their nation's organizations.

4. Maintenance of inventories in digital form of all digital bathymetric data, including digital contour data, and production of an annually updated catalogue of recently acquired bathymetric data. The Centre will provide the catalogue to the IHB in a form analogous to the present IHO publication BP-0004.

5. Maintenance of trackline catalogues of newly collected data to be provided upon the request of an IHO Volunteering Hydrographic Office (VHO) on behalf of its area of GEBCO responsibility.

6. Collaboration with various international organizations in the development of exchange formats and standards to expedite bathymetric data exchange, including digital bathymetric contours.

## (c) *Land information systems*

## A STRATEGY FOR DESIGNING AN INTEGRATED LAND INFORMATION SYSTEM FOR A LARGE THIRD WORLD CITY: THE BANGKOK LAND INFORMATION SYSTEM PROJECT

*Paper submitted by Australia*


### RÉSUMÉ

Les organisations internationales d'assistance et de prêt dans le monde admettent de plus en plus qu'il faut améliorer le fonctionnement et la gestion des villes du tiers monde, qui sont bien souvent les moteurs économiques du pays. L'un des outils essentiels à cet effet est la gestion de l'information foncière, même si les méthodes employées par les pays développés ne s'appliquent pas nécessairement au tiers monde. Dans ce document, on présente une manière importante et novatrice de mettre en place un système d'information foncière pour la ville de Bangkok, une ville débordante d'activité et en expansion rapide, qui compte environ 8 millions d'habitants. Le Projet de système d'information foncière de Bangkok est le fruit d'une coopération entre cinq grandes administrations de la ville. Cette coopération est en soi un exemple quasi unique. On présente le déroulement et la stratégie du projet biennal, en soulignant certains de ses premiers enseignements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There is increasing recognition that cities are the economic engines of the third world. For example, approximately 60 per cent of the gross national product (GNP) of developing countries comes from urban areas, even though these areas contain only about one third of the total population in such countries. Also, about 80 per cent of the growth of GNP of developing countries is in urban areas. Over the past three or four decades, urbanization in the third world has increased from less than 300 million of population to about 1.3 billion today. In 1989 the urban population in developing countries will increase by some 45-50 million as compared to 7-8 million in developed countries.

Despite progress in some areas, the urban environment continues to deteriorate in most developing countries. One evidence of this is the rapid expansion of informal settlements with poor infrastructure facilities and dilapidated

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integration of spatial data with natural resource databases in geographic information systems (GIS).

In the area of GIS, both agencies pay attention to the future direction and future challenge of the joint effort. USGS is making considerable effort to explore innovative GIS applications of spatial databases, and also is continuing to expand the contents of the 1:100,000-scale digital database by adding Public Land Survey System, boundaries, and hypsography digital data. The 1:100,000-scale base categories of digital data are especially well suited for regionally based applications such as mineral resource analyses, hydrologic analysis, and regional planning, within a GIS environment. The addition of Census Bureau information in the 1990s will allow spatial analysis of vast amounts of socio-economic data and may serve as a catalyst for the widespread use of GIS technology in the United States.

### CONCLUSION

The United States Geological Survey and the Census Bureau reached a major milestone with the completion of their cooperative project to develop a 1:100,000-scale transportation and hydrography digital database for the United States. Reaching this milestone provides the map user community with a significant new product: 1:100,000-scale digital data for the roads, hydrography, railroads and miscellaneous transportation features shown on the printed 1:100,000-scale maps. The nationwide digital data coverage at this scale combines the qualities of sufficient detail, and adequate content, that can serve as a framework for use in geographic information systems. The compatibility of census data with USGS digital cartographic data can only offer increased benefit to all federal, state, local, and private users.

## IHO DATA CENTRE FOR DIGITAL BATHYMETRY*

*Paper submitted by the International Hydrographic Bureau*


### RÉSUMÉ

La première édition de la carte bathymétrique générale des océans, publiée en 1903 à l'initiative du prince Albert I[er] de Monaco, a été suivie de quatre autres éditions, la plus récente (la cinquième) ayant été publiée en 1982.

Les données bathymétriques qui ont servi de base à la compilation des planches de la carte générale ont été collationnées manuellement par le Bureau hydrographique international (BHI) à Monaco, de 1930 à 1965, date à laquelle il a fallu, en raison de l'accroissement du volume de travail, répartir cette tâche entre un certain nombre de bureaux hydrographiques qui ont accepté d'y participer.

Dès le début des années 80, avec l'augmentation des données numériques fournies par les spécialistes des sciences de la Terre, on a compris qu'il fallait créer un centre international qui regrouperait les données de bathymétrie numériques. Les Etats-Unis d'Amérique ayant proposé d'abriter ce centre au Centre national de données géophysiques de Boulder, dans l'Etat du Colorado, il a été décidé, à l'issue de consultations avec les Etats membres de l'Organisation hydrographique internationale, d'accepter cette proposition et d'y créer officiellement le Centre de données de bathymétrie numériques de l'OHI le 1[er] juin 1990.


The General Bathymetric Chart of the Oceans (GEBCO) traces its origin back to the early twentieth century, when Prince Albert I of Monaco offered to organize and finance the production of a world-wide bathymetric chart series, at scale 1:10 million. Several editions have been issued since the first was completed in 1903; the last (and fifth) edition was completed in 1982.

Bathymetric data were collated on plotting sheets at scale 1:1,000,000, by the International Hydrographic Bureau (IHB) at Monaco from 1930 until 1965, when the task was shared between a number of IHO volunteering hydrographic offices (VHOs), which are still responsible for recording all available oceanic soundings.

These bathymetric plotting sheets now form a unique database, upon which most ocean bathymetric charts rely heavily. Copies of the plotting sheets are available for purchase from the VHOs concerned. Allocation of the plotting sheets among the VHOs is indicated in the IOC/IHO publication *GEBCO Catalogue of Bathymetric Plotting Sheets* (BP-0002). For the Indian and West Pacific Ocean areas, the VHOs concerned are Australia, India, Indonesia, Japan, the Philippines and New Zealand.

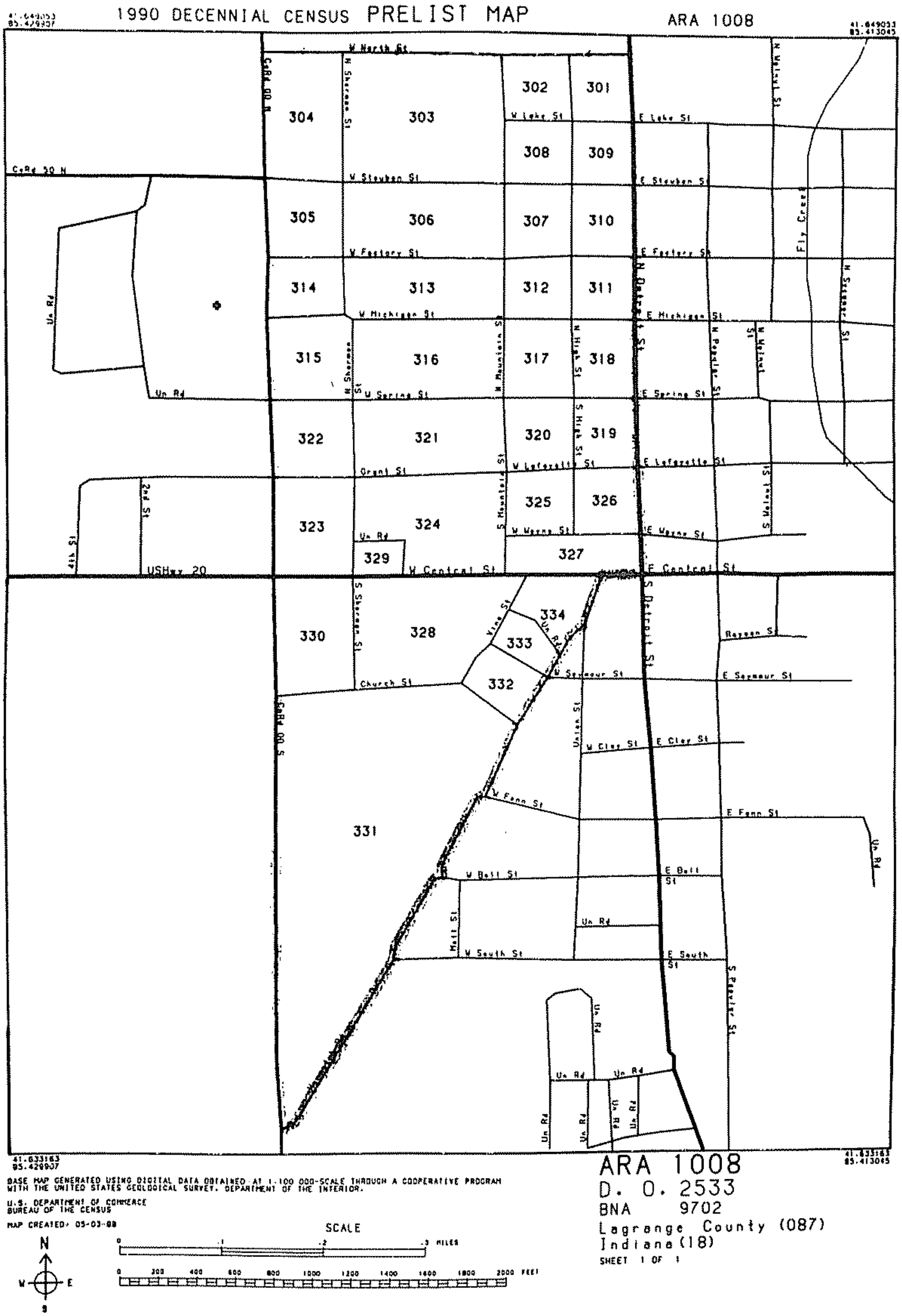
In 1984, at a meeting of the IOC/IHO Subcommittee on Digital Bathymetry, the need to set up an International Data Centre for Digital Bathymetry while still maintaining the existing VHO network, was emphasized, in view of the problems of managing the increased flow of digital data between more numerous customers, including the geoscientific community.

Consequently, in 1986, at a meeting of the Joint IOC/IHO GEBCO Officers, the National Oceanic and Atmospheric Administration (NOAA) of the United States of America, with considerable experience in handling marine geological and geophysical digital data at its National Geophysical Data Center (NGDC) at Boulder, Colorado, volunteered to establish within the NGDC, an IHO Data Centre for Digital Bathymetry. This proposal was also discussed at the 1987 International Hydrographic Conference, which decided to forward it to the IHB for further clarification.

The NOAA/NGDC proposal was discussed and finalized by correspondence between the IHO member States and an agreement was eventually reached in 1990 between all the parties. The IHO Data Centre for Digital Bathymetry was

*The original text of this paper appeared as document E/CONF.83/L.6.

**Figure I. 1990 Decennial Census prelist map**



Indian reservations. The computer assigns the 1990 census block numbers to all blocks in the country based upon an algorithm that uses the feature class code of the bounding line segments and the size of the polygons.

7. Finally, to tabulate and present the results of the 1990 decennial census, the Census Bureau added the 1990 geographic area boundaries and identification codes for statistical areas such as Census Designated Places, and Census County Divisions. The Census Bureau also corrected the political boundaries in the TIGER file to represent the 1 January 1990 Boundary and Annexation Survey (BAS). The Census Bureau conducts the BAS annually, and beginning with the 1988 BAS, sent local governments a map of their governmental unit plotted from the TIGER file. The local officials used this in reviewing their boundaries and for showing the new boundaries caused by annexations or detachments.

In October 1987, the Census Bureau began the production of over 250,000 individual map sheets for the approximately 82,000 enumeration areas (block groups) from which the Census Bureau field staff created address lists for use by enumerators performing preliminary field-work during the summers of 1988 and 1989. These maps were plotted on electrostatic plotters. (A sample section from an enumerator assignment map produced from the TIGER file appears as figure I.) The Census Bureau prepared these map products using a totally automated production system that determines the scale of each map based upon the features to be displayed for the particular area. This mapping software also automatically determines when to produce "inset" sheets for areas of congested street pattern; places all of the text (street, river and railroad names) and all of the geographic area codes (such as the block numbers) in the appropriate polygons. When necessary, the mapping software determines if a feature name needs to be displayed more than once, or if any census block needs "fishhooks" (a line connecting two blocks indicating that the adjacent block has the same block number); it displays landmark symbols, and generates related marginal text, including map identification numbers, a map sheet index (if required), state and county names and codes, and a bar code representing the map identification information in machine-readable form.

The Census Bureau estimates that before the 1990 census is over, it will produce over 2 million individual map sheets on their electrostatic plotters. All of these maps will be plotted without manual intervention. The only human involvement is the submittal of the computer processing runs; the mounting of tapes on the computers and electrostatic plotters, and cutting the map sheets as they come from the plotter.

## Availability and distribution of data

On 4 August 1987, the two agencies announced plans for the cooperative promotion of their products resulting from this project at the annual meeting of the Urban and Regional Information Systems Association. These products, known as United States GeoData (for DLGs) and TIGER data respectively, can be ordered from either agency. Both agencies have information regarding the complete set of products available from this effort.

The Census Bureau completed release, in April 1989, of the first public product from the TIGER database—the TIGER/Line file. This product is being made available in four versions: Prototype (available April 1989), Precensus (available February 1990), with Initial Voting District Codes (available October 1990), and the 1990 Census (available beginning in January 1991 with the last files released by the end of March 1991). The price for these files is based on the number of counties purchased at one time within a single state; the price varies with the version of the TIGER/Line file. The Precensus TIGER/Line file is $200 for the first county in a state and $25 for each additional county in the state ordered at the same time.

The Census Bureau expects to release additional extracts from the TIGER file in 1991 after the completion of the census. These additional extracts will include the TIGER/Database, an extract file that will contain the most complete set of releasable geographic and cartographic data possible in standard interchange format; TIGER/Comparability, an extract file that will contain records that equate 1980 census tracts to 1990 census tracts; TIGER/Boundary, extract files that contain coordinate data for several specific boundary sets such as county and census tract boundaries; and TIGER/GICS, a file providing the name and some related status codes for each geographic area for which the Census Bureau tabulated data in the 1990 census.

On July 15, 1986, USGS began distribution of United States GeoData (DLGs) from 1:100,000-scale maps. All the transportation and hydrography digital data collected from 1,823 1:100,000-scale quadrangles are available through the USGS NDCDB. The 1:100,000-scale DLGs are topologically structured, attribute coded, and available in standard DLG format (has an internal file coordinate system) or optional DLG format (has already been converted to UTM coordinates). Data on transportation and hydrography are presently distributed in two packaged versions. In the first (preliminary) version, the 7.5-minute files (except for railroad, pipelines, and power lines, which were digitized and are distributed as 30-minute files) are not edge-matched but are made available for each 30 × 30-minute area of coverage (east or west halves of the 1:100,000-scale maps). For each 30-minute block, the two categories of data—hydrography and transportation—are sold separately. All hydrography (flowing water, standing water, wetlands) data is contained in one file; transportation data is contained in three separate files: roads and trails; railroads; and pipelines, transmission lines, and airports. For the second (final) distribution version, the aforementioned 7.5-minute files have been processed through panelling, partitioning and edge-matching software and are produced and distributed as four 15 × 15-minute files for each 30 × 30-minute block, except in high-density areas, where the 15-minute file size precludes the joining of the 7.5-minute files. The process of repackaging results also in a 30 × 30-minute unit of railroads or miscellaneous transportation data being partitioned into four 15 × 15-minute data files. As data sets are paneled and partitioned into 15-minute blocks, they are replacing those 1:100,000-scale 7.5-minute files currently in the NDCDB. This panelling and partitioning process is complete for 60 per cent of the 1:100,000-scale files. The price for each 30 × 30-minute area of coverage is dependent upon the total number of 30-minute block units purchased. If six or more units are being purchased, the cost is a base charge of $90 plus $7 for each additional sales unit.

## Applications/Future directions

The USGS and the Census Bureau serve rather different markets. The Census Bureau serves customers interested in portraying political and statistical areas, producing thematic maps based on 1990 census information, performing density calculations, and undertaking other related statistical data analysis. The USGS serves customers needing base map digital data and those customers who perform automated integrated the four resulting data files to create a single topological file in a preliminary TIGER structure. After successfully passing this final check, the 1:100,000-scale digital data were archived by USGS for sale to the public through the National Digital Cartographic Data Base (NDCDB).

*Problems related to file production*

The project was not without problems. Just ironing out the logistics associated with the transfer of data and materials between the two agencies, and even within each agency, created some complex and sensitive situations. In addition to the general problems associated with expediting the production of the 1:100,000-scale graphics, there were numerous technical problems that arose in establishing a digitizing, editing, and processing routine to convert these graphics into digital form. These issues can be grouped into two primary areas: data problems and quality-control procedures. The area of data problems includes four categories:

(*a*) *System implementation*: problems introduced due to techniques and software development during the initial stage of the project, and primarily involving the development and adaptation of software for utilization on different versions of the same equipment;

(*b*) *Data processing*: problems introduced due to clerical errors and miskeying of input data;

(*c*) *Interpretation*: problems introduced due to operator misunderstanding of attribute coding standards or map symbology;

(*d*) *Geometric*: problems introduced by system digitizing and processing routines and resulting in the automatic generation of extraneous lines and gaps in line segments.

The first three categories were short-term problems that eventually disappeared with increasing experience of personnel and stabilization of the production process. The fourth category, geometric problems, was the area where the most effort was expended for resolution. New software had to be developed and procedural changes in both agencies were required. In some instances, completed data sets had to be reprocessed and reverified.

Since 1:100,000-scale digital data comprised a new product, the establishment of quality-control procedures was essential to ensure that the final product met not only the needs of the Census Bureau but also USGS standards for entry in the DCDB. Several procedures were adopted to minimize the potential for occurrence of errors in data. The most significant was the implementation of a criterion for verification and acceptance of corrected and tagged road data. Quality-control procedures included a recheck for all attribute codes for randomly selected sections of a 1:100,000-scale quad; the use of topology-verification software routines; visual inspection of plots to check the digital data against the graphic; and a final delivery acceptance/check of each data set (hydrography and transportation) performed by the Census Bureau through a process called horizontal and vertical integration of the data.

## Census Bureau use of the digital data

The Census Bureau is using the digital data from this cooperative project as the "heart" of a bold new system to modernize its cartographic and geographic processes. This new database, called the TIGER system, will support the Census Bureau's future demographic and economic data collection, processing, and tabulation activities, beginning with the 1990 decennial census. To use the 1:100,000-scale digital data for this purpose, the Census Bureau enhanced and reformatted the USGS DLG data to support its field and processing operations. This involved completing seven major tasks:

1. The Census Bureau's Geography Division vertically integrated the four separate data categories for each 1:100,000-scale map in an automated process that determines where the hydrographic, railroad, and miscellaneous transportation features intersect the road features and each other. This process results in a single topological database where a Census Bureau feature class code identifies each line and a numeric code identifies each area enclosed by a set of lines.

2. While the process of building the digital file was under way, the Census Bureau's 12 regional office geographic staffs compiled map update information on 1:24,000-scale USGS map sheets using sources gathered from local government officials. These new features included roads, railroads, and hydrographic features. Appended to each feature, both old and new, was a key number that represented the name of the feature where the geographic staff could determine the name. Where multiple names were known, one name was designated as the primary name and all others were designated as alternates.

3. The Census Bureau created individual 7.5-minute files from the topological database for use on their standalone microcomputers in four field digitizing sites (FDS) in Boston, Atlanta, Dallas, and Denver. The data were downloaded from the Sperry mainframe computer to 8-inch floppy disks for use in the Tektronix-4125 microcomputer graphic workstations. The FDS staff updated the digital file based upon the information posted to the 1:24,000-scale maps; this update included the new features and feature names. A total of 60 Tektronix 4125 microcomputer graphic workstations were used for this work. The updated files were returned on 8-inch floppy disks to the Geography Division where the files were uploaded to the Sperry for further processing.

4. Staff in the Census Bureau's Data Preparation Division in Jeffersonville, Indiana, annotated maps, primarily using USGS quadrangles, showing the 1980 census geographic area boundaries. The geographic area boundaries and codes shown on these maps were entered by Census Bureau staff, using an additional 20 Tektronix 4125 microcomputer graphic workstations, in Jeffersonville, Suitland, and the four field digitizing sites into the growing preliminary TIGER database. Again, the file transfer between these sites and the Sperry computer was by 8-inch floppy disk.

5. Once the 1980 census geographic area codes were in the preliminary TIGER database, the separate 7.5-minute files were horizontally integrated. During this step, all of the 7.5-minute "cells" that comprise a county are put together into a single file and all lines that cross a cell boundary are edge-matched. Once the horizontal integration is complete, the county file is created by "trimming" away all of the polygons that are outside the county. The outer edge of this file is now fixed for the duration of the census to ensure that adjacent files exactly match.

6. Using copies of maps produced from the county files, the geographic staff in the Census Bureau's 12 regional offices annotated the 1990 census "collection" geographic area boundaries delineated by local statistical area committees and state agencies. Staff in the Geography Division and the Boston and Denver FDS's added these additional geographic area codes to the database for use in collecting 1990 census data. These geographic areas include census tracts and block numbering areas, block groups, and American

### *Florida pilot project*

In early 1983, a cooperative digital pilot project was begun to collect and process the transportation and hydrographic data shown on the 48 1:100,000-scale maps that cover the State of Florida. The purpose of the project was to enable the USGS to develop and test new production procedures and software, to incorporate the Scitex response scanning and editing system into its current digital production system, and to enable the Census Bureau to develop the necessary software and production procedures to encode and structure data for incorporation into the National Digital Cartographic Data Base (NDCDB). This pilot project was designed with: (*a*) USGS performing the initial collection and processing of all transportation and hydrographic information using the Scitex system; (*b*) the Census Bureau performing all attribute coding and structure of the roads data; (*c*) the USGS performing all the attribute coding and structuring of the hydrographic and other transportation data; and (*d*) the USGS performing final data verification, testing and storing of the information. Each phase of this project provided valuable insight on data gathering and processing procedures. It also provided data sets for evaluation and testing by both agencies.

### *The official start*

The results of this pilot project led to the commitment by both agencies, through an agreement signed in December 1983, for completion of a conterminous United States 1:100,000-scale transportation and hydrography digital database by mid-1987. To meet the deadline, both agencies proceeded with the implementation of complementary 1:100,000-scale digital production systems. The data digitized to build this database were all the transportation (roads, railroads, powerlines, pipelines and airports) and hydrographic (streams, rivers, water bodies) features shown on the 1,823 1:100,000-scale quadrangles covering the conterminous United States.

## PRODUCTION SYSTEMS:AGENCY RESPONSIBILITIES

The production procedures and software that were developed as a result of the cooperative pilot project for the State of Florida have been described in considerable detail in other papers. The following paragraphs summarize the production process during the project, which improved the quality of the data and resulted in efficiencies in the data collection procedures.

### *Base map operations*

The fundamental graphic product required for digital data collection was the USGS 1:100,000-scale map series. The framework and content of the 1:100,000-scale base map is derived primarily from 1:24,000-scale maps, with updates during the production process. This production process generally has the following phases: (*a*) reducing larger scale maps to 1:100,000-scale and mosaicking on the Universal Transverse Mercator (UTM) projection; (*b*) updating the mosaicked base; (*c*) scribing the planimetric feature separate manuscripts; (*d*) scribing the contour manuscript; and (*e*) printing the complete topographic edition.

Since the 1:100,000-scale mapping programme began in 1976, the map series has been predominately topographic contour editions. When the cooperative digital project began in December 1983, only 960 of the required 1,823 maps were available for digitizing. In order to ensure that the remaining base maps were available for digitizing, emphasis was shifted from preparing topographic editions to producing planimetric bases without contours. This compilation change coupled with increased personnel resources enabled conterminous United States coverage to be achieved in October 1986, 5 years ahead of the original mapping goal.

### *Digital operations*

As mentioned previously, in order to meet the mid-1987 deadline, complementary high-volume digital production systems were established in each agency. The USGS had dedicated to this project effort 2 Scitex scanners; 15 Scitex R-280 editing stations; 26 Intergraph Interactive editing/tagging stations; 13 Altek digitizing tables; and 4 Gould 9780 minicomputers. This equipment was dispersed among four regional mapping centres: Eastern Mapping Center in Reston, Virginia; Mid-Continent Mapping Center in Rolla, Missouri; Rocky Mountain Mapping Center in Denver, Colorado; and Western Mapping Center in Menlo Park, California. The Census Bureau employed the use of a Sperry 1100/74 and subsequently a Sperry 1100/92 mainframe computer. Connected to these computers were 18 Tektronix 4115 computer graphic terminals (later upgraded to Tektronix 4125 terminals) located at the Census Bureau in Suitland, Maryland, and an additional 8 Tektronix 4115/4125 terminals located in the Census Bureau's Boston Field Digitizing Site.

Each agency staffed most of this equipment in three 8-hour shift operations per day. The USGS was responsible for digitizing all transportation and hydrographic features and assigning feature classification codes to all data except roads; the Census Bureau was responsible for assigning feature classification codes to the road data.

Two basic production procedures were used by USGS to capture the data: manual digitizing and automated scanning techniques. Owing to lack of density, the miscellaneous transportation data (pipelines, powerlines, airports etc.) were digitized using manual line-following techniques, subjected to both manual and computer editing, processed through topologic structuring software, and archived. The hydrography and road files were typically much more dense and complex. They were, therefore, scanned by machine; edited via both batch and interactive procedures; and through software, converted from raster to vector data. At this point the hydrography and roads categories took two separate processing paths. The hydrography data were tagged with appropriate attribute codes and further edited using interactive graphic systems by the USGS. The road data were sent to Census for attribute tagging geometric corrections, and then returned to USGS for review and acceptance.

Following the completion of the editing and tagging operation, both data sets were processed through the Unified Cartographic Line Graph Encoding System (UCLGES) or, more recently, the DLG Production System (PROSYS) software resident in each production centre. These systems perform all final data structuring and verification of digital line graph (DLG) files. Both systems also perform several logical checks to verify topology and the proper use of attribute codes. Errors were corrected either through batch editing routines or the data sets were returned to the producer (USGS or Census Bureau) for correction. When a file was completely verified, the files were archived and prepared for delivery to the Census Bureau.

At this juncture, both categories for each 30 × 60-minute quadrangle were delivered on tape to the Census Bureau where a final check was conducted to ensure that both categories were internally consistent. This check was accomplished using software that first horizontally integrated the individual 7.5-minute quadrangle data files that comprised each 30 × 60-minute quadrangle, and then vertically

## A COOPERATIVE DIGITAL MAPPING PROJECT: A UNIQUE SUCCESS STORY*

*Paper submitted by the United States of America*


### RÉSUMÉ

Entre décembre 1983 et juin 1987, le Geological Survey et le Bureau of the Census (Census Bureau) des Etats-Unis d'Amérique ont collaboré à l'établissement d'une base de données numériques au 1/100 000 concernant les transports et l'hydrographie. L'ampleur de la tâche consistant à convertir en données numériques les informations relatives aux transports et à l'hydrographie contenues dans les 1 823 feuilles au 1/100 000 et les brefs délais impartis pour réaliser cette entreprise ont obligé ces deux institutions à mettre au point et à appliquer des systèmes de production de pointe. Les fichiers de données numériques au 1/100 000 ainsi établis font désormais partie de la National Digital Cartographic Data Base (NDCDB), tenue à jour par le Geological Survey. Ce dernier les diffuse sous le nom de USGeoData et sous forme de courbes numériques au 1/100 000. Les données relatives aux transports et à l'hydrographie sont diffusées par blocs de 30' × 30' qui correspondent aux moitiés orientales ou occidentales des cartes au 1/100 000. Les données sont structurées sur le plan topologique, comportent des caractéristiques codées et sont disponibles sous forme classique ou numérique. Du fait que les courbes numériques au 1/100 000 sont topologiquement structurées et que les interconnexions entre les caractéristiques sont codées, les données peuvent servir à des applications spatiales d'ordre général, au calcul statistique ou aux tabulations.

Le Census Bureau se sert des données numériques au 1/100 000 relatives aux transports et à l'hydrographie comme base cartographique pour l'établissement du système TIGER (Topologically integrated geographic encoding and referencing system), qui couvre non seulement les Etats-Unis mais aussi Porto Rico, les îles Vierges et certaines régions périphériques du Pacifique. Le Census Bureau a ajouté des informations complémentaires telles que noms de lieu, frontières politiques, découpages aux fins du recensement et codes, qui permettront d'utiliser les fichiers du système TIGER pour la série de recensements des années 90 et pour des enquêtes économiques ultérieures. Pour la seule série de recensement des années 90, le Census Bureau produira plus de 2 millions de feuilles cartographiques à partir de ces données.

L'entreprise menée conjointement par le Geological Survey et le Census Bureau est d'une importance économique capitale. La base de données cartographiques numériques au 1/100 000, du fait même qu'elle est suffisamment détaillée, que le contenu en est adéquat et qu'elle couvre l'ensemble du pays, favorisera le recours plus fréquent aux méthodes d'analyse spatiale. Ainsi, après 1990, les données communiquées par le Census Bureau à partir des informations recueillies lors de la série de recensements des années 90 peuvent être reliées à des caractéristiques de la base de données au 1/100 000. Les centres d'information du Geological Survey et du Census Bureau sont chargés de diffuser l'ensemble de ces données. La compatibilité des données recueillies lors du recensement et de la base de données cartographiques numériques du Geological Survey ne peut qu'être avantageuse pour tous les utilisateurs (administration fédérale, Etats et administrations locales et secteur privé).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### THE BEGINNING

#### *Initial test project*

The need for a digital cartographic base as the "heart" of the full range of cartographic and geographic support processes necessary to serve the data collection, tabulation, and dissemination needs of the 1990 decennial census, led the Bureau of the Census to begin discussions with the United States Geological Survey (USGS). These discussions led to the formation of an interagency task force and initiation of test projects to determine the feasibility of building the required digital database.

With the formation of the interagency task force in 1981, USGS and the Census Bureau wanted to answer the question of comparability between a digital cartographic file based upon digitizing the 1:24,000-scale map sheets and a digital cartographic file based upon the 1:100,000 map sheet. Two 1:100,000-scale map sheets were selected for the test: the USGS raster-scanned the map sheets and created vector files, and the Census Bureau manually digitized the corresponding 1:24,000-scale map sheets using its Intergraph equipment. The USGS provided the 1:100,000-scale vector file to the Census Bureau which then plotted the data from the two separate files in different colours at the 1:24,000 scale. This test showed that the 1:100,000-scale data compared favourably at 1:24,000 scale and could be further enlarged and used to produce maps for enumerator use.

This test answered only the first question—that data digitally captured from the 1:100,000-scale maps could be used to produce an acceptable large-scale map. The remaining question was whether the USGS and the Census Bureau could undertake this process for the entire nation. The two agencies decided to undertake a pilot project to answer this second question.

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probably require about the same amount of time to digitize as the RVMs. With few overlays, small in size, and limited in complexity and coverage, they could be completely photoscribed and reviewed every 56 days. Their short revision cycle takes full advantage of the automated flow of update information from the CDB. The cost benefits from automation of the IAPs may even prove greater than those shown for the RVM series because of the greater frequency of revision and greater degree of automated compilation that will be introduced for the IAPs.

Development of automated cartographic production, beginning with the conversion of the IAP Chart Series, will be a cooperative endeavour involving the efforts of both cartographers and computer specialists. Once established, IACS will not eliminate the role of the cartographer from the compilation process. Instead, that role will expand to include new responsibilities in the operation and monitoring of the system.

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## Glossary of terms

*Analog*: Representing data by physical quantities. For example, the geographic distance between two locations is represented as a scaled analog distance on a map

*Basemap*: The collection of photographic, engraved or digital/feature overlays that are used to create the photographic plates for lithographic reproduction of a map.

*Batch processing*: Computer processing occurring independently of any current session at the computer terminal—a background job.

*Chart*: A map used in navigation

*Compilation*: The process of assembling, organizing, and laying out data to create or revise a map, or the layout manuscript itself

*Compiler*: The cartographer who makes a compilation.

*Database*: A collection of data organized for retrieval as useful information

*Digital*: Defined by numerical units. For example, computer data is defined by binary (0's and 1's) digital data

*Digitize*: To convert to digital form. For example, at a graphics workstation, an analog map can be converted into a digital file

*Enroute chart*: Aeronautical chart that is used by pilots to navigate with information obtained from instrument readings and radio contact

*Expert system*: A computer system that makes complicated decisions to resolve certain problems based on logic developed by human experts.

*Feature*: A man-made or natural phenomenon depicted on a map. For example, the prescribed flight path between two cities is an aeronautical feature, while the cities themselves are topographic features

*File*: An organization of digital data created by and accessed by a computer

*Graphics workstation*: A type of computer terminal that allows digital data to be created, modified, and displayed as visual patterns. The techniques used to create or modify the digital graphic display appear to the user to be similar to manual graphic techniques

*Instrument Approach Procedure chart*: Aeronautical chart that is used by pilots making an approach to landing based on instrument readings and radio contact.

*Interactive processing*: Computer processing that requires connection of the user to a computer through a session at a terminal

*Laser-plotter*: A plotter that uses a laser beam to expose a photographic negative

*Overlay*: The collection of all map features of a similar type on a sheet of semi-transparent plastic film, or the collection of all such features on a transparent, electronic, digital display. The set of layered plastic film sheets or digital displays for all the features shown on the map is the "basemap".

*Photo-plotter*: A plotter that uses a light beam to expose a photographic negative

*Photoscribe*: To expose a photographic negative using a laser-plotter or photo-plotter

*Plot*: To use a file of digital information as input to a plotter to produce lines on paper, photographic negatives, or other material

*Plotter*: The output device that translates a digital graphics file into a visual design on paper or other material

*Processor*: A computer

*Relational database*: A type of digital database that depends on existing similarities of data to find relationships between different subsets of the data

*Scribing*: Engraving of lines on a coated sheet of plastic film

*Sectional chart*: Aeronautical chart used by pilots navigating by topographic landmarks

*Stick-up*: Attaching pre-printed symbols, lines, and text to feature overlay sheets

*Symbol*: A graphic design used to represent a feature on a map

*Symbolize*: To represent a feature on a map using a symbol

*Terminal area chart*: Aeronautical chart covering the geographic area of an airport terminal, similar to a Sectional chart but larger in scale

*Topographic*: Pertaining to the configuration of a surface, such as the surface of the Earth

The NCB will maintain two databases. The Nautical Information Data Base, a general purpose database, will be used to derive and maintain the separate Chart Graphics Data Base (Smith, 1988, p. 1374).

A private, commercial organization, Jeppesen Sanderson, Inc., has used Intergraph systems in its production of IAPs and Enroute charts for several years. Its current software system, now providing many automated capabilities, will soon be superseded by Intergraph's recently developed, third generation aeronautical charting product, Intergraph Aeronautical Charting System—IACS (Kelly, 1990). The production process now, as demonstrated in their promotional videotape (Jeppesen Sanderson, Inc.), involves the transfer of updated aeronautical information from a general purpose database maintained on a VAX 11/750 to an Intergraph processing system dedicated to the maintenance of the digital charts. Updates applying to each chart are interactively validated or rejected by compilers at workstations connected to the Intergraph processor. The compilers interpret the update status of each chart feature on the basis of its displayed colour, with red indicating deletion from the database, yellow indicating a change, etc. Once all database generated revisions have been either validated, modified, or rejected, a hardcopy, electrostatic print is made of the workstation display on a Versatec V80 plotter and given to another compiler for quality-control review. Finally, a copy of the digital chart is put on magnetic tape and transferred to a Scitex laser-plotter system, which uses the digital chart to produce high-resolution film positives or negatives suitable for reproduction.

To achieve its automation goals as efficiently as possible, ACB also plans to install IACS, which uses existing hardware and software, including Ingres, WMS and IGDS. Ingres has already been installed for other purposes and is being developed to provide a general aeronautical information database, similar to CONDOR but more powerful and flexible. This database will remain distinct from the cartographic database but eventually may be used to update it. With Ingres, IGDS, and WMS software currently operational, no great financial outlay will be required to provide the initial environment in which to develop prototype applications of IACS.

ACB's cartographers have already used WMS and IGDS software at the workstations and will be familiar with these components of the IACS system. They will not have had experience with Ingres, the relational database that constitutes the third component of the IACS system. Intergraph, however, has designed a user-friendly, form-driven menu to the Ingres cartographic database that will make it more accessible (Intergraph, 1989, 1:7-9).

Initially, both the features depicted in the charts and the specifications defining each chart will need to be established in the cartographic database. The Aeronautical Chart Automation Section cartographers and computer specialists will work closely with cartographers in other sections to accomplish this. Much feature data in the charts may need to be digitized manually in the WMS environment. Other feature data used to populate the database may be derived from existing CONDOR files. Chart specifications will need to be entered interactively through IACS's forms-driven interface to Ingres.

After the CDB has been populated, the cartographer will be able to generate charts from it and maintain digital charts previously generated. Beyond the need to define new chart specifications, there will be little difference between the procedures for creating a new chart or for maintaining an existing chart with IACS (Intergraph, 1989, 6:1-11).

In maintaining a chart, the cartographer will receive an IACS generated report identifying any changes to it subsequent to any update of the CDB. Whenever the decision is made to compile these pending changes to the chart, the compiler activates IACS, identifying the chart and initiating the batch extraction of updated feature data to be applied to it from the CDB. On completion of the extraction process, the compiler initiates another IACS process to automatically symbolize the extracted feature data according to the specifications of the chart. The symbolized, updated data is then automatically incorporated into the digital chart. At the workstation, the cartographer makes final judgements on the disposition of any of the displayed pending changes. Here too, the cartographer's judgement must be exercised in cleaning up the chart to final standards.

IACS is not an "expert system". Such systems have not developed sufficiently to replace human skill and knowledge in the field of cartography (Gallant, 1987, p. 386). Many situations will arise requiring deletion, displacement, or other modification of features included automatically in the digital compilation. Considering the critical application for which the aeronautical chart product is designed, the need for human validation of changes propagated automatically will be of increased, not diminished, importance at ACB.

Chart series considered as candidates for IACS need to be evaluated for ease of original conversion and for adequacy of feature coverage in the general aeronautical database to be used to update the CDB. Since the demands placed on graphics workstations and photoscribing equipment will increase with the automation of more charts, the time required to produce charts of varying complexity using these limited resources must also be considered in the cost-effectiveness equation. The production of Radar Video Maps has already undergone partial automation. At some point, these maps may be considered candidates for IACS. Priority now, however, should be given to commercial charts produced on short, regular cycles. The cost-effectiveness of pipelining the flow of information from database to chart will be greater the more frequently and extensively the chart must be revised.

Sectional and Terminal Area Charts are revised every six months and are rich in topographic feature detail. The topographic features, derived primarily from the United States Geological Survey 7.5-minute quadrangle maps, are not supported by the aeronautical database, making the full automation of these series unlikely. In the future, however, it may prove feasible to maintain aeronautical feature overlays for these charts, using an automated system while continuing to maintain the topographic overlays of the basemaps manually (Tamm-Daniels, Cooper, and McCollough, 1985, p. 514).

The primary candidates for IACS automation are the Enroute and IAP charts. These chart series are maintained on 56-day cycles. Presentation of topographic feature data is extremely limited. The Enroute charts are the more complex charts, consisting of 20 or more feature overlays. The monochromatic IAP charts have only 3 overlays, cover smaller geographic areas, and are physically smaller (about 5 × 7 inches). Photoscribing new feature negatives and reviewing new chart prints for charts of the size and complexity of the Enroute charts will be time-consuming. To reduce demands on equipment and personnel, photoscribing of new negatives could be limited by continuing to make minor modifications to film overlays by hand after having first established these modifications in the digital map through IACS.

The charts that will most easily be adapted to IACS are the IAPs. In the initial conversion process, these charts will of the maps from analog to digital format, ACB has accomplished considerable automation of certain elements of the production process.

The first step toward automation was taken in 1987 with the decision to convert more than 2,000 radar video maps (RVMs) into digital format. The RVMs are not published but are produced as photonegatives, reduced, and ultimately projected on the video screens of airport surveillance radar equipment. Besides being atypical of ACB's chart products in form, they differ significantly in specification of their content and are unique in having only one feature negative. The specification of feature presentation on an RVM is not standard across the map series, but varies according to the needs of the particular air traffic control centre requesting the map. The area of chart coverage is limited and the presentation of features simplified, so that a cartographer familiar with the operation of the graphics workstation can digitize an existing RVM in 4 to 8 hours (Bolton and Hoover, 1989, p. 9).

In producing the digital maps, cartographers have predictably found the operation of the Intergraph workstations and the application of Intergraph's graphic software—Interactive Graphic Design System (IGDS) and World Mapping System (WMS)—straightforward: "a nearly direct translation of existing manual operations to the computer" (Calkins and Marble, 1987, p. 105). By letting cartographers create the RVM basemaps digitally, ACB has enabled automation of the production of the photonegative. The digital compilation has replaced both the hardcopy standard previously used to specify the engraving of the basemap, and the engraved basemap itself. The photonegative is now produced directly from the digital chart and is plotted on-site with a high-precision, Gerber photoplotter. The manual engraving procedure, with its lengthy turnaround time, has been completely eliminated, reducing the time required for revision or creation of an RVM from several weeks to a week or even days (Bolton and Hoover, 1987, p. 10).

Recently ACB has begun to widen its application of the Intergraph system to produce digital charts of greater complexity. Four new charts of the Enroute Low Chart Series have been created. The workstations, each with a capacity to represent 63 separate design file overlays, have easily managed the task of separating the features of the digital basemaps. As with the RVMs, the creation of the new Enroute Low Alaska charts was mostly accomplished interactively by cartographers at the workstations using computer-assisted methods analogous to manual techniques.

Because the products of the compilation process for these charts were themselves digital files, other digital files could often be directly incorporated into the compilation, bypassing the traditional manual transfer of information from hard-copy source documents (Thornburg, 1990). Geographic coordinates of features maintained in ACB's general aeronautical database, CONDOR, for example, were extracted into digital files in a separate process. At the workstation, using WMS, the cartographer was able to access these files directly and use them to place fully symbolized features in the digital maps. Although the Alaska Enroute charts were not, in fact, used to produce photographic feature overlays directly, the potential for doing so was clearly demonstrated (Thornburg, 1990).

ACB has used digital maps to eliminate the need to manually engrave or stick-up features on basemap overlays and even to make the compilation process itself more efficient. It now plans to establish a unified cartographic database from which dynamically linked digital charts can be derived and maintained and, thus, to achieve the full potential of cartographic automation (Bundock, 1987, pp. 294-295).

Considering ACB's collection of analog and digital basemaps as a "database" of map information, it is apparent that such a collection is far from unified. A feature occurring on more than one chart is represented more than once in the "database", and may be represented differently in each "database" occurrence. The same real, geographic feature, for example, appearing on both an Instrument Approach Procedure (IAP) chart and an Enroute chart may be shown on each chart at a different scale. Revision of the feature entails two separate basemap revisions, with each revision varying according to the scaled representation of the feature. The symbol for another feature, such as an airport, may be shown in blue or brown on an Enroute chart and in black on a Standard Terminal Arrival (STAR) chart. On a Sectional chart, the same airport feature may be shown by a different symbol entirely—again, necessitating more than one revision and more than one type of revision.

Developing a unified cartographic database (CDB), dynamically linked to the digital chart products derived from it, will help eliminate the problem of multiple revisions for a single feature. Any change, addition, or deletion to the CDB will automatically propagate from the database to the individual charts derived from the database on which the feature occurs. The revision of each feature occurrence will be in accordance with the defined specifications for scale and symbolization of the feature for the chart containing the occurrence.

These cartographic specifications, and others, will themselves be part of the CDB, and, by their inclusion in that database, will link the CDB to each of the digital charts. A CDB can be created using one of the commercially available database management systems (DBMS):

> "Many of the above problems can be solved using any one of a number of commercially available database management systems. Hence it is proposed that a DBMS be utilized to manage not only the geographic attribute data, but also the cartographic data. The data defining the cartographic entities to be displayed can be managed within a DBMS in much the same way as any other data." (Bundock, 1987, p. 295)

While the revision process will become more efficient with such a system, the design process will also become more flexible. New charts, at larger scales, representing portions of existing maps are sometimes required to relieve feature congestion in the smaller-scale existing maps. Projects such as the redesign of the H3 Northeast Enroute chart and creation of the H6 Eastcoast Enroute chart would be accomplished more easily and quickly since feature data would exist in the CDB "seamlessly", independently of any chart boundaries, and could be extracted to fit any chart configuration at any scale.

Other organizations attempting cartographic automation based on these principles include the Nautical Chart Branch of the National Ocean Survey, and Jeppesen Sanderson, Inc., a private aviation chart producer.

The Nautical Chart Branch is currently developing the prototype for its Automated Nautical Charting System (ANCS II). Intergraph Corporation is providing the Nautical Chart Branch with workstations, graphics software, and a cartographic database design based on the commercially available relational DBMS, Oracle (Poltivolo, 1990).

## IMPLEMENTING A CARTOGRAPHIC DATABASE TO ENABLE AUTOMATION*

*Paper submitted by the United States of America*


### RÉSUMÉ

L'Aeronautical Chart Branch (ACB) du National Ocean Service commence à automatiser la production de certaines de ses cartes. La transformation du processus de production est un effort continu dont le succès dépend de considérations humaines et de facteurs techniques. Actuellement, les techniques de production pour les produits de l'ACB vont des méthodes traditionnelles manuelles de compilation, de gravure et de composition sur film pelliculable à l'utilisation d'outils cartographiques automatisés à des degrés divers. Chaque série cartographique, avec son échelle standard, sa complexité de représentation, son cycle de révision et autres caractéristiques, constitue un défi dans le processus d'automatisation.

Le document décrit dans quelle mesure les activités de l'ACB sont automatisées et évalue la possibilité d'adopter des solutions d'automatisation encore plus poussées pour l'établissement de divers types de cartes. En utilisant une base de données cartographiques, en ayant recours à un système commercial de gestion de bases de données relationnelles, on peut accroître l'efficacité et la souplesse pour la production d'un grand nombre de cartes. Le document résume les notions qui définissent une base de données cartographiques et comment ces notions servent à résoudre les problèmes de redondance dans la révision des cartes, accroissent la souplesse pour la création de nouveaux produits et permettent le passage automatique d'informations cartographiques de la base de données aux produits cartographiques numériques.

Le document se termine par une brève présentation du fonctionnement d'une base de données cartographiques à vocation commerciale mise au point par la société Intergraph Corporation pour la production de cartes aéronautiques. Il décrit le logiciel du Intergraph Aeronautical Charting System que doit installer l'Aeronautical Chart Branch et présente un scénario de l'interaction entre le cartographe et le système, en mettant l'accent sur ses responsabilités accrues dans le contrôle du processus de compilation automatisé.


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As a result of four years of aggressive acquisition and development of new hardware and software systems, the Aeronautical Chart Branch (ACB) is ready to implement state-of-the-art cartographic automation. Expanding the use of the computer to assist its traditional cartographic compilation and production methods throughout this period of development, the ACB can now take the next step—linking its volatile databases of aeronautical information directly to the production of digital maps. By doing so, ACB will position itself to automate the physical production of feature negatives and many aspects of the compilation process itself. Benefits accruing to ACB from the automation of these processes would be significant.

Expediting the logistics of maintaining more than 8,000 charts, most subject to revision every 56 days, automation will permit less rigid scheduling and coordination. By eliminating the scribing or stick-up of feature overlays from the production cycle of many charts, automation will also eliminate much of the present dependence on contractor turnaround to complete the cycle. Beyond its cost-effectiveness, automation will serve ACB by enabling it to satisfy growing demands for cartographic digital interfaces from other organizations and from consumers.

Since the success of the automation depends on an understanding of what is being automated, the report will review the traditional, manual techniques currently being used. The report will then trace the initial progress already made toward automation and will describe what further steps remain to be taken to develop a more fully automated system. Methods being implemented by other cartographic organizations approaching automation will be presented to provide a sense of the state-of-the-art. Finally, the report will deal specifically with the Intergraph Aeronautical Charting System, the next phase in ACB's ongoing efforts to automate the production of aeronautical charts.

Cartographers now access numerous hard-copy source documents, including notices, reference manuals, and existing maps, in the process of compiling a chart. Some hard-copy source material is provided them by the Aeronautical Information Section in the form of computer generated listings, calculations, and schematic plots. Painstakingly, manually transferring feature information from these source documents, properly positioning and symbolizing it, the compiler creates a hard-copy "standard", the annotated map manuscript used by contract agency technicians to create or revise the stable plastic film feature overlays that the basemap comprises. Increasingly, as ACB has expanded its aeronautical information database, the cartographer has used feature data derived from its files as input to computer graphics programs that produce quality-control plots against which the manually compiled map standard may be checked. Only rarely, however, can a computer-generated plot be used to produce a feature negative directly.

The compiled map standards and the basemaps produced from these standards exist in purely physical form. Considering the collection of basemaps for all of ACB's published charts to represent a physical (or analog) "database" is useful. Such a "database," however, whether in digital or analog form, remains a discrete collection of maps. Having no unifying relationship between its components, it will not serve as a database of map information from which full automation can proceed. Nonetheless, by converting some

*The original text of this paper, prepared by Virginia G. Galvin, National Ocean Service, appeared as document E/CONF 83/L 29 analysing networks, and clustering and aggregation operations. These operations are ideally performed in an interactive mode on the spatial component of the data, as well as on non-spatial attribute data. Such operations can range in complexity from simple Boolean queries to reclassification and creation of new map displays.

The typical GIS has capabilities for display and product generation. Maps, charts, graphs, and tables can be produced, and displays can range in complexity from tabular reports and simple monochrome plots to publication-quality, three-dimensional colour graphics.

GIS hardware components can be divided into six major categories of devices: data capture/input, processing, communications/networking, interactive display and edit, external storage, and hard-copy output. These categories can be further divided into hundreds of hardware components used in an information processing system. Hardware components can be tested against a number of measures: performance (speed of the central processing unit, rate of graphics display), accuracy (precision of a digitizing table, resolution of a plotter), and capability (maximum plot size, disk storage size). The total specification of all aspects of GIS hardware is laborious and probably not required. Users should focus on aspects of hardware specifications that directly affect performance.

## Testing

Once users decide what to test, they must consider how to perform the testing. Do they test a specific function such as polygon overlay with or without sliver removal, or do they test a number of system components simultaneously? For example, the structured query language (SQL) statements that follow test a variety of system components including the ability to optimize queries, the effectiveness of indexes, and the performance of the spatial operator WITHIN. This series of statements asks the GIS to find all public schools located within areas of high radon concentration.

```
SELECT *
FROM BLDG
WHERE BLDG.LOC WITHIN RADON.POLY
  AND BLDG.LOC IN
    (SELECT BLDG.LOC
    FROM BLDG
    WHERE BLDG.TYPE = 'PUBLIC SCHOOL')
  AND RADON.POLY IN
    (SELECT RADON.POLY
    FROM RADON
    WHERE RADON.POT > 4.0)
```

Another factor to consider is accuracy. How do users know if the results are correct? One way is to test GIS functions with mathematically generated data sets for which correct answers are known. For example, two sets of concentric ellipses could be intersected as one test of the correctness of a polygon overlay operation.

Users must also remember that test results are dependent on the data sets used. "Stress testing" systems with large data sets may reveal problems. Systems that behave well with modest-size data sets may rebel when processing large data sets.

## The Bottom Line

The traditional methods of acquiring, storing, and analysing spatially referenced data are becoming too costly and inflexible in meeting today's information requirements. Even so, potential users of GIS should understand all aspects before adopting this new technology. Is GIS an appropriate tool for the intended application, and if so, which GIS should be used?

Users and independent testers can work together to provide answers to this question. Users must ensure that the system has the software functions required to support their applications, and that their hardware configuration is adequate to support their software and provide a path for growth. Independent testers should ensure that key GIS functions produce accurate results, and should "stress test" key GIS functions by using a standardized set of test data.

Evaluating GIS technology will help managers and technical specialists understand GIS technology from a realistic perspective.

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Pilot test results can also be used to refine evaluation criteria that were derived from the user requirements analysis.

All or part of the GIS designed for the organization may be tested, depending on the organization's familiarity with GIS. Testing only portions of the GIS that are most critical to organizational needs, or that represent the elements with which the organization is least familiar, may be desirable.

### Identification of GIS functions

Defining processing functions to meet specific needs is an important step in the design and evaluation of a GIS and is a direct outgrowth of the user requirements analysis. Identifying required functions often begins with a detailed list of GIS products and their specifications. Further analysis leads to identifying the type of processing functions needed to produce each product. My paper on evaluating GIS (Guptill, 1988) includes a checklist of GIS software components.

Mandatory and desirable individual processing functions should be identified. Mandatory software capabilities, when merged with such specific application needs as required response time, accuracy, precision, product-generation frequency, and data volumes, lead directly to mandatory hardware capabilities

Existing GIS's are extremely diverse in function and database structure Systems use various methods for digitizing, assigning, and storing attribute, coordinate, and topological information. The capability to manipulate, analyse, and display this information varies among systems. Capabilities of a given system are often oriented toward a specific function or application, such as computer-aided design and mapping, surveying, natural-resource management, terrain analysis, or image processing. Users must find the best match of system capabilities and user requirements. This is where benchmark testing can help.

Benchmarking is a process in which computer systems such as GIS are tested for function and performance. Benchmarking is accepted as part of the acquisition process by both private industry and the federal Government. The success of benchmarking depends on the extent to which tests can be constructed that are representative of expected workloads. The following ten procedural steps for benchmark construction are described in Federal Information Processing Standard Publication 75, *Guidelines on Constructing Benchmarks for ADP System Acquisition* (United States National Bureau of Standards, 1980):

*Step 1. Define benchmarking objectives and complete such preliminary activities as defining an agency's service, operational, and workload requirements.*

*Step 2. Quantify the present workload requirements.*

*Step 3. Obtain information from users on present applications and user forecasts of new or changing applications.*

*Step 4. Estimate future workload requirements.*

*Step 5. Categorize future workloads into distinct categories.*

*Step 6. Determine the relative contribution of each category.*

*Step 7. Scale each category. Weight the running times for each category's set of benchmarks according to its contribution.*

*Step 8. Represent workload categories with benchmarks. Select programmes that represent the workload categories identified in step 5.*

*Step 9. Fine tune the mix of benchmarks on the present system.*

*Step 10. Prepare the benchmarking package, which consists of documentation of the mix of benchmarks and rules for the live test demonstration, and test the benchmarks.*

A key point is that benchmarking must be done on products and capabilities identified through a user requirements analysis and must reflect estimated future data volumes. Users must also recognize that the preparation of a comprehensive benchmark may be a major task. Factors such as the size of the procurement must be weighed against the effort required to conduct benchmarking, and then a decision can be made on the appropriate level of testing.

### What to test

The functions of GIS can be grouped into five categories: user interface, system/database management, database creation/data entry, data manipulation and analysis, and display and product generation. It is possible to develop function and performance requirements for each of these areas.

The user interface is the way operators communicate with the database and GIS application modules. It consists of such software capabilities as menus, help screens, and graphic displays that simplify and organize the interaction between user and GIS software.

The database management component provides the environment in which the GIS functions and the means by which the data are controlled. The system management environment is furnished by the operating system of the host computer. GIS database functions parallel those of a non-spatial database management system (DBMS), but with extensions beyond the addition, deletion, revision, and Boolean retrieval capabilities of a standard DBMS. The GIS DBMS contains hardware and software facilities for storage, retrieval, and update of spatial information in alphanumeric and digital graphic forms, and incorporates storage structures to minimize data redundancy and to aid spatial searches. In addition, the GIS DBMS must have file management capabilities to handle a potentially large archive of geographic data files.

Database creation/data entry refers to the process of bringing data into the GIS environment. A GIS database contains a series of thematic categories or topics (layers) of information. These layers may contain information captured from aerial photographs, remote-sensing images, conventional maps, or other sources.

Data entry is the process of loading data into a GIS database. Data in a computer-compatible format, such as digital remotely sensed data, can be loaded directly. A database may also be created by digitizing or scanning maps or by digitizing information on aerial photographs to create a computer-readable data set. This effort is sometimes referred to as data capture.

Two types of data are generally collected: locational or geographic and accompanying feature attribute data. Locational information is usually digitized from existing graphics, maps, or images. Attributes identify what the features represent in the form of numeric or textual information such as soil type, feature name, or road class.

If spatial information capture and management are performed properly, the accuracy of the data will be maintained. The GIS user may then proceed to the primary GIS activities, data manipulation and analysis. Spatial analysis tools are used to model, make predictions, and reach conclusions about problems. Such analysis involves combining data from multiple spatial data categories and performing analytical, statistical, measurement, and other operations on the GIS data sets to transform the data into information suitable for a given application. Spatial analysis techniques include compositing areas, performing proximity searches, allows the information to be pulled from the database in one pass through the CD-ROM, speeding access time. Features can be added to the query set incrementally; however, this would require many re-reads of the disk and would slow access considerably.

Once feature selection is complete the information can be displayed to the terminal screen. The operator will have the option to change the colour and size of the symbols, to highlight select features, and to zoom using set increments. Once displayed, the software will provide cursor position read-out in latitude-longitude and simple distance measuring capabilities. The software also provides the capability to save selected data from the database, the query selection set, and a bitmap of the graphics display on hard disk. The bitmap will allow quick recall and re-display of information previously extracted from the CD-ROM. The user may also off-load a simple plot file.

Although the application software provided is not a geographic information system, it allows the user to examine the database and provides some basic utilities. The accompanying source code is provided to allow geographic information systems developers and other computer literate individuals to bring the Digital Chart of the World database into their operating environment.

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## HOW TO BENCHMARK YOUR GEOGRAPHIC INFORMATION SYSTEM*

*Paper submitted by the United States of America*

### RÉSUMÉ


Les systèmes d'information géographique s'avèrent être de plus en plus les meilleurs instruments de traitement des données spatiales pour la solution de problèmes géographiques complexes. Il existe cependant peu de directives pour aider les utilisateurs potentiels à déterminer le matériel et le logiciel appropriés. Les utilisateurs doivent évaluer les mérites de la technologie des systèmes d'information géographique en fonction des normes et directives, des fonctions des logiciels, des éléments du matériel et des essais comparatifs qui permettent de déterminer la combinaison optimale matériel/logiciel. En prenant conscience de tous les aspects de l'adoption de la technologie des systèmes d'information géographique, les utilisateurs pourront décider si un système donné constitue pour eux l'outil approprié et quel système ils devraient utiliser.


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Some users feel that independent testing and rating of GIS, much like evaluations of personal-computer software by *InfoWorld* magazine, would aid their decision-making. Although independent testing may be useful for some types of evaluation, the user of GIS technology must be deeply involved in the evaluation process. Why is this the case? First, the process of benchmarking a GIS is a complex, difficult, and potentially expensive task. Second, and more important, GIS benchmarks should be driven by user requirements. In the end, users must benchmark their systems. This article will examine various components of GIS benchmarking, review what independent testers of GIS technology can provide, and discuss what users should do.

#### User requirements

GIS technology is successful when it meets users' needs comprehensively and consistently. Development of a successful GIS depends on well-defined user requirements; therefore, a user requirements analysis should be performed. The analysis should identify the operation, users, and data requirements of the existing system; identify potential uses and users of the GIS; define digital and hardcopy products required; evaluate work flow; estimate database requirements that support GIS implementation; refine GIS product characteristics; calculate necessary production rates; and estimate data volumes. The analysis should also include a cost/benefit study

The user requirements analysis documents how an organization functions and supports its users, and quantifies and defines an alternative operation on the basis of GIS technology. It does not address such issues as the organization's objectives, goals, or staff capabilities, which are not quantifiable technical issues. However, such factors could override conclusions based solely on technical considerations.

If, upon completing such an analysis and assessing the appropriateness of GIS for the organization's missions, it is determined that GIS technology should be used, evaluation criteria must be devised for selecting a specific GIS. The evaluation criteria should be incorporated in the specifications for benchmark testing.

Hands-on experience with GIS capabilities is valuable in developing evaluation criteria. One method for acquiring such experience is to perform a small-scale pilot project. The pilot project should be designed to test the ability of GIS technology to meet an organization's needs. Pilot tests are a source of realistic data on production rates, memory and storage requirements, and user response to GIS products.

*The original text of this paper, prepared by Stephen C. Guptill, United States Geological Survey, appeared as document E/CONF 83/L 28 tations of these standards in Digital Chart of the World production. They specify the level of topology, integration, data collection criteria, and a specific sub-set of the tiling and indexing within the standards. They also implement other standards, such as United States Military Standards for accuracy and ISO 9660 for CD-ROM.

## THE DIGITAL CHART OF THE WORLD PRODUCT

### *Background*

The secondary goal of this development effort is no less ambitious than the primary goal of standards development; this is the development of the Digital Chart of the World product itself. Once completed, the database will contain 1.5-2.0 gigabytes of data stored on 8-10 CD-ROMs, providing a comprehensive 1:1,000,000-scale digital base map of the world. The Digital Chart of the World will be the largest spatial database designed specifically for exploitation on relatively inexpensive PC-class computers. Special indices will be provided to guide the user through the database.

Several factors led to the decision to produce a product with global coverage. First, there has long been interest in the international mapping community for a global database. The International Cartographic Association and its Working Group developed the concept for a World Digital Database for the Environmental Sciences in 1984 (International Cartographic Association, 1989); and the International Geographical Union and others have documented the requirements for a global database over the years. Secondly, a global database fills the digital data needs of a wide variety of users. Anyone with regional, strategic, or global interests will have use for this type of data; it is applicable to the operational problem sets addressed by intelligence agencies, command, control, communication and intelligence groups, the mission planning community, theater and strategic commands, and environmental and global monitoring organizations.

Finally, development of a global database provides the opportunity to comprehensively address the issues of tiling and indexing by uniquely challenging design efforts in these areas. Tiling must not only divide the global data set into manageable units, but these units must be nested, because different users work with different amounts of area coverage. Likewise, users of large databases encounter difficulties in determining which data they need to extract, and how to extract it. Elaborate indices, directories, and application software must be provided to guide users through the data extraction session. Large databases covering smaller regional areas also face these same problems. The Digital Chart of the World is providing the means to test and prove out global design solutions that can be applied to regional digital data sets in the future.

### *Source*

The 270 sheets in the 1:1,000,000-scale ONC series comprise the primary source for the Digital Chart of the World. This series was selected because it is the largest-scale series that provides worldwide coverage; its scale allows expedient conversion to digital form; and Operational Navigation Charts are a product included in the digital production system. The series is also free from the restrictions governing the distribution of other products, allowing widespread dissemination of products derived from it. This primary source has been augmented by six charts from the 1:2,000,000-scale Jet Navigation Chart (JNC) series in order to include Antarctica in the final product, making it truly a Digital Chart of the World. Conversion of hardcopy materials to digital form will provide the initial product; future editions and other Vector Product Standards compliant databases can be supplied by the digital production system.

The ONC series provides standard topographic information consistent with basic 1:1,000,000-scale map products. This includes terrain elevation contours at 1,000-foot intervals; major transportation routes, including roads, single- and multi-track railroads, and canals; populated places with city outlines; major drains and coastlines; and international boundaries.

### *Approach*

To create the digital database, the chart production separates from the ONC and JNC series will be scanned and converted to vector form. The majority of separates (over 2,000) will be scanned using a Scan-Graphics CF 1000 scanner. Three vectorization technologies are being employed to convert the raster data: the Optigraphics 3100 conversion system, Scan-Graphics Rave, and Hitachi CADCORE. Some separates will be hand-digitized for efficiency. The vector data from these processors are then fed into the ARC/INFO system for creation of topological data structure, cartographic processing and editing, and quality control functions. Once the data have been converted into the Digital Chart of the World structure, the data will be transferred to the CD-ROM medium for distribution.

## THE DIGITAL CHART OF THE WORLD

### *Database*

The database will be designed to support both geographic analysis functions and graphics display. Although the data are being collected from cartographic source, it will be treated as if it were geographic information. Linear features such as roads and railroads that were deleted in the original source due to cartographic symbology, precedence or displacement protocols will be connected. Additional source material is being used to connect transportation routes through built-up areas. Contours will be stored as continuous lines, closed at the ends and connected through elevation labels. This enhancement will support network analysis on the transportation data, elevation range determination on the hypsographic data, and many other spatial operations. The database, used in conjunction with a symbol library and a large display device, will provide briefing and planning graphics. Each CD-ROM will be richly indexed to allow comparatively rapid access. The Digital Chart of the World will be available for distribution by early 1992.

### *Software*

The Digital Chart of the World project is providing a comprehensive database for commercial geographic information systems, as well as an application software package. The application software, along with its source code, allow simple database query. It is a user-friendly interface employing a pop-down windows menu that will provide immediate access to the data.

The software provides a variety of methods for defining a study area. The user can retrieve data by delimiting an area on a coverage map of the world; by entering a latitude and longitude position; or by selecting a feature name from gazetteer query. Once an area has been defined the operator can then select the feature types to be extracted from the database. A query list will be generated to allow all features of interest to be extracted at one time; the menu will display only those feature types available in the area of interest. This rica, southern Italy), prototype 4 tested the digitizing, feature tagging, transformation into the product format, indices and directories, CD-ROM production, and quality control throughout the process. This prototype and its specification constitute the first sample of the future Digital Chart of the World product.

This method of prototyping worked very well. Engineering ideas were quickly tested; the designs that didn't work well were quickly discovered and discarded, saving months of study and debate. Sound ideas were expanded and further proven with each iteration.

### *Studies*

A number of special studies have been initiated by the Environmental Systems Research Institute to support prototype development. The Vector Product Standards have been separated into protocols, and the Institute has conducted research investigations into the various elements comprising each protocol. The lowest level protocols, those for CD-ROM, are following existing ISO 9660 standards and are not studied. The mid-level protocols consist of the spatial data structure, feature identification codes, and product content rules; at this level the studies include the data storage structure study, the data dictionary study, the digitizing convention study, the aeronautical study and the elevation data study. The high level protocols consist of the data directory protocols; at this level the studies include the tile design study, and the indexing studies: coverage, thematic, gazetteer and spatial query.

These studies were conducted in an iterative manner. The Institute initiated each study by investigating user needs, then conducted literature searches, consulted with area specialists, and issued a preliminary study which was sent to appropriate development participants for comment and enhancement. Responses were consolidated and used by the Defense Mapping Agency to direct the contractor in refinement of the studies. The study findings were then folded into the prototypes for testing. The study delivery dates were staggered, each timed to mature coincident with the integration of the study element into the suite of Vector Product Standards. This method allowed the designers access to the substantial knowledge and experience base of the cooperative partners and maximized their input to the final standard.

In this second year of development the special studies continue with investigations into Digital Chart of the World product maintenance issues and Digital Chart of the World product organization.

### *Vector Product Standards*

Now that the Vector Product Standards development cycle is complete, the final suite has been submitted as United States Military Standards. While the Vector Product Standards will enforce commonality among future Defense Mapping Agency vector data sets, they have been designed for generic application. The Vector Product Standards consist of the following subsections:

*Tiling.* This standard addresses the units of area coverage into which a geographic database is divided. In large data sets it is awkward to work with the entire database as one unit. This is solved by dividing the data into manageable areas. The design of the tile standard is determined by performance criteria, data maintenance issues, data manageability, most acceptable access time, CD-ROM medium characteristics, and size and configuration of the computing environment.

*Indices.* Indices provide a mechanism for quickly finding information stored on the CD-ROM. The Vector Product Standards provide format and structure for Spatial Query Index, Tile Index, Coverage Index, Gazetteer Index, and Thematic Query Index.

*Digitizing conventions.* The Vector Product Standards digitizing conventions define how to collect linear data as a continuous feature; how polygon features should be closed; and how intentionally coincident features should be stored in separate layers when required. The digitizing conventions do not define procedures for the physical transfer of data from hardcopy to softcopy.

*Digital marginalia.* The Vector Product Standards define how information normally stored in the margin of a paper map should be included in the database. This includes such information as data currency, compilation date, last revision date, and intended use.

*Vector product format.* The vector product format is the heart of the Vector Product Standards. This subsection defines the conceptual and physical data model. In the vector product format, features are created from four basic primitives: nodes, edges, faces and text. These are physically implemented in binary primitive and feature tables. There are four types of primitive tables: node tables, edge tables, face tables and text tables. These tables contain topologic relationships and coordinate data. There are three types of feature tables: point feature tables, line feature tables and area feature tables. These tables contain a primitive record ID and attribute values.

The Vector Product Standards are designed to support varying levels of topology and varying degrees of integration. This relational approach will allow data to be separated into layers. When applications do not require querying of the relationships among data types, data can be stored in separate layers, allowing efficient storage and access. When such querying is required, the layers can be integrated, carrying full topological relationships in the process. After much consideration the geo-relational model was selected because (*a*) a majority of the reviewers of previous prototype products expressed a desire for thematic separate data, and many future products may be very thematic in nature; (*b*) the natural indexing of relational tables will allow data producers to distribute data without building special purpose indices to speed access for each user's separate needs; (*c*) the minimum target configuration is best supported by simple file structures; and (*d*) special purpose weapon systems can more easily use the data.

Once the Vector Product Standards become United States Military Standards all Department of Defense vector product users will be required to conform to the standards. Command, service, and agency contracts for map digitization will require adherence to this standard. This will create a pool of digital mapping and charting data generated to a known standard, allowing data exchange within the Department of Defense and Intelligence communities and enhancing a common goal of interoperability.

### *United States Military Specifications*

Whereas the United States Military Specifications are designed to be as generic as possible, a product's military specification is quite constrained. The United States Military Specifications define the data dictionary, the features and attributes included in the product, the feature coding schemes employed, the convention for portrayal of special feature relationships such as complex features, and all other product specific requirements. The Digital Chart of the World United States Military Specifications reference the Vector Product Standards and define the specific implemeninteractive use, tiling, indexing, and manipulation of the data.

With the projected increase in both the generation of digital data, and the number of applications for the data, the need for digital product generation and user exchange standards became evident and motivated this research and development effort.

### *Approach*

In October 1989 the Environmental Systems Research Institute was contracted by the Defense Mapping Agency to develop the vector product standards and the Digital Chart of the World. The vector product standards was designed to provide direct database utility and be oriented to provide Defense Mapping Agency products for use in commercial geographic information systems.

Given enough time, any group of engineers can come up with a standard. The quest here is to establish standards that can be readily embraced by the customer community. To accomplish this, two things are required: (*a*) well designed standards that support a wide range of user demands; and (*b*) a wealth of data produced according to the standards, to attract the users and promulgate the standards.

To meet this primary goal the Environmental Systems Research Institute was required to develop a comprehensive suite of vector product standards. To ensure that these standards would fulfil a broad range of needs, be as generic as possible, and work in a wide range of computing environments (both product and platform), the following design constraints were imposed:

(*a*) The standards must be designed to work within the constraints of a microcomputer (IBM 80286) with a limited amount of hard disk storage (30 megabytes). This would allow the use of vector products with inexpensive and in many cases portable equipment. With the exception of tile size any design slated for PC class environment will also operate in workstation and larger environments with increased efficiency;

(*b*) The standards must be designed for data distribution on Computer Disk-Read Only Memory (CD-ROM). This medium was selected for distribution because it is cost effective, efficient, and operates under established media standards;

(*c*) The standards must support interactive use of the media, so that small computers can use the medium as "on-line" storage;

(*d*) The standards must be user-oriented. They must support geographic modelling and analysis and graphics display. They must be usable by individuals oriented toward geographic information not computer science. The database access software will be available to users of data stored in the vector product standards, and the source code will be available without restriction;

(*e*) The standards must be designed to work in a variety of computing environments regardless of manufacturer. They must work with a variety of vector data types regardless of the scale of the information or level of topological information;

(*f*) The standards must be compatible with the Defense Mapping Agency's digital production system.

#### *Prototyping*

In order to insure that the standards would be user-oriented and meet user requirements, an incremental, iterative prototyping approach was employed. With each prototype, increasing quantities of data from several ONCs, hydrographic charts, and a topographic map were digitized and converted to a trial data structure and delivered to over 60 review sites. Review participants included the international development partners and a cross section of Defense Mapping Agency product users from the United States Department of Defense and intelligence communities. A variety of product types were included in the prototypes to ensure that the standards would apply to a range of geographic information systems applications at varying scales.

The first prototype, actually an ARC/INFO "mock-up" of the Digital Chart of the World, was delivered to the evaluation team in December 1989. This prototype consisted of a small section of ONC G-18 (Santa Barbara, California) and a small patch of British Admiralty Chart 2693 (Harwich, England). The evaluators were provided with PC ARC/INFO software, an evaluation guide, hardcopy plots of the database, and complete instructions. By performing feature queries, viewing the data on the screen, and using a mock-up of the Digital Chart of the World software, the evaluators were able to assess the capabilities they wanted the application software to provide. Armed with this information the applications software programmers were able to quickly develop the software for prototype 2, which was released in April 1989.

Prototype 2 used original "C" code and provided a newly implemented data structure. The data consisted of an expanded area of the two previous charts and also included National Ocean Service Charts 12245 and 12222 (Norfolk, Virginia) and a section of a 1:50,000 topographic map (Killeen, Texas). This prototype, which used five floppy disks to carry the data and one to store the software, provided evaluators with a good vehicle to analyse the database design and the new application software.

Prototype 3, released in early August, was the first prototype to use CD-ROM. The sources for prototype 3 were:

Operational Navigation Chart G-18 (California, United States)

Operational Navigation Chart N-13 (Northern Australia)

Operational Navigation Chart E-18 (Ontario-Quebec, Canada)

British Admiralty Chart 2052 (Harwich, England)

National Ocean Service 12245 (Chesapeake Bay, United States)

Jet Navigation Chart 120 (Antarctica)

The application software was supplied on a separate floppy disk. This was the first prototype on the target medium and the first to implement the Vector Product Standards. The objectives of this prototype were twofold: first, to provide the standards, the software, and the data to the evaluation team; and secondly, to provide a test bed for the organization of the data, directories, and indices on CD-ROM. Along with the basic prototype sets the Environmental Systems Research Institute added eight test sets. These sets, with various structures of indices and directories, were used to test data organization directly, with the CD-ROM in various drives. The sets provided calibration data for off-line tests to determine the optimum methods for storing this information. This will allow the Digital Chart of the World and other products to optimize the slow seek time and fast read time of the CD-ROM medium.

Recommendations from prototype 3 were then tested in prototype 4. Prototype 4 tested both the data structures and the production process. Using four ONCs from western Europe, E-01 (UK), F-01 (France, northern Spain), G-01 (southern Spain, northern Africa), and G-02 (northern Af-

# THE DIGITAL CHART OF THE WORLD PROJECT*

*Paper submitted by the United States of America*

## RÉSUMÉ

La Defense Mapping Agency met au point un nouveau produit, à savoir la carte numérique du monde qui assurera une couverture à l'échelle mondiale en utilisant une représentation vectorielle topologiquement structurée de l'information relative à la surface terrestre du globe sur un support accessible par micro-ordinateur. L'objectif ultime de ce projet est de mettre au point, d'affiner et de définir une série de normes pour appuyer les futures activités de production de données numériques de la Defense Mapping Agency et accroître l'utilité de l'information numérique spatiale dans un format vectoriel. La base de données sera utilisée pour tester et définir les normes pour les produits Une fois que les normes auront été définies, la carte numérique du monde servira d'exemple pour les futurs produits de la Defense Mapping Agency.

Les normes et la carte numérique du monde sont mises au point en coopération avec le Royaume-Uni, le Canada et l'Australie. Des représentants de chaque pays passeront en revue les projets de normes et spécifications, essaieront et évalueront les prototypes, aideront à la conception des voies d'accès des utilisateurs à la base de données et élaboreront le matériel et les logiciels utilitaires pour envoyer, recevoir et exploiter les données.

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The Digital Chart of the World Research and Development project, initiated in 1988, has as its primary goal the development of vector product standards for the provision of digital geographic information to the United States Department of Defense and Intelligence Community activities.

As a secondary goal, the project will develop the product specifications for a 1:1,000,000 vector map database. Over 275 Operational Navigation Charts (ONCs) and Jet Navigation Charts will be digitized to provide a product with worldwide coverage. The new product, the Digital Chart of the World, will contain several gigabytes of topologically based vector data.

The Environmental Systems Research Institute of Redlands, California, is the prime contractor for the project. The project is a multinational effort. The development partners are the United States, Canada, Australia and the United Kingdom. The military map producers from these four nations, the primary producers of the ONC series that will provide the information for the Digital Chart of the World, have joined in this effort to establish standards for data structures that will support direct use in geographic information systems, CRT displays, and special computer environments. The Digital Chart of the World will be the first product generated according to these standards. This paper discusses the process followed for accomplishing the project goals of standards development and product development.

## Standards development

### *Background*

#### *Increasing demands for digital data*

While the demands for the Defense Mapping Agency's conventional paper products are as high as ever, the demand for video and digital data is increasing. There has been a significant increase in the number of automated systems supporting military functions. Some are captive or special purpose developments, some employ commercial off-the-shelf geographic information systems technology; all require machine readable mapping and charting data. The Defense Mapping Agency currently produces video products and digital products which use a raster model (ARC Digitized Raster Graphics), but there is a need for "smart" vector data for selective display and geographic modelling and analysis. To support these functions, the data sets must carry topological relationships and be fully attributed.

#### *Increasing availability of digital data*

The Defense Mapping Agency production process is undergoing a modernization programme: an end-to-end Digital Production System will be phased in over the next five years. Foreign military mapping agencies are increasing their output of digital data; the nations participating in the Digital Chart of the World project are also extending their production systems to produce more digital data. The digital data pool is also being filled by scanning and digitization efforts in the private sector.

#### *Demand for a "user oriented" structure*

At present, there is a variety of structures and standards for digital vector data. Available non-commercial data transfer structures include:

TIGER: topologically integrated geographic encoding and referencing files (Bureau of the Census)

DLG-E: digital line graph enhanced (United States Geological Survey)

SDTS: spatial data transfer specification (Federal Geographic Data Committee)

DIGEST: digital geographic information exchange standards (Digital Geographic Information Working Group (an ad hoc group of NATO nations))

MC&GFDES: mapping, charting, and geodesy feature data exchange structure (Defense Mapping Agency's digital production system)

All of the referenced standards were designed to accommodate producer exchange of data, not user exchange. They support specific implementations rather than a general purpose; apply to bulk transfer of data, with built-in overhead and redundancy; have no requirement for communication between parties; and lack application software. In general, these standards do not support customer requirements for

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*The original text of this paper, prepared by David M. Danko, Defense Mapping Agency, appeared as document E/CONF 83/L 27

The Geological Survey also distributes DEM's produced from digital terrain elevation data collected by the Defense Mapping Agency from 1:250,000-scale maps. Elevations are interpolated every 3 arc-seconds of longitude and latitude, except in Alaska, where spacing varies. These DEM's are distributed in 1-degree cells. The 3 arc-second DEM's consist of more than 1.4 million elevation values. Coverage is available for all the 48 contiguous states and Hawaii, and most of Alaska and Puerto Rico.

### *Land use and land cover data*

For the 48 contiguous states and Hawaii, land-use and land-cover data are made by digitizing land-use polygon outlines from 1:250,000-scale and 1:100,000-scale source maps.

Work in progress includes digitizing land-use and land-cover data and associated map data, including hydrologic units, political units, and census county subdivisions. Federal and state land ownership has been digitized in selected areas.

These data are available in vector and raster forms. The vector data, encoded in the Geographic Information Retrieval and Analysis System (GIRAS) format, are topologically structured. The raster data, encoded in the Composite Theme Grid (CTG) format, are composed of an array of cells. Each cell is completely identified with attribute codes for all land use and land cover and associated map data.

Digital data are available for more than 80 per cent of the 48 contiguous states and Hawaii. Completion is scheduled for 1992.

For Alaska, land-cover data are generated using LANDSAT multispectral scanner digital data. These raster data are encoded in a format different from the CTG format described above. Approximately 2 per cent of the coverage planned for Alaska is available.

### *Geographic names data*

Information about places, features and areas in the United States identified by proper names and geographic locations is distributed through the Geographic Names Information System. This national database contains about 2 million entries; when completed, between 1998 and 2002, it will hold about 5 million entries. The Geographic Names Information System is the federal Government's official source of geographic names as sanctioned by the United States Board on Geographic Names.

## Coordination of data standards

The Geological Survey is also active in coordinating matters related to federal digital cartographic data.

In 1980, the National Institute for Standards and Technology agreed to assign to the Geological Survey leadership in defining and maintaining federal earth-science standards.

Under this agreement, the Geological Survey is coordinating the development of a standard for the exchange of digital cartographic data, called the Spatial Data Transfer Standard. This standard was developed through grants to the National Committee for Digital Cartographic Data Standards, which functioned under the auspices of the American Congress on Surveying and Mapping. The Federal Interagency Coordinating Committee on Digital Cartography also contributed to the development of the standard.

The need to transfer spatial data between different systems is becoming increasingly important. The concern for common data formats and coding conventions cuts across all aspects of cartographic data handling. Users find it difficult and inefficient to use data because of differences in underlying concepts, terminology and formats.

The proposed Spatial Data Transfer Standard provides a national standard for the exchange of digital spatial data. The standard includes definitions of terminology, a transfer specification, recommendations on reporting data quality, and terms and definitions of features commonly found on topographic maps and hydrographic charts. The federal Government, the private sector, and the academic community have been working for several years to develop this proposed standard.

Empirical testing of the Spatial Data Transfer Standard was completed in 1989. Improvements have been made to the standard based on the test participants' suggestions. The standard will be submitted to the National Institute for Standards and Technology in mid-1990 for designation as a Federal Information Processing Standard.

## Geographic information system facilities and research

Spatial analysis is an emerging discipline being applied to geographic information systems at the Geological Survey. Over 500 Geological Survey scientists and engineers have received formal training in geographic information system technology. Geographic information system applications software is available on a nationwide network consisting of approximately 85 minicomputers, a mainframe computer, plus additional stand-alone microcomputer and workstation systems. Within the Geological Survey (and in more than 100 cooperative application and demonstration projects with other federal and state agencies), geographic information system technology has been applied in fields as diverse as water quality, geologic mapping, minerals exploration, oil and gas development, earthquake and other natural hazards analysis, forest management, public health, environmental analysis, wildlife management, agriculture, soils mapping, urban planning, and the 1990 census.

The Geological Survey operates 3 interdisciplinary geographic information system research laboratories, located in Virginia, Colorado and California, to support cooperative applications development and to facilitate evaluation of advanced geographic information system technologies. Long-term research is designed to address land-surface characterization for global change and other dynamic, time-dependent, process modelling activities. The Geological Survey's EROS Data Center in Sioux Falls, South Dakota, will serve as the national archive and data manager for land surface data for global change research.

## Earth science information and sales

The Geological Survey's Earth Science Information Centers (ESIC's) offer nationwide information on earth-science data holdings and sales service for Geological Survey map products and earth-science publications. This network of ESIC's provides information about geologic, hydrologic, topographic, and land-use maps, books and reports; aerial, satellite, and radar images and related products; earth-science and map data in digital form and related applications software; and geodetic data.

dans les domaines des systèmes d'information géographique et des technologies connexes et distribue aux utilisateurs des données cartographiques numériques et autres données relatives aux sciences de la terre.

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The United States Geological Survey is a source of many kinds of topographic and special-purpose maps of the United States and its outlying areas. It is also a source of digital map data.

Many public agencies, private organizations and individuals need reliable cartographic and geographic knowledge about the country. To serve such needs, Geological Survey maps are compiled to exacting standards of accuracy and content.

Today, an ever greater extent of the country's landscape is being translated into digital map data. These data are collected from Geological Survey topographic maps or acquired from satellite or other non-photographic sensors. Such data help to create and update a comprehensive set of line, image and thematic maps. The data can be analysed to find answers to a host of cartographic and geographic questions.

## Digital cartographic data products

Needs are growing rapidly for digital cartographic data to support map-making and geographic information systems. Moreover, sound earth and water resources management now calls for computer-compatible cartographic and special-purpose data to provide a basis for analysis.

The Geological Survey produces digital cartographic data and distributes them through the National Digital Cartographic Data Base (NDCDB). The NDCDB includes:

(*a*) Topographic line map data as digital line graphs (DLG's);

(*b*) Elevation data as digital elevation models (DEM's);

(*c*) Land use and land cover data.

In addition, the Geographic Names Information System contains digital descriptions of places, features and areas in the United States identified by proper names.

### *Digital line graph (DLG) data*

DLG's are vector files of cartographic data made primarily by digitizing point locations, lines and polygon outlines from map-separation materials. They are prepared from primary series (ranging in scales from 1:20,000 to 1:63,360) and from 1:100,000- and 1:2,000,000-scale source maps.

These data are a framework of reference for other data about the Earth and its natural resources. These data are useful for computer-assisted production of cartographic products. They are organized to support the analytical functions of geographic information systems.

The spatial data are topologically structured. Spatial relationships, such as adjacency and connectivity among data elements, are explicitly encoded.

In addition, DLG data elements may have coded attributes. These feature codes identify the major category, such as hydrography, to which a data element belongs and add other specific feature information, such as "shoreline" or "spring" or descriptions and parameters, such as "intermittent" or elevation of the water surface.

Work in progress includes the conversion of boundary, contour, hydrography, transportation, United States Public Land Survey System (PLSS), and other selected data to digital form.

DLG data derived from primary series topographic line maps are available for portions of all 50 states and Puerto Rico. For the 48 contiguous states and Hawaii, digitizing of boundaries is 25 per cent complete; contours, 1 per cent; hydrography, 6 per cent; transportation, 5 per cent; and PLSS, 26 per cent.

Coverage is available for approximately 2 per cent of Alaska for each category. Most of the DLG data are distributed as 7.5-minute cells.

Transportation and hydrographic data were digitized from 1:100,000-scale quadrangle maps to meet Bureau of the Census needs for base map information for the 1990 census. Coverage is available for all the 48 contiguous states and Hawaii. Boundary, PLSS, and contour data are being collected. These data are distributed in 30-minute blocks.

Boundary, hydrography, and transportation data were digitized from revised 1:2,000,000-scale sectional reference maps from the *National Atlas of the United States of America*. Coverage of the 50 states is available in 21 regional sections.

An improved data model, called "digital line graph-enhanced" (DLG-E), will soon be in use. DLG-E provides for the explicit representation of individual cartographic features, such as roads, counties, buildings, and streams, in addition to the topologically structured spatial data provided in the current DLG. This enhancement also provides a more extensive set of attributes and relationships for these features than exists in a DLG.

### *Digital elevation model (DEM) data*

DEM's are arrays of elevation data, usually at regular intervals. DEM's can be used to generate simulated views of a landscape; to calculate capacities of reservoirs and volumes of lava flows; to assess terrain in relation to other environmental factors; to predict brush and forest fire behaviour; and to calculate slope for such applications as hydrologic process modelling to gauge the effect of precipitation on groundwater and surface-water run-off.

The Geological Survey produces DEM's by computing elevations from digitized vector contour data, by scanning stereomodels produced from aerial photographs, or by resampling higher-resolution DEM's.

For DEM's corresponding in coverage to 7.5-minute topographic quadrangle maps, elevations are processed to produce data at 30-metre ground spacing with the Universal Transverse Mercator coordinate system as a framework. For Alaska, the DEM's, corresponding in coverage to 15-minute topographic quadrangle maps, are processed to produce data at 3 arc-seconds of longitude by 2 arc-seconds of latitude spacing. Coverage is available for 35 per cent of the 48 contiguous states and Hawaii, and for approximately 8 per cent of Alaska.

Recently, the Geological Survey began producing DEM's from 1:100,000-scale DLG contour data or from resampled 7.5-minute DEM's. These data are processed to produce data at 2 arc-second spacing, and are distributed in 30-minute blocks.

(Harrier) and F/A-18. For this system, the Navy uses ADRG disks to derive a compressed aeronautical chart, which is then used to develop mission-specific flight path images. This ADRG-based product is put on the aircraft as an aid to the pilot. The AV8B and F/A-18 program currently use ADRG coverage of TPC.

At the battle management system level, the United States Department of Defense systems use ADRG data to support activities over a specified area.

The United States Army's Maneuver Control System (MCS) is a mobile mission planning system for field command. MCS uses a compressed product derived from the ADRG images of existing maps.

The Navy's Tactical Air Mission Planning System can be based afloat on a land-based command centre. ADRG data can be used as a background display for positioning aircraft or ships in a given area.

The Joint Operational Tactical System is a command and control battle management system designed for a desktop computer, shipboard or ashore. ADRG data will be used experimentally to support this interrogative tactical display system.

ADRG will also support the Navy's shipboard MH-53 mine-sweeping helicopter activity. Helicopters will report satellite Global Positioning System (GPS) positions of mines to the carrier ship. The mine positions will then be displayed on an ADRG image as the data is collected. Although still in the prototype phase, ADRG coverage of harbour and approach and coastal charts is intended to support the planned MH-53 activity.

The widest use of ADRG data is for command and control mission planning over large areas.

The Joint Visually Integrated Display System is a fast interrogative tactical display that uses ADRG as a raster background. This system, located at the National Military Command Center, will be used by the Joint Chief of Staff to overlay intelligence information in vector format to support counter-narcotics activities. Identical systems support the Drug Enforcement Agency and the Commanders in Chief for counter-narcotics.

The FULCRUM system used by the United States Air Force is another GIS-like system that supports intelligence and operations planning. FULCRUM can use ADRG data for background images and can exploit other digital mapping products such as digital terrain elevation data, digital feature analysis data, and interim terrain data, in conjunction with ADRG.

Other mission planning systems intending to use ADRG background raster data include Tactical Air Command's Mission Support System, which will use compressed ADRG data, and the Strategic Air Command's Strategic Mission Data Preparation System.

### Conclusion

The ADRG production process represents a rapid means of incorporating existing hardcopy maps and charts into the realm of digital processing. As a database, ADRG is well on the way to providing a wide range of raster background data; there are currently over 1,000 ADRG CD-ROMs available for distribution, many of which are available for public sale. Incorporation of ADRG data into any GIS is limited only by a user's application software.

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## DIGITAL CARTOGRAPHIC DATA PRODUCTS AND ACTIVITIES OF THE UNITED STATES GEOLOGICAL SURVEY*

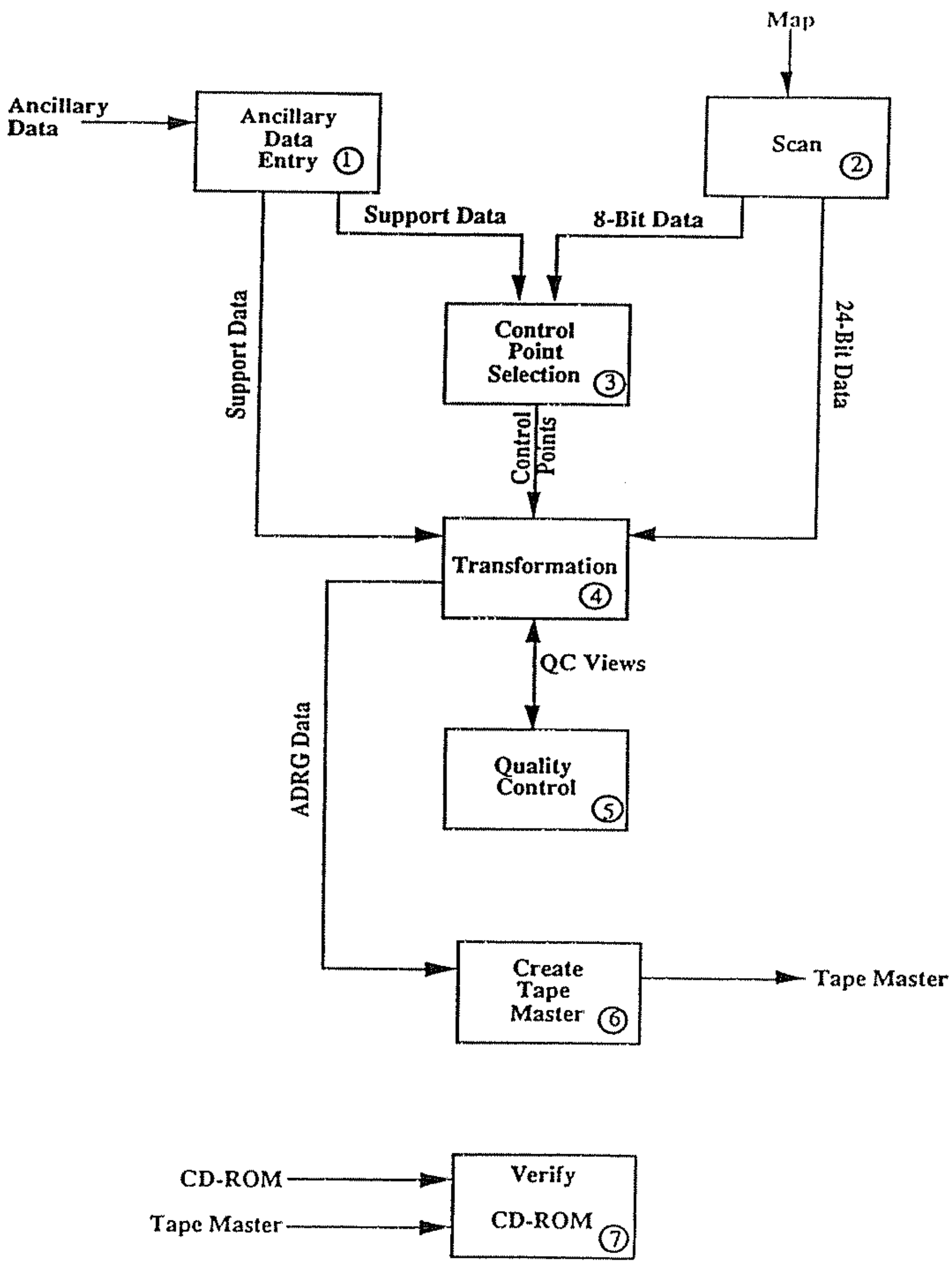
*Paper submitted by the United States of America*

### RÉSUMÉ


Le Geological Survey des Etats-Unis est la principale source de nombreux types de données cartographiques numériques des Etats-Unis et des régions avoisinantes. Ces données englobent : 1) des données graphiques linéaires numériques, qui comprennent des informations sur les frontières, l'hydrographie, l'hypsographie, les transports et autres caractéristiques figurant sur les cartes topographiques du Geological Survey; 2) des données altimétriques numériques, qui comprennent les cartes d'altitude, d'un ensemble régulier de points observés; 3) des données sur l'utilisation des sols et la couverture végétale, qui comprennent des informations sur les schémas observés en matière d'utilisation des sols et de couverture végétale et des informations connexes; 4) des données relatives aux noms géographiques. Le Geological Survey coordonne également la mise au point de normes pour les données cartographiques numériques, fait des recherches


*The original text of this paper, prepared by Michael A. Domaratz, United States Geological Survey, appeared as document E/CONF.83/L.26

Figure II. ADRG production flow



hours, depending on the size and type of charts to be distributed on the particular CD-ROM.

*Source preparation*

Although ADRG production is highly automated, initial chart preparation and data collection is manual. Cartographers manually update aeronautical charts with Chart Update Manual information to reflect conditions hazardous to navigation. Chart series in which adjacent charts overlap are also examined for any features or labels in an overlap region that need to be moved. Relevant chart parameters such as datum, projection, sheet corner coordinates, graticule spacing, and accuracies are collected from the chart itself and from other databases as text information. Other data collected identifies which marginalia, such as boundary diagrams or elevations tint diagrams, should also be captured as raster images. All text or ancillary data are entered into a microcomputer database from which a floppy disk is extracted for interface to the ADRG production system.

*Processing*

The ADRG production flow consists of seven main steps that are summarized in figure II. The production process begins with the entry of ancillary data into a data preparation workstation via floppy disk (step 1). System resources are allocated during this step to ensure availability of adequate disk space for processing and to assist in automated tracking of data files through the production system. In addition, system operations may interactively verify and edit input ancillary data before data processing begins.

Upon completion of the data input process step, required data items are automatically validated and Metric Support Data (MSD) is generated. MSD is a set of polynomial coefficients for rapid transformation from WGS-84 or the ARC system to the source datum or projection for those ADRG users who require map information on its original datum and projection.

In the next process (step 2), the paper map is mounted for scanning. The scanner collects swaths of 250 lines per inch around the circumference of the scanner drum. The 24-bit red, green, and blue data are deswathed and rotated so that the raster image is in row-major format. The result is a north-up, right-reading data file. During the scanning process, a copy of the 24-bit colour data is condensed to 8-bit colour data using a colour table. The 24-bit data are sent over the network to a transformation node for later batch processing. The 8-bit data are sent to a data preparation node for control along with a condensed overview of the entire scanned area for use as a working file.

The system operator uses the 8-bit image data to select marginalia to be stored as raster images and to perform map registration (step 3). Once the legends are selected, the control point selection software automatically generates a list of candidate areas for control, using map corners and graticule spacing information defined in the ancillary data. Then the operator ties the geographic coordinates to the scanned image by visually identifying the (row, column) coordinates that represent the four map corners. The software automatically presents to the operator an expanded view of the region surrounding each candidate area for subpixel refinement in identifying control points.

As each candidate point is measured, a sequential least squares adjustment is performed and the resulting residuals are displayed to aid the operator in detecting blunders. Once an adequate control solution is achieved, the control information and legend information is saved for the ARC transformation process step.

On the transformation nodes, control and legend information is merged with ancillary data, MSD, and the 24-bit colour raster image data (step 4). The ARC transformation algorithm is based on a single math model that dewarps the hardcopy map, performs the projection transformation to ARC and the datum transformation to WGS 84, and performs colour resampling on the resultant pixels all in one step. In addition, the transformation software creates the overview image as a 16:1 spatial compression of the ARC image, modified by black enhancement algorithm to retain the map graticule.

The text and image files are placed in their proper file and directory structure according to the ADRG United States Military Specification. The final step of the transformation process is formatting the ADRG files according to the ISO 8211 specification. A text data rep and an image tiling rep are then generated for quality control review.

*Quality control*

ADRG quality control is performed on a large screen quality control workstation and consists of visual and quantitative checks (step 5). The quality control cartographer visually reviews all marginalia images. The overview image is used to select a number of views from the full resolution ADRG image. Measurement of geographic graticule and grid intersections are made on the full resolution image. The software computes a measured point's displacement from its theoretically correct position, based on known characteristics of the geographic graticule or grid; 90 per cent of the measured points must be within two pixels of their correct position.

*Manufacturing and distribution*

Once an ADRG data set has passed quality control, an image of the final CD-ROM, including ISO 9660 formatting, is output on a set of nine-track master tapes (step 6). The tapes are sent to a commercial compact disk manufacturer for mastering and replication. Sample copies of each ADRG CD-ROM title undergo a full or partial bit comparison to the original master tapes (step 7). For further verification, an ADRG CD-ROM can be read back into a quality control workstation for visual display. After verification, ADRG CD-ROMs are sent to the Defense Mapping Agency Combat Support Center, Philadelphia Distribution Center, for worldwide distribution.

## ADRG APPLICATIONS

ADRG is designed to be a raster image database supported by cartographically significant text information that is adaptable to a variety of user-specific applications. The Defense Mapping Agency does not distribute any application software with ADRG CD-ROMs. Sufficient information is available in the United States Military Specifications for ADRG (also available through the Defense Mapping Agency) to allow applications programmers to access any ADRG data appropriate to a specific user need.

ADRG raster map images are rapidly becoming the background and overview data for a variety of Department of Defense systems with geographic information systems characteristics. These Department of Defense systems primarily support mission planning activities, but some applications also support on-board and battle management systems.

One of the earliest ADRG applications was an on-board moving map display for the United States Navy AV8B an area of 4,550 sq. km. and contributing to flood damage equal to billions of Baht per year.

*Building construction activity*

First-class residential condominiums, office buildings, hotels and shopping centres are empirical evidence of intensive land development and economic growth, especially in the central areas of Bangkok.

Due to the growth of the overall economy and foreign investments, the demand for office space alone will see the current stock more than double by 1993. In the case of first-class condominiums, which are becoming a common mode of living, there are approximately 200 projects in Bangkok. Construction activity within Bangkok has recorded a big increase over recent years, with the demand for construction permits alone from BMA increasing last year by 34 per cent over 1988.

*Telephone installations*

Despite recently announced plans for a three million line phone expansion project, TOT has currently 800,000 subscribers on the waiting list for installation of phones and the annual demand for phones is rising by an average 15 per cent per year. Waiting periods for the installation of phones can currently be up to seven years, largely owing to the lack of cable lines to connect to the subscribers' buildings.

*Waste-water treatment*

By 1994, BMA will have completed the construction of five water treatment plants in a major step towards water treatment and pollution control of the city's waterways. Nevertheless, these plants will be capable of treating only one quarter of Bangkok's waste-water.

*Motor vehicles and traffic problems*

The number of cars on the streets of Bangkok has doubled over the past ten years and passed the 2 million mark during 1989. During the first quarter of 1990, sales averaged about 20,000 vehicles per month. BMA expects that some 520 vehicles will be registered daily next year.

Inadequate road space is normally blamed for traffic jams, as Bangkok has a total road surface equivalent to 8 per cent of the city area; for most major cities, 20-25 per cent is the norm. Uncontrolled growth, lack of city planning and an increased demand for private cars in Bangkok brought about by the economic boom, have made the current traffic problems intolerable.

Air pollution in traffic-choked areas is well above recognized danger levels, and last year over one million residents suffered from respiratory diseases.

*Land development boom*

Land prices have drastically increased since 1987 as land within a 60-km radius of Bangkok could be profitably converted for urban uses in preference to agricultural uses.

The Lands Department has experienced a fourfold increase in ownership transfers over that of 1987. In fact, during the first three quarters of fiscal year 1990, ownership transfers increased 70 per cent over the same period of the previous year. However, of the total 1,560 sq km land area of Bangkok, there exists a large amount of inner city land left undeveloped or under-developed, resulting in inefficient land uses and haphazard growth to other areas.

## History of the BLIS project

For some time the BMA, in particular, has recognized the need to establish some form of land information system (LIS), for the City of Bangkok to assist in overcoming the ever increasing problems facing the city. Many countries have provided technical assistance in the area of LIS to the BMA and other utility authorities over the past six years, including Canada, Japan, Australia, Belgium and Germany.

Within the BMA, the BLIS concept was well supported during the term of the Deputy Governor, Dr. Wicha (1986-1989), the former Head of Department of Survey Engineering, Chulalongkorn University. This support culminated in agreement being reached, in early 1988 with the major utility authorities, coordinated by the BMA, to set up the pilot project and allocate the necessary funds for the purchase of equipment.

Continuing commitment for the project has been provided by the current Deputy Governor of the BMA, Khun Krisda Arunvongse and the Department of Policy and Planning, BMA in particular.

Due to the significant commitment of the participating authorities in BLIS in terms of capital expenditure, staff commitments to the project and the degree of cooperation, this project is naturally seen as providing a considerable focus for the development and implementation of LIS/GIS strategies for the Royal Thai Government.

## Strategy behind the BLIS project

The City of Bangkok has had many consultants undertake many studies to determine an appropriate strategy to develop a land information system for the city. However, there was one fundamental weakness in all these studies which were all done by overseas advisers or organizations under a variety of international aid programmes. None of the studies were undertaken by the Thai organizations themselves, although they fully cooperated in the studies. The overseas organizations came into the country, did their study, prepared a report and left. The result was that little of the experience of these LIS studies remained in Thailand. The studies were, however, critical in raising the level of interest and commitment for BLIS. Owing to the magnitude of the problems in Bangkok and the resulting size and complexity of any proposed land information system, the key Thai organizations in the City of Bangkok came together to undertake their own study and pilot project, called the Bangkok BLIS project. It was recognized that the overriding objective of the BLIS project was for the relevant Thai organizations to gain experience in designing and building their own systems.

In summary, the objectives of the BLIS project are as follows:

(*a*) To offer education, training and gaining of experience of Thai Government officials in the key organizations required to establish a future computerized land information system for the City of Bangkok;

(*b*) To determine an appropriate common base map for the City of Bangkok which could be used by all organizations that will be developing land information systems in the city. Without doubt this is the most important technical objective of the project;

(*c*) To establish an operational pilot land information system for the City of Bangkok;

(*d*) To ensure that a future land information system for the city of Bangkok will include efficient record-keeping systems for land related information;

(*e*) To better understand the existing land information processes in the respective authorities;

(*f*) To determine an *achievable* long-term strategy for the development of BLIS. From the overseas studies, from visits, from attending conferences and from LIS/GIS vendors, the Thai officials have seen many highly developed and complex systems. In Bangkok, important issues are involved in determining what is possible and what are the priorities in establishing a LIS for the city. The long-term strategy will address such questions as:

How should the base map be prepared?

Who should prepare it?

Who should manage the updating of the map?

Who should pay for the preparation and updating of the map?

What should be included in the base map. Should it be only topographic data, land parcel data, or buildings?

Should any attribute data be included on the base map?

Should the private sector be involved in the preparation of the base map?

What are the priorities in developing the LIS?

What institutional arrangements should be put in place to facilitate and encourage coordination when each authority wishes to develop its own system inhouse?

There is a clear recognition with the Thai officials that if the system gets too complex it has little chance of success;

(*g*) Obviously a very important requirement of the project is to determine the structure of the future LIS and to determine the appropriate data model. It is important to remember that there are a large range of data gatherers and data users in the proposed system, all of which have different needs. For example, the utility authorities are not particularly interested in the land tenure and land parcel base and wish to have a map of all the roads and buildings so they can show their services and customers. On the other hand, parcel information is essential for land tax and planning, although a considerable amount of tax is raised from levies on buildings;

(*h*) A key element in the pilot project is to determine what technology and sophistication is required for the establishment of a LIS for the City of Bangkok. It will be important to evaluate software and hardware maintenance and the reliability of the systems in Bangkok;

(*i*) It was quickly realized that education and training of staff in all the relevant organizations would be a key in the long-term success of BLIS. The project will have to develop a ten-year education and training strategy for the introduction of LIS/GIS which will require a major input from the academic institutions already involved in LIS/GIS in Thailand, such as the Department of Surveying Engineering at Chulalongkorn University.

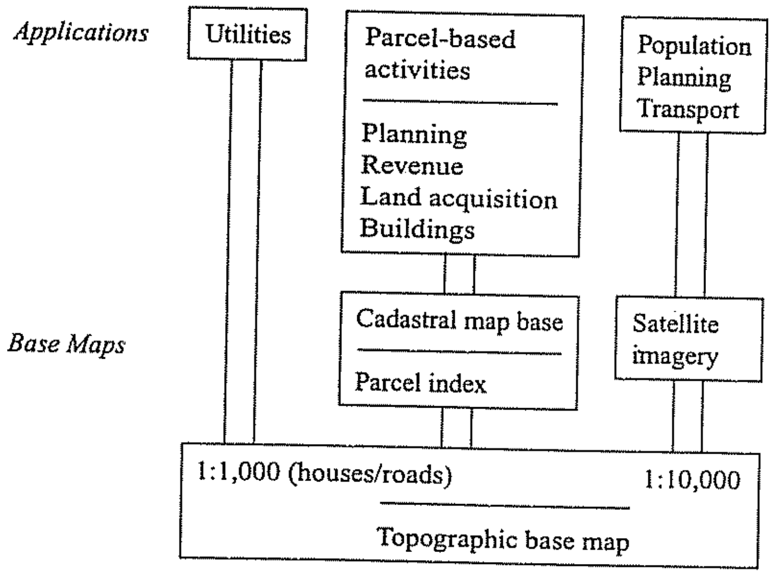
The Thai Steering Committee for the BLIS project realized that in the short term there was not sufficient experience in Thailand to undertake the pilot project. As a consequence Thailand asked for assistance from the Australian International Development Assistance Bureau (AIDAB). The assistance provided is a full-time land information system adviser for two years, provided by the Overseas Projects Corporation of Victoria (OPCV) and a Senior Adviser and Project Coordinator on a part-time basis, provided by the consulting arm of the University of Melbourne (UNIMELB). These advisers are not undertaking or managing the BLIS project. They will simply be drawing on their experience in establishing similar systems in Australia and overseas to give advice where required.

The overriding success of the project to date is the recognition that a LIS for the City of Bangkok will only be possible if the key agencies cooperate and coordinate their activities through an integrated approach.

### LINKS BETWEEN BLIS AND THE LAND TITLING PROJECT

The Land Titling Project (LTP) is an important initiative in Thailand which has had a major influence on the establishment of BLIS and has played a central role in establishing the topographic and parcel base map for BLIS (Angus-Leppan and Williamson, 1985; Angus-Leppan, 1988; Smith and Holstein, 1987; Williamson, 1990). The LTP is a major land administration project spanning 20 years, which has the objectives of issuing land administration in both rural and urban areas of Thailand and of establishing an equitable land valuation system. A major component of the LTP is to prepare up-to-date land parcel maps for Bangkok based on large-scale (1:1,000) aerial photomaps, together with the

*Diagram 1. Conceptual model for the BLIS project*



relevant parcel data, including valuation data provided by the new Central Valuation Office (CVA). These parcel data, together with the photomaps, will form an important part of the base data for BLIS. Without these data it would be difficult to establish BLIS in the proposed form. Approximately 2,000 cadastral index maps within Bangkok Metropolis have been produced at the end of the first stage of the project, i.e. 1990.

## THE BLIS PROJECT

### *Management Structure*

The overall management and co-ordination of the BLIS Project is by an inter-agency Steering Committee chaired by the Deputy Governor, BMA. Day to day responsibility for the Project rests with the BLIS project manager assisted by assistant project managers from each of the other organizations, who meet on a periodic basis. This group is responsible for all staffing, technical direction and administrative activities associated with the project.

### *Hardware and software*

Basically the system consists of six high performance SUN graphic workstations, each with a large digitizing table, cartridge tape and hard disk drive. Four NEC 386s PCs and printer are also included in the network, as is a laser printer.

The system also incorporates a Calcomp colour electrostatic plotter, pen-plotter, line printer and dual speed tape drive. The system is connected together via Ethernet cables and has a large Sunserver (3/480) as the main processor/storage device.

System software is based on ESRI's (Environmental Systems Research Institute) ARC/INFO graphics and database software.

### *Summary of work plan*

A detailed work plan has been produced for the duration of the project, which places the major emphasis on the training of the BLIS project staff in both the design of the system and in the development of software applications.

Recognizing that the BLIS project staff had little prior exposure to this type of technology within their own particular organizations, additional training courses were scheduled with the suppliers of the equipment, DIAL (Digital Information Associates Ltd.), to supplement the initial system hardware/software related training course.

The evaluation and clarification of user needs was a significant activity designed to ensure that the project staff and senior officials fully understood their organization's particular project goals in order that the design of the system reflected these needs. The close involvement of senior officers from each organization was sought in order to prioritize the various proposed applications of the system and to focus on these software development activities.

Regular demonstrations of the development of the system throughout the pilot period have been scheduled, illustrating the importance placed on the exposure of the system to staff from major user areas and senior officials in each participating organization.

The various project activities, such as collection and preparation of maps, establishment of data dictionary, development of data input procedures, field checking and verification etc., have been scheduled in a manner to ensure that good understanding is gained in each component.

### *Progress to date*

#### *Demonstration of a prototype area*

A small area of 0.5 sq km was selected as a prototype area for the purpose of creating an initial demonstration and to provide practical training on the system by the project staff following the system training courses. In addition, it also served to illustrate to senior officials, some examples of the potential applications of the system at an early stage of the project.

For this demonstration, the major graphical items of each authority, together with samples of associated attribute data were input onto the digital map base. Project staff approached the study enthusiastically and were able to produce impressive demonstrations of the system's capabilities to senior officers of their respective organizations during an official opening of the project at Chulalongkorn University in early October.

## BLIS PROJECT GROUPS

### *Broad objectives*

Although the objectives may differ according to the specific services for which each of the participating authorities is responsible, they all basically face the same problem: i.e., the lack of reliable and accurate existing base maps which tends to lead to inefficient use of resources, since most work associated with the base maps is performed on a case by case basis without continuous follow up.

### *Metropolitan Electricity Authority*

The Metropolitan Electricity Authority (MEA) hopes to realize a complete inventory of its network on a graphical base in order to improve its services by better maintenance and operation.

The Planning Division intends to complete a graphical database that includes the low voltage and street light network, which are currently not recorded on the maps. In addition, it is intended that the computer mapping system will provide input data to existing engineering software packages, such as the small area load forecast and the transformer load management packages.

### *Metropolitan Waterworks Authority*

Within the Metropolitan Waterworks Authority (MWA), three major objectives are sought from a system such as BLIS.

(*a*) Establishment of a network inventory in order to identify and exactly locate pipe segments and their appurtenances with corresponding house connections and meters;

(*b*) Short-term planning in order to efficiently operate the water-supply network and long-term planning associated with network analysis, designing of future works and evaluation of the performance of the existing systems;

(*c*) Ability to enable effective coordination with the other servicing authorities in exchanging reliable map-related data on underground and above ground structures and obstacles. This objective is seen as saving considerable time in the planning, designing and upgrading of services.

### *Telephone Organization of Thailand*

The proposed users of the Telephone Organization of Thailand (TOT) graphical database can be identified broadly as primary and secondary users. The primary or direct users consist of the Division of Outside Engineering, which is responsible for updating the map base with the telephone network layers and the Division of Demand Forecasting, which also requires the above data with, in addition, location of cabinets, distribution points, and land and building usage data.

Secondary users are divisions that require data concerning exact locations of buildings, roads, underground and overhead facilities and cadastral parcels.

### *The Department of Lands*

While the Department of Lands (DOL) is not a user of the proposed products of the BLIS Project, it provides the raw data to enable the 1:1,000 scale digital map base to be produced on the UTM coordinate base for the pilot area.

The staff from DOL, working full time on the project, are gaining invaluable experience in utilizing the system and experiencing first hand the development of BLIS on equipment similar to that used within the DOL.

### *Bangkok Metropolitan Administration*

As discussed previously, the BMA provides many services throughout Bangkok and as such, the potential applications of an operational BLIS are many and varied. However, the broad objectives of the major user areas are largely as follows:

(*a*) The City Planning Division's main objective is to establish and maintain current base map data including building records covering the entire Metropolis;

(*b*) The Public Works Department needs accurate, current, building map-sheets, up-to-date inventory of the road network and existing signboard locations and a system that provides coordination and exchange of records with the other utility organizations;

(*c*) The Drainage and Sewerage Department's greatest need is for constructed drawings and current base-map data which facilitates coordination and data exchange with the MWA network;

(*d*) The Department of Finance requires current cadastral map-sheets and current building records in order to correlate the graphic and non-graphic data sets as a basis for improving revenue collection and identifying those who avoid payment;

(*e*) The Policy and Planning Department basically requires access to all of the data stored in a LIS, including a tax database, cadastral file and even recorded BMA enterprises, with corresponding statistical data.

## LESSONS

Even though the BLIS pilot project is only nearing completion of the first year of a two-year programme, there are to date a number of key lessons arising from the project, as follows:

(*a*) The cooperative effort between the key land management authorities in the City of Bangkok is proving successful; however, it has been essential to give feedback on the project as soon as possible. For this purpose, the project organized a comprehensive seminar three months after the equipment was commissioned which proved successful in maintaining the momentum and progress of the project;

(*b*) It is important for the respective authorities to make a significant commitment of money and staff to the project. Without such commitment it may be difficult to maintain the long-term support of the authorities;

(*c*) One of the most difficult aspects of the project has been the establishment of an independent Thai Government Unit within the BMA to manage the project. However, once established, it gained a momentum of its own, which was essential for the project to proceed. As in any government organization worldwide, to instal a new office and facilities supporting a high technology project with over 20 staff is not easy. The success of the project to date is due to the perseverance of a number of key senior Thai Government officials who fully support and believe in the project;

(*d*) The roles of the Australian advisers have proven essential in establishing the project, especially the experience of the full-time adviser. In addition, the three monthly visits of the senior adviser has allowed the project to focus regularly on performance against objectives. Without the support of AIDAB for the project, it is unlikely that it would have progressed as planned;

(*e*) A key to the success of the project has been the full support of Thai Government officials at the most senior levels. This support has come from elected officials as well as the permanent officers in all the participating authorities. Without this support the project would definitely not have commenced;

(*f*) The importance of undertaking a comprehensive pilot project is proving a very worthwhile decision. Already a significant number of directions with regard to identifying a common base map and the appropriate associated indexes, and methods of capturing and maintaining those data, are becoming evident. The pilot project certainly confirms the view that the establishment of a comprehensive land information system is not easy and that many technical, institutional, management and personnel problems must be overcome;

(*g*) It is heartening to see that the Thai authorities are taking a long view of the creation of BLIS. They are placing significant emphasis on the determination of a clear and simple vision for the future. The pilot project will ensure that the vision and the long range plan are reasonably achievable;

(*h*) Already the pilot project has highlighted the very real differences of user needs between digital mapping, land information systems, facility information systems and geographic information systems. Briefly, the user needs and requirements for each of these systems is not the same;

(*i*) The pilot project has also highlighted the different needs for education and training. At the operator/technician level there is a requirement for basic training in the system. At the professional level there is a whole range of requirements, generally divided between operation and management of the system. It will take at least a year of education to teach the scientific, technical, management and institutional theory underlying development and operation of LIS/GIS/FIS.

## CONCLUSION

The Bangkok Land Information System Project is proving to be a successful and valuable initiative for all the participating authorities. To date the strategy to develop a cooperative pilot project linking key land management authorities in Bangkok is proving successful; however, this is not by accident. The Thai authorities, over the last five years, have seen numerous LIS/GIS studies from countries that have their own successful systems. In the traditional Thai style, the country is learning from the mistakes of others to develop a system that will serve the particular needs of the City of Bangkok. While the experiences of the BLIS Project will not be directly applicable to other countries around the world, the project should provide to others some valuable lessons and experiences.

There is no certainty that the BLIS project will make a major contribution to an improved management of the City of Bangkok. In order to fully introduce land information management principles across the city would require enormous costs, major institutional changes, a very large education and training programme and a fundamental change in government culture spread over at least ten years; on the other hand, there could be very significant economic benefits arriving from such a programme. What the project will definitely do, however, is help to determine what is possible and what systems and technologies are applicable. Unfortunately, Bangkok and many similar cities do not have a choice; they must explore every possibility and opportunity to improve their management. At this point in time land information management offers one of the best hopes.

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## THE COUNTY OF OXFORD LAND-RELATED INFORMATION SYSTEM*

*Submitted by Canada*

### RÉSUMÉ


Le Système d'information foncière (LRIS) du comté d'Oxford incorpore les données de six bases de données des gouvernements provinciaux et fédéraux, et des municipalités locales, grâce à un système d'information géographique. Le LRIS offre une ressource commune, partagée entre huit municipalités locales et le comté d'Oxford. Les données intégrées sont accessibles par des sous-systèmes axés vers la tâche, à partir de menus qui permettent aux usagers avec plus ou moins de connaissances en informatique d'afficher, de récupérer, de mettre à jour et d'ajouter de l'information. La conception et la réalisation du système ont changé l'organisation institutionnelle interne et interdépartementale au niveau municipal et au niveau du comté. De plus, grâce au développement d'applications spécifiques, le système commence à se refléter sur le personnel et le processus de prise de décisions politique. Les deux caractéristiques qui rendent unique le LRIS du comté d'Oxford sont l'accès partagé et l'intégration des bases de données gouvernementales.


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The County of Oxford has been an early participant in the development of an integrated municipal land-related information system (LRIS) in Ontario. The province defined the first step when, in 1983, the Ontario Ministry of Natural Resources conducted a "User Needs Study" examining the needs of municipalities for digital geographic and land related information. As part of the user needs study, detailed interviews were conducted with the county and the City of Woodstock. The study evaluated their use of mapping data and existing manual and computerized tabular data and concluded that municipalities required a parcel database asssociated with other locally generated and topographic data.

In 1985, Oxford County proceeded to implement the study's recommendations and create a land-related information system (LRIS) as an integrated corporate database for the county and eight local municipalities. The County was restructured in 1975 and today consists of eight municipalities, five rural townships, the Town of Ingersoll, the Town of Tillsonburg and the City of Woodstock which form part of the county level of government. The county's population of approximately 87,000 is evenly split between urban and rural residents. The provision of hard services, such as sewer, water and waste disposal as well as overall county-wide planning policy, approval of plans of subdivisions, severances, health care, social services and financial responsibilities such as debenturing are provided at the county level. The local municipalities are responsible for the maintenance and operation of many of the hard services, as well as local planning implementation, recreation, transit and tax billing.

In implementing a county-wide LRIS, the county recognized that the input of data to the system would far exceed the costs of installing and maintaining hardware and software. The initial costs of hardware and software were approximately $800,000 in 1986, with total costs for full implementation approaching $1.2 million. On an annual basis, the county expends approximately $350,000 to maintain hardware and software and the telephone communications system to provide the corporate database to all municipal-

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ities. To maximize the efficiency of establishing a county-wide LRIS, the county established two major goals early in the project; one, to maximize the input of data from provincial and federal sources, both graphic and tabular and two, to integrate and share this system among as many municipalities and agencies as possible. It was recognized that the major obstacle to an effective implementation would be organizational and institutional problems arising from the level of coordination required between both provincial and federal ministries as well as among county and local municipal departments.

### Hardware and software

The "User Needs Study" identified the requirement to establish relations using topologically related data as well as the need for a database management system that could effectively handle a transactional system. In 1986 the system was implemented using ESRI ARC/INFO geographic information software running on a PRIME mini-computer in an office environment. The County of Oxford did not have computer staff and required a system where existing staff could be efficiently trained to oversee both system administration as well as ongoing maintenance of the graphic and tabular databases. Since 1985, two staff have been added to the organization to provide computer programming for the review and development of user applications. Otherwise, substantial retraining has occurred of existing county and local staff for intensive users and the development of a simplified menu system to provide access to the data for a typical municipal user, such as building inspectors, planners and clerks. As applications were developed, it was recognized that a more sophisticated database management programme was required to effectively implement and integrate a transactional municipal system, and the development of the system was migrated to the ORACLE database in 1988.

The system currently has 120 users spread among staff of nine municipal and other agencies, which are connected to the central county computer with dedicated telephone lines. The communication system also provides access for each user to the automated POLARIS title index of property transactions stored on the province's IBM mainframe computer in Toronto. Since the original hardware installations, there has been a continual need for increased storage capacity and the addition of new disk space on the system. In addition, the number of users together with the requirements for intensive graphic display has put a considerable strain on the existing PRIME system. In 1989, the county moved to augment the hardware with a SUN workstation, which provides an additional file server for approximately 20 intensive users, and approximately 1.5 gigabytes of additional storage. The design of the county LRIS has always proceeded in spite of hardware limitations, with software development far outpacing upgrades of hardware. This has been a practical solution in a small municipality where the benefits and justification for the implementation of an expensive LRIS have had to be proven in advance of expenditures for hardware upgrades.

### Data sources

In line with the county's goal to maximize the use of outside data sources, the LRIS has effectively integrated diverse sets of land data from federal, provincial, county and local municipal sources. The core of the system is the provision of parcel data, both graphic and tabular which has been transferred from the Ontario Ministry of Consumer and Commercial Relations responsible for property transactions in the province. The graphic data was input by coordinate geometry from original deeds and surveys into an integraph system and effectively transferred to the county's ARC/INFO system. The Ministry of Consumer and Commercial Relations also provides an automated title index of property transactions which is transferred through the county's communication systems on-line approximately once a week.

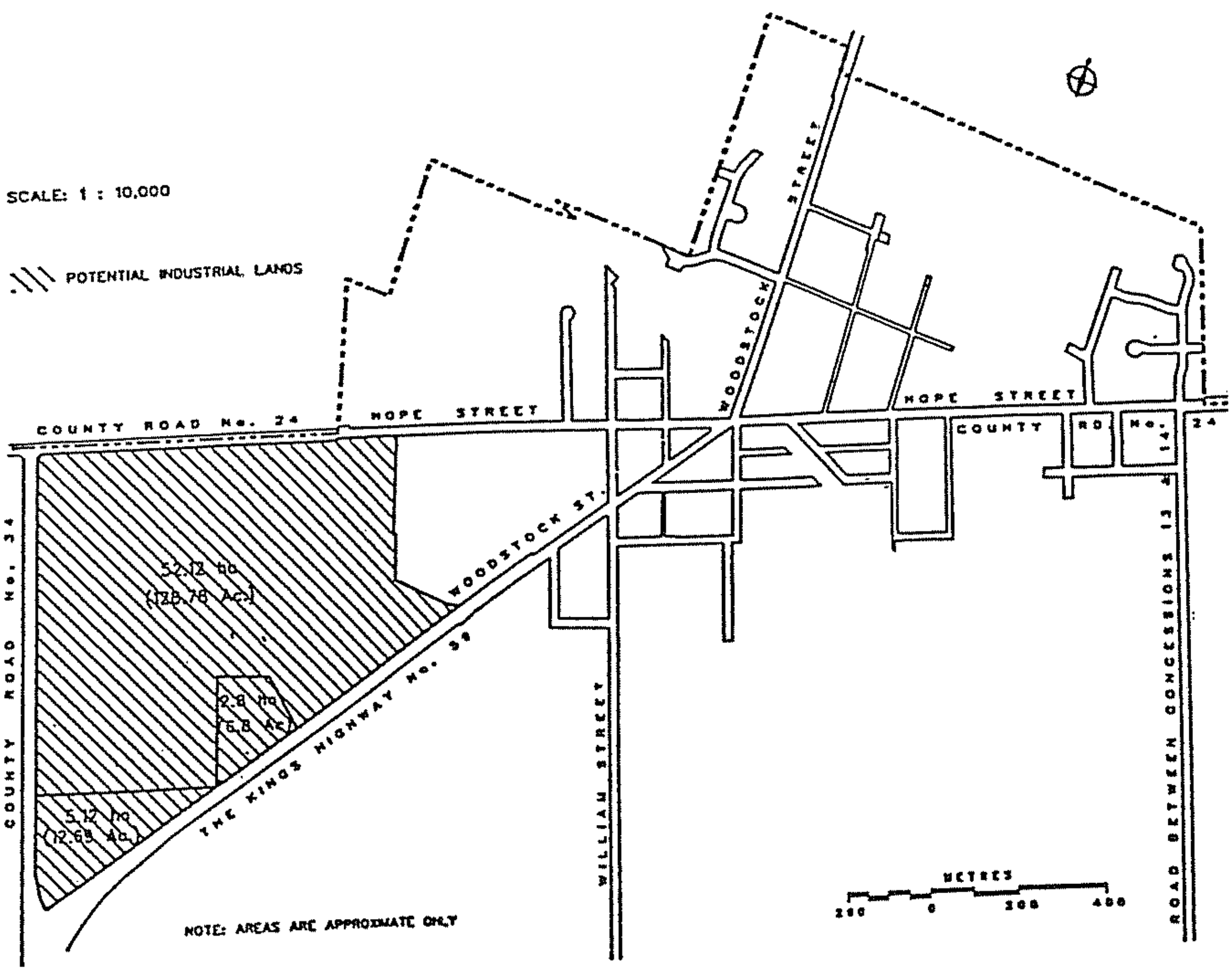
A digital topographic database tied to ground control and based on UTM coordinates provides the built environment at scales 1:2,000 and 1:10,000, as well as land features such as soils, drainage systems, contours and vegetation. A digital street network with address matching was provided from the Statistics Canada Area Master File and it also gives the county access to census information by specialized geographic areas. The Ontario Ministry of Revenue provides a master assessment and population database for all properties and structures within the county, by tape transfer on a yearly basis. From the municipal level, the county system integrates a wide range of data, including the location of hard services such as water lines, zoning and official plan designations, land use and Conservation Authority flood lines, which are linked to the parcel-mapping database.

While the county LRIS has established that municipalities can effectively integrate a diverse set of graphic and tabular data, the county is still in the process of resolving the update issues for outside and local data (see figure 1). From the experience of 120 municipal users, from a broad range of departments, the county has clearly identified the intolerance of municipal users for out-of-date information. Resolving the update issue has been largely an organizational and institutional problem rather than a technical issue and has meant that the county has had to establish that there is a mutual benefit for provincial and federal agencies in maintaining and sharing data between government levels. It has been our experience that the agency responsible for the data is best equipped to provide both the original input as well as ongoing update functions. Also, we have strived to maintain the update function as part of ongoing day-to-day operations of municipal departments rather than creating updates as separate tasks. For example, the input of "as built" structure surveys is part of the building permit application function of the system, and can provide updates to the digital infrastructure layer of the 1:2,000 topographic mapping as well as the tabular structure data of the assessment system.

#### *Institutional impacts*

The greatest impact of the system's implementation has been the institutional changes within and between municipal departments as well as relationships with provincial ministries. The sharing of the corporate database has allowed departments to rely on the input of data from other department functions. For example, the Building Department can rely on the input of zoning from the Planning Department which is responsible for the maintenance on-line of up-to-date zoning changes. The Ministry of Consumer and Commercial Relations is working with the county to make the county responsible for the update of parcel mapping based on the county's approval function for plans of subdivisions and severance which change the parcel fabric. The result has been a redirection of the flow of data between organizations to more effectively represent the original source of data. These types of organizational changes can be construed as invasions of territories or interference in the operation of departments. We have relied on establishing mutual benefit to departments to compensate for the perceived threat of changed systems.

Figure I. Potential industrial lands: village of Tavistock




It was also critical during the implementation of the Oxford LRIS to achieve a high level of political senior management support for the implementation of an integrated corporate database. Politicians and senior staff have been involved in organizational decisions as well as the initial "User Needs Study" and hardware and software selections. The system has also been developed with a high public profile in the local communities ranging from utilizing the system in workshops and seminars with agencies such as a local real estate board to extensive demonstration and tours to schools from elementary to high-school levels.

## Impacts of the Land-Related Information System

As well as maximizing the efficiency of day-to-day operations of municipal departments, the LRIS was designed to improve access to information and as part of the decision making-process at the municipal level. The system is used for special projects that often have a high political profile in the community and require decision-making in a contentious environment. For example, the City of Woodstock was faced with a critical problem in their provision of fire service within the community. In the past the city had operated two fire stations, one of which, built in the 1890s, was located in the downtown area of the city. The building could no longer function as an adequate fire station and the city was forced to move firemen into temporary quarters that were not ideally suited to provide adequate fire protection to the community. It was difficult to search for a new fire station location in older established areas of the city while avoiding land-use conflicts. Initial discussion of the issue resulted in wide divergence between politicians and staff as to the appropriate site or location for a new fire hall and there was no way, using traditional decision-making tools, to determine the best location to meet established criteria of access and reduced impact.

The city utilized the LRIS to provide a complex analysis of the most appropriate street locations in the city to begin searching for specific properties suitable for a fire station. The database includes a street network with address matching, prepared in conjunction with Statistics Canada. Attached to each segment was an impediment level designed for the City's five vehicles; this included the speed of the street segment taking into account traffic volumes and grades, stop signs, stop lights, turning movements, one-way streets, railway crossings, bridges, load limits etc. This allowed the street network to simulate the movement of fire trucks throughout the city. Data from fire response call-sheets for a period of two years was input into the system which established a geographic distribution for types of fires across the municipality. The structure data of the assessment database provided information by street addresses regarding the land-use categories and ages of buildings which, when linked to fire calls, enable the establishment of a pattern of high fire-risk structures.

Discussions with the Council identified buildings where it was critical to provide efficient fire protection, such as hospitals, schools and nursing homes. Again by extrapolating the land-use codes from the assessment and local data, properties were factored in terms of their demand for rapid fire response. By totalling the factors for risk and cost along street segments, certain areas of the city were weighted as being high-priority areas for fire protection.

The analysis required a large data matrix and entailed calculations, using the street network, the time from each intersection to every other intersection in the city, weighted with the factors for access to properties of high risk and high cost. The intersections which minimized travel time and maximized access to high risk and cost properties were identified for the council. To involve the council in the decision-making process, interactive models were developed on the computer allowing a method to test hypothesis for site locations to produce instant responses on the screen. This on-line testing process established a credibility for the results of the computer analysis and was able to satisfy public concerns that the decision reached was logical for the city's requirements. After the analysis narrowed the search, the detailed property mapping together with infrastructure data such as buildings, driveway locations, contours and vegetation, were produced to analyse, on a small scale, appropriate sites within the selected areas. The result was a unanimous Council decision which they had confidence in defending publicly.

As the cost of providing municipal services escalates, it is important to effectively demonstrate that municipalities are providing an effective and efficient service. By utilizing LRIS to locate an expensive capital project such as a new fire hall, the county has begun to realize benefits from the implementation of the system. Other expensive municipal services, such as garbage collection, can be analysed in a similar way.

### Conclusion

While the County of Oxford has not conducted a formal cost-benefit analysis of their implementation of a county LRIS they are beginning to perceive the benefits arising from improved access to land information for municipal staff and an improved basis for decision-making at staff and political levels. The county has achieved its goal of effectively integrating provincial, federal and municipal data sources and is currently tackling the more critical issues of long-term maintenance and update of integrated data.

## MÉTHODE DE SAISIE DE LA COUCHE OCCUPATION DU SOL DE LA BASE DE DONNÉES CARTOGRAPHIQUES DE L'IGN-FRANCE*

*Document présenté par la France*

### SUMMARY

Work has begun on the compilation of a cartographic database that will cover the entire territory of France. The database has nine layers (road network, railway network, linear hydrography, inter-network crossings, powerline network, isolated objects and other networks, administrative units, relief features and land use). Data gathering for the first seven layers will be completed by the end of 1991. Data gathering on land use has just been commenced, and the exercise is expected to require from 90 to 100 man-years to complete. Among possible uses for this layer are base-line maps, environmental studies (pollution, nuisances, etc.) and studies for the installation of telecommunications transmitters involving digital terrain models.

Following an initial study phase, IGN opted for a simple land-use reference system and a new data-gathering method. Depending on the reference system headings, one of the following three processes is used: scanning, automatic image processing and interactive data gathering using a geographical information system equipped with an image-based digitalization unit.

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### Le contenu de la couche occupation du sol

#### *Structure des données*

Les données, conformément aux spécifications générales (Salgé, Sclafer, Faad) de la base de données cartographiques (appelée bdcarto), sont structurées en trois niveaux :

Géométrie : elle est bidimensionnelle.

Topologie : elle est composée de trois types d'objets (faces, arcs et sommets) et des relations de proximité entre ces objets.

Sémantique : on distingue les objets simples (constitués directement par des objets topologiques) et les objets complexes.

Le schéma suivant (modèle conceptuel des données représenté avec le formalisme HBDS (Bouillé, 1987) résume la structure des données d'occupation du sol de la base de données cartographiques (bdcarto).

*The original text of this paper, prepared by M-C Combes, Institut géographique national, appeared as document E/CONF 83/L 46

*Définitions*

Les domaines homogènes forment une partition de l'espace. L'attribut "nature" les décrivant peut prendre une des 16 valeurs suivantes ou la valeur "autre": bois, vigne, verger, broussailles, surface minérale à nu, bâti, infrastructure de communication, eau libre, eau douce non permanente, eau douce non permanente avec végétation, mer, sable dans l'estran, rochers dans l'estran, zone mixte dans l'estran, eau libre dans l'estran, névés et glaciers. On a ainsi une légende composée de 17 thèmes. Des spécifications détaillées définissent ces 17 thèmes et leurs critères de sélection; critères de surface (surfaces minimum) et/ou critères de forme (longueur, largeur minimum). La plupart des domaines homogènes sont retenus à partir de 4 ha ou 2 ha pour le bâti. Seize des thèmes correspondent à une logique "occupation du sol", seul le thème "infrastructure de communication" correspond à une logique "usage du sol"

Les toponymes sont affectés à des objets complexes (agglomération, ...). Un domaine homogène peut appartenir à 2 objets complexes et porter ainsi 2 toponymes (cas d'un parc compris dans une ville : il est concerné par le nom du parc et le nom de la ville). Un toponyme est affecté à un objet et non à une position $(x,y)$ : il s'agit bien de constituer une base de données et non un fichier numérique destiné uniquement à des utilisations de type cartographie automatique. Pour affecter un toponyme, on est parfois amener à morceller un domaine homogène, les limites créées étant alors plus ou moins arbitraires (cas d'une zone de bâti constituée de quartiers de différentes dénominations).

*Généralisation*

La généralisation est une opération que l'interprète effectue implicitement et souvent de façon subjective. Afin d'assurer au maximum l'homogénéité des données d'occupation du sol, on a tenté de spécifier les règles de généralisation à employer. Ces spécifications comprennent deux parties :

*Généralisation de la géométrie des contours* : les règles définies sont en accord avec la précision décamétrique de la bdcarto.

*Généralisation due aux critères de sélection* : les règles définies permettent de répondre à la question "Que faire d'une parcelle de tel thème dont la surface ou la forme ne vérifient pas les critères de sélection ?". On a donc établi des coûts relatifs de rattachement entre un thème de la légende et les 16 autres thèmes possibles (il est "moins coûteux" de rattacher une petite parcelle de broussailles à une parcelle de bois qu'à une parcelle d'eau)

*Cohérence avec les autres couches*

Les différentes couches de la bdcarto doivent être en cohérence :

*Cohérence au niveau géométrique et topologique* : un axe de route et une limite de lac séparés par moins de 50 m sur une distance suffisante partagent la même géométrie;

*Cohérence au niveau sémantique* : on crée les relations entre des objets de la couche ocupation du sol et des objets d'autres couches (par exemple, "une agglomération contient un sommet du réseau routier").

*Sources des données*

La source des données d'hydrographie zonale est mixte : elles proviennent de SPOT et de la carte au 1/50 000. Une image SPOT étant une prise de vue instantanée, elle ne permettrait pas d'extraire correctement toutes les données d'hydrographie (en particulier, les laisses et les limites de zones inondables).

Les thèmes "vigne" et "verger" sont également pris sur la carte au 1/50 000. SPOT ne permet pas de les distinguer partout et sans ambiguïté.

Les autres thèmes proviennent des images SPOT-XS, soit par photointerprétation (broussailles, surface minérale à nu, bâti, infrastructure de communication, autre), soit par classification automatique (bois).

## LA MÉTHODE DE SAISIE

*La chaîne de saisie de la bdcarto*

La saisie des données s'opère couche par couche et département par département (découpage administratif de la France). Le département constitue ce qu'on nomme un chantier. Un chantier est couvert par un certain nombre de feuilles au 1/50 000, la feuille au 1/50 000 étant l'unité élémentaire de saisie. La chaîne de saisie de la bdcarto est calquée sur cette organisation de production :

*a*) Les chantiers terminés sont stockés actuellement sur bandes magnétiques et plus tard sur le serveur général que l'IGN compte acquérir d'ici 1 à 2 ans;

*b*) Un chantier en cours de saisie (ou de mise à jour plus tard) est stocké sur un des serveurs de chantier (serveur SUN, logiciels *ARC/INFO* de la société ESRI et *Oracle* de la société ORACLE CORPORATION);

*c*) Au fur et à mesure de l'avancement du travail, les données concernant une feuille au 1/50 000 sont extraites du serveur de chantier, traduites au format du logiciel *Tigris* (réf 5) et envoyées sur un des postes interactifs (station de travail INTERPRO et logiciel *Tigris* de la société INTERGRAPH);

*d*) Lorsque la saisie d'une feuille est terminée, les données sont renvoyées sur le serveur de chantier, traduites au format du logiciel *ARC/INFO* (Salgé *et al.*, 1990) contrôlées visuellement (dessins de contrôle) et automatiquement avant d'être raccordées et fusionnées avec les feuilles adjacentes.

A ces trois grandes fonctions de la chaine de saisie bdcarto (serveur général, serveur de chantier, poste interactif), s'ajoutent deux fonctions de saisie automatique des données :

*a*) Gravure puis scannage et vectorisation sur le système SEMIO de l'IGN;

*b*) Traitement d'image automatique sur le système TRIAS de l'IGN (logiciel : IGN, matériel VAX de la société DEC, consoles I2S).

La configuration informatique de la chaîne de saisie est donc la suivante, chaque réseau local correspondant à un atelier de saisie.

*La méthode de saisie de l'occupation du sol*

*Les thèmes d'hydrographie zonale*

Les domaines homogènes sont sélectionnés sur la carte au 1/50 000; leurs contours sont gravés, puis scannés. Les fichiers obtenus sont alors codés (attributs "nature" et "toponyme") sur des consoles du système SEMIO, puis vectorisés. Les feuilles terminées sont archivées, puis envoyées sur un des serveurs de chantier au moment de la saisie des autres thèmes d'occupation du sol. Là, une procédure automatique assure la mise en cohérence géométrique avec les autres couches (réseaux routier et hydrographique). Les fichiers sont ensuite envoyés sur un poste interactif pour la saisie des thèmes restants. L'image SPOT étant affichée, on peut alors corriger ou compléter ce qui a été saisi d'après la carte au 1/50 000.

*Le thème bois*

A partir de 1991, il sera extrait automatiquement par classification automatique des scènes SPOT-XS. Avant de vectoriser les fichiers maillés ainsi obtenus, on effectuera des opérations de lissage destinées à éliminer les petites zones et généraliser les formes. Les fichiers vecteurs des contours de bois seront alors envoyés sur un des serveurs de chantier pour y être découpés en unités de saisie (c'est-à-dire en feuilles au 1/50 000). Une procédure automatique assure la mise en cohérence géométrique avec les autres couches.

Actuellement, ce thème est saisi avec les thèmes restants, par photointerprétation à l'écran.

*Les thèmes restants*

Ils sont saisis sur poste interactif. A l'écran apparaissent initialement l'image SPOT-XS en composition colorée et les données correspondant aux couches déjà saisies (réseaux routier et hydrographique) et aux thèmes provenant d'une saisie automatique (hydrographie zonale et bois). Une fonction du SIG permet de caler ces données maillées et vecteurs entre elles. On cale alors sur la table à numériser la carte au 1/50 000 et on peut commencer à numériser les zones correspondant aux thèmes restant à saisir. Cette méthode de saisie permet d'assurer dès le départ le partage de géométrie avec les autres couches (une limite de bois qui devrait suivre un axe de route n'est pas numérisée, on s'appuie sur l'axe de route déjà saisi et présent à l'écran).

*L'enchaînement des opérations*

On distingue cinq grandes phases :

*Phase A : saisies automatiques.* Cette phase fait intervenir le scanner du système SEMIO et le système de traitement d'image TRIAS ainsi que le SIG *ARC/INFO* pour le découpage de données par feuille au 1/50 000 et la mise en cohérence géométrique. Cette dernière opération n'est pas une fonction standard d'un SIG (que ce soit *Tigris* ou *ARC/INFO*) et a donc demandé une analyse puis une programmation à l'aide du langage de macro-commande d'*ARC/INFO*.

*Phase B : préparation des données pour la saisie interactive.* Il s'agit de préparer les images SPOT (corrections géométriques au niveau trois calculées à partir de la base de données altimétriques de l'IGN, améliorations radiométriques, découpage par unité de saisie et mise au format maillé *Tigris*) et les données vecteurs (les extraire du serveur de chantier et transformer le format *ARC/INFO* en format *Tigris* (Salgé *et al.*, 1990). Les opérateurs préparent aussi un calque de toponymie (sélection des toponymes sur la carte et dessin des contours des zones auxquelles ils seront affectés).

*Phase C : saisie interactive.* On saisit les contours manquants (on entend par contour manquant un contour dont la géométrie n'existerait pas déjà soit en tant qu'axe de route ou rivière, soit en tant que frontière d'un domaine de bois ou d'hydrographie). On crée alors les domaines homogènes en choisissant leur nature puis en pointant une à une les faces topologiques qui les constitueront (mode de numérisation "place by face" du SIG *Tigris*). On code les toponymes à l'aide du calque de préparation.

Cette phase comprend aussi les opérations de corrections de géométrie ou de codage d'attribut.

*Phase D : contrôles.* Ils sont de divers types et effectués par divers acteurs :

*a)* L'opérateur peut lancer des contrôles automatiques en fin de saisie d'une feuille au 1/50 000 : on vérifie ainsi la notion de partition de l'espace (chaque face topologique appartient à un et un seul domaine homogène) et le respect des critères de sélection portant sur la surface des domaines homogènes;

*b)* A l'aide d'un dessin de contrôle, l'opérateur vérifie la saisie des toponymes par comparaison avec le calque de préparation;

*c)* Le contrôleur vérifie ensuite, sur fond d'image SPOT à l'écran, l'interprétation et la généralisation des fichiers que les opérateurs ont terminés (il peut utiliser *a priori ARC/INFO* ou *Tigris*, ces deux SIG possédant des fonctions d'affichage de données vecteurs sur fond raster);

*d)* Enfin, un contrôle qualité *a posteriori* est mené par sondage aléatoire (inspiré de la méthode des segments utilisée par le SCEES, organisme français dépendant du ministère de l'agriculture [Scees, 1986] sur des prises de vue aériennes au 1/30 000. Les zones échantillons sont numérisées sur *Tigris*, puis envoyées sur un serveur de chantier et traduites au format *ARC/INFO* [Salgé *et al.*, 1990]. Les calculs de critères de qualité [Bianchi, 1990] pour la définition) par croisement des données de la bdcarto et de ces zones-échantillons sont effectués à l'aide du SIG *ARC/INFO*.

Dès que l'expérience acquise sur les premières saisies nous donnera une idée plus précise des valeurs que peuvent prendre ces critères, nous définirons des seuils d'acceptation ou de rejet des données de la zone concernée.

*Phase E : intégration en base de données.* Cette dernière phase se résume en trois opérations :

*a)* Raccord et fusion des feuilles adjacentes pour créer un seul fichier sur le chantier (ou département) en cours;

*b)* Contrôle de la cohérence des données de ce fichier par rapport aux spécifications de la bdcarto;

*c)* Structuration des données selon le schéma relationnel de la bdcarto : création des objets complexes et des relations avec les autres couches.

## ORGANISATION DU TRAVAIL

De la méthode de saisie qui vient d'être décrite découle une organisation du travail où l'on distingue quatre types d'acteurs :

*Le préparateur et gestionnaire des données* : il s'occupe de la gestion de données sur le serveur de chantier et des changements de format des données (phases B et E);

*Le contrôleur* : le profil correspond à un photointerprète expérimenté. Il assiste les opérateurs dans les cas d'interprétation ambiguë (phase B) et il contrôle les feuilles dont la saisie est terminée (phase D);

*L'assistant informatique* : il assiste les opérateurs et le préparateur dans l'utilisation des logiciels et du réseau informatique. Il intervient en cas de panne sur un des systèmes;

*L'opérateur* : il a en charge la saisie, les corrections et les premiers contrôles. Au départ, il n'est pas photointerprète de formation. Il a donc à s'habituer au travail d'interprétation suivant des spécifications précises, dans un environnement de type SIG. Il est associé, au travers de réunions régulières, au travail de complément ou de précision des spécifications au fur et à mesure des cas particuliers rencontrés.

### Conclusion

Il reste encore à définir une méthode de mise à jour des données d'occupation du sol de la bdcarto. L'intention de l'IGN est de mettre au point un processus plus automatisé que la méthode utilisée pour la saisie initiale. A base de traitement d'images SPOT, ce processus ne devrait nécessiter comme travail interactif qu'une phase finale de contrôle et retouches. Les algorithmes classiques de segmentation ou de classification ne seront pas suffisants car il faudra tenir compte des points suivants :

*a*) Contenu de la version précédente de la couche occupation du sol de la bdcarto et probabilités de changement entre deux thèmes sur la période entre deux mises à jour (une zone de bois peut devenir une zone de broussailles, mais une zone de bâti ne peut devenir une zone de bois);

*b*) Généralisation effectuée lors de la saisie de cette version précédente (on ne mettra pas à jour un contour de domaine homogène si la correction géométrique à apporter est de l'ordre du déplacement dû à la généralisation effectuée lors de la saisie précédente).

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## (d) *Geographical information systems*

# FOREST MANAGEMENT AND GIS: LESSONS LEARNED IN NEW BRUNSWICK*

*Paper submitted by Canada*

### RÉSUMÉ

Cet article analyse et fait la chronique de l'évolution de la gestion forestière et d'un SIG au Nouveau-Brunswick. Il débute par une explication du raisonnement derrière le lien foresterie-SIG suivi de l'élaboration du SIG et la gestion forestière. Cet article démontre que la prise de décisions en gestion forestière, qui dépend du temps et de l'emplacement, fait du lien foresterie-SIG un lien naturel. Ensuite, par l'examen de l'évolution et de l'orientation future attendue d'un SIG au Nouveau-Brunswick, on établit le rôle et l'impact d'un SIG en gestion forestière. L'article conclut que le SIG a un role à jouer dans les quatre aspects de la gestion forestière : l'inventaire; le scénario de gestion; la mise en œuvre sur le terrain des interventions de gestion forestière; et la surveillance de la réaction forestière face aux interventions de gestion. Par contre, même s'il est évident que le Nouveau-Brunswick a développé des applications d'un SIG pour l'inventaire, la mise en œuvre et la surveillance, l'article constate qu'il ne semblerait pas y avoir d'organisation ayant fait d'incursion significative dans l'application d'un SIG au scénario de gestion. L'article révèle les impacts de la gestion dans la réduction de l'incertitude des décisions, la prise de décisions plus éclairée, l'accélération du processus de prise de décisions, l'ouverture de nouvelles opportunités en gestion et l'encouragement de la recherche dans d'autres disciplines. Finalement, l'article indique qu'un SIG occasionne des effets organisationnels, soit l'introduction de nouvelles procédures pour rassembler l'information, de nouvelles exigences en traitement, de nouveaux produits de sortie, de nouvelles responsabilités du personnel et de nouveaux coûts.

New Brunswick is an acknowledged pioneer and leader in forest management in Canada (see figure I). Because the well being of the province is so heavily dependent upon its forest resource, a serious commitment has been made to forest management as an essential province-wide undertaking. Evidence of this commitment lies in three important initiatives taken in the early 1980s to promote the type of management necessary to sustain the desired flow of benefits from New Brunswick's forest. First, in 1980, new legislation was introduced to establish a policy environment conducive to long-term decision-making (New Brunswick Crown Lands and Forests Act, 1980). Secondly, in 1981, a new forest resource inventory was undertaken to provide reliable information underpinnings for the decision-making. Finally, in 1982, geographic information system technology (GIS) was acquired to provide necessary tools to manage the resource information in support of decision-making.

The Timber Management Branch (TMB) of the Department of Natural Resources, charged with implementing many of these efforts, chose and installed ARC/INFO to meet its anticipated GIS requirements in forest management. This installation, the first of ARC/INFO worldwide, marked the beginning of a forestry-GIS phenomenon that has since swept much of Canada and the United States.

*The original text of this paper appeared as document E/CONF.83/INF.50

Figure I. The Province of New Brunswick, Canada


The installation and use of GIS in TMB effectively provided necessary information handling technology but, more importantly, it set an example for GIS use in forestry that has been picked up by industrial managers and university researchers in the New Brunswick forestry sector. To date, four industrial and two academic GIS installations are in place. As a result, the province is now in the enviable position of having: (*a*) a serious and demonstrated commitment to forest management; (*b*) a complete seven million hectare (ha) digital forest resource database; (*c*) a substantial pool of professionals, distributed across several agencies, with in-depth GIS understanding and skills; and (*d*) a seven-year accumulation of experience in implementing and using GIS in the practice of forest management. From that position, this paper will elaborate on the forest management-GIS linkage, and consider the role and impacts of GIS in forest management, now and in the future.

## THE FORESTRY-GIS LINK

In recent years the introduction of forest management legislation and programmes arising from public concern for the state of their forests and dependent forest industries has been commonplace. At the same time the proliferation of GIS technology within Canada, particularly in the forestry sector, has been evident (Tomlinson, 1987). The coincidence of these phenomena may be more than accidental.

Forest management, like other types of management, is dependent upon availability of data describing the resource to be managed and by the extent to which these data can be transformed into information useful for decision-making. However, forest management requires data that describe the present and future forest resource in terms of both conditions and their geographic distribution. These spatial data typically consist of conventional inventory data that describe the physical condition of the forest's component stands and cover-type maps that define the geographic location of stands (see figure II). It is for this reason, therefore, that forest management programmes generate a great demand for computer-based, information-handling systems capable of accommodating both data types. GIS is an obvious choice for forestry because such systems are unique in providing that capability. Thus, the forestry/GIS link is a logical one, and it could be argued that this link has pushed GIS technology to its current place of prominence in North America.

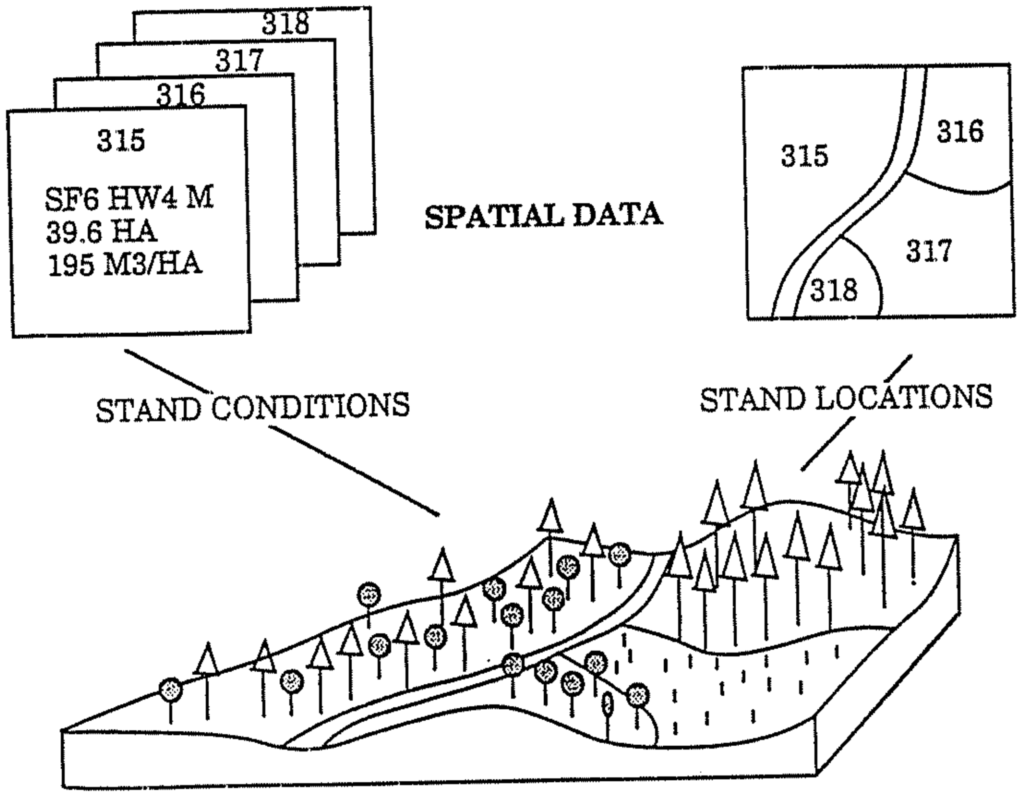
## THE ROLE AND IMPACT OF GIS IN FOREST MANAGEMENT

The domains of forest management and GIS are often oversimplified and poorly understood. Therefore, the significance of GIS in forest management decision-making is open to misrepresentation. Contrary to common public perception, forest management involves much more than harvesting and planting trees. Likewise, GIS can do much more than quickly produce maps of covertype or ones that highlight the distribution of this or that forest condition.

### *Understanding forest management*

What is forest management, really? Forest management is the design and implementation of a set of actions in which stands are harvested, products are distributed, cut-overs are renewed, and protection against insects, fire and disease is provided (Baskerville, 1986). These activities are controlled in timing, amount and geographic space, so that their cumulative effect generates a desired mix of benefits (e.g., timber, habitat, recreation opportunity) from the whole forest over

Figure II. The two components of spatial data describing a forest: (i) stand conditions and (ii) geographic locations




time. In figure III, a very simple forest is subjected to a schedule of stand interventions. This initiates a course of forest development and benefit availability which will differ from some alternative schedule.

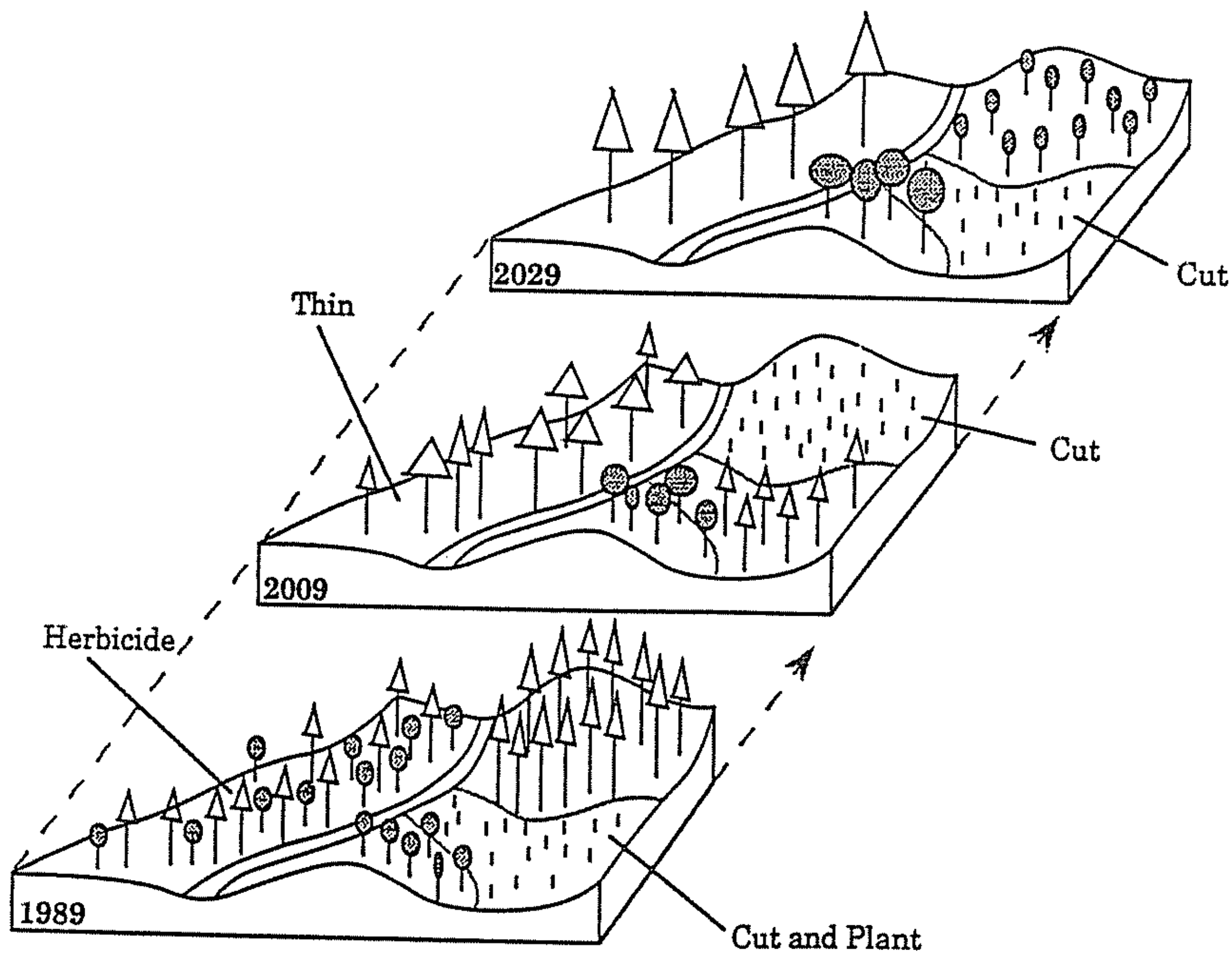
However, this forest is a simple case. Designing and implementing a schedule for a real New Brunswick forest, where hundreds of thousands of stands spread over perhaps 500,000 ha or more must be considered for dozens of interventions, is daunting indeed. Further, because forecasts are inherent in the process, considerable uncertainty exists about future outcomes. In this complex setting, the forest management challenge is to: (*a*) find one schedule, i.e., design, that appears likely to produce the desired future forest development pattern and flow of benefits; (*b*) implement that schedule year by year; and (*c*) monitor forest performance periodically to look for and remedy divergence between expected and actual outcomes. The first challenge requires the forest to be modelled and its cumulative response to stand interventions forecast in terms of not only conditions but their geographic distribution as well. Only then is it possible to choose the one schedule, from among the many possibilities, that appears best. The second challenge—implementing the schedule on the ground—requires that yearly harvesting, harvest distribution, renewal and protection activities be assigned appropriate equipment and personnel, seasonally linked and efficiently deployed. The third challenge—monitoring forest performance—requires the comparison of actual forest response against that originally forecast for the schedule selected. Forecasting is a key ingredient in forest management design; cost-effective linking (over time and geographic space) of interventions is a key concern in forest management implementation; and an accurate, up-to-date log of stand intervention and growth responses is essential in monitoring cumulative forest performance. All require an up-to-date, accurate present forest inventory. It is in these four aspects of forest management—inventory, design, implementation and monitoring—that GIS has the most to contribute.

*Understanding geographic information systems*

What is a GIS, really? A GIS is computer-based technology characterized by specific hardware and software that permits the digital storage, processing and display of data simultaneously with their geographic location. In other words, it is a spatial database management system, sharing much in common with the more prevalent database management system (DBMS) technology but distinguished by its ability to accommodate locational as well as thematic data, i.e., map-based or spatial data. It shares much in common with automated cartography technology, but is more than graphical storing, editing and composing of maps.

A GIS, like most computer packages and languages, for example SAS, FORTRAN, INFO or DBase 111, provides a software toolbox of function. Most important, however, it adds some that are aimed specifically at spatial data analysis and modelling. Many and varied spatial functions have been researched, developed and in many cases incorporated, into commercially available geographic information systems (Berry, 1987; Dangermond, 1982; Tomlinson and Boyle, 1981). The long list of analytical functions may be condensed into six categories: (*a*) query and display of thematic and locational data (tables, thematic maps); (*b*) calculation of area and length of map features; (*c*) reclassification of thematic attributes of map features (arbitrary, rule-based);

**Figure III. A schedule of stand interventions alters the course of forest development**
*(Adapted from Baskerville, 1985)*




(*d*) overlay of features, along with associated thematic attributes, of two or more geographically coincident maps (combination, composite, statistical summary); (*e*) distance measurement (simple, weighted, constrained); and (*f*) neighbourhood characterization (comparison, statistical summary, contiguity, slope, aspect).

There are great differences among available geographic information systems currently on the market with respect to their ability to support this full range of functions.

### THE EVOLUTION OF FOREST MANAGEMENT AND GIS IN NEW BRUNSWICK

The TMB/GIS initiative of 1982 was, more by necessity than choice, a solo effort. Although a pioneering Canadian GIS research and development project, the Canada Geographic Information System, had been under way since 1963 (Lands Directorate, Environment Canada, 1973), even as late as 1980 very few provincial institutions or government departments were actively involved in GIS. Certainly there was little activity in New Brunswick. Being the first on the scene in New Brunswick had its advantages. It left TMB with a free hand to select and implement a GIS to meet its forest management mandate under the Crown Lands and Forests Act, unhindered by interdepartmental squabbles over GIS responsibility and control that have occurred in other provinces. It did, however, leave TMB with the responsibility for digital base-mapping and ownership mapping in addition to its formal mandate of digital forest inventory production. Even so, provincial coverage (involving some 2,000 map sheets at scale 1:12,500) was accomplished in four years. By early 1987, New Brunswick had the first complete digitally mapped forest inventory in North America.

Building and maintaining a province-wide forest inventory is one thing, but using it and a GIS to serve forest management is another. As stated previously, a GIS is a toolbox of basic functions and not a toolbox of ready-to-use forest management support tools. The progression of a GIS implementation to management support capability is a long and arduous undertaking involving careful planning and many man-years of data automation, research, and programming effort. TMB estimates that it has expended over 10 man-years of effort on approximately 10,000 lines of programming to tailor a GIS environment specific to its forest management needs.

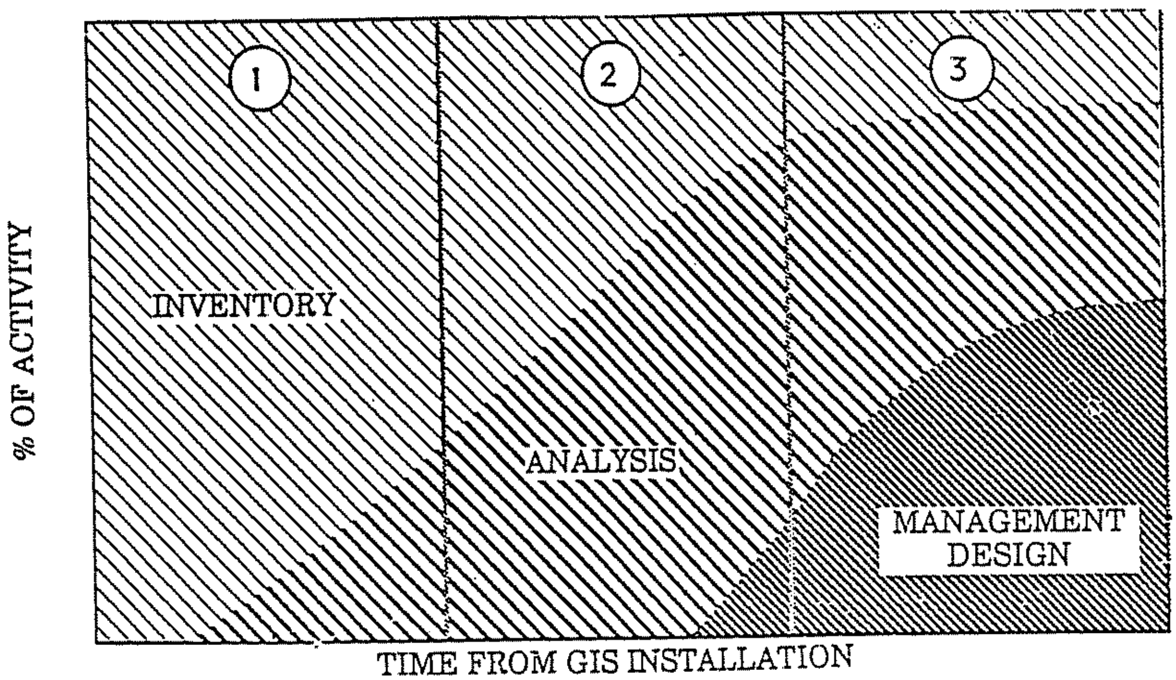
In 1983, Crain and MacDonald first described a model of the evolution of operational geographical information systems. According to the model, systems evolve through three stages of activity/application over time: initially, an inventory stage, followed by an analysis stage and finally a management design stage (see figure IV). In the inventory stage, spatial data input and editing predominates, as well as simple map and tabular reporting of what forest conditions exist, and where. Inventory-type activities continue into the second stage—analysis—but at a diminished proportion. The analysis stage is characterized by the predominance of often complex transformation, by reclassification, overlay, distance, and neighbourhood functions, of data in the database to generate descriptive and/or prescriptive map and tabular outputs useful in forest management implementation, decision-making and forest performance monitoring. The final and most sophisticated stage is the management design stage. While significant amounts of inventory and analysis activities will still exist, the use models for forecasting—as stated earlier, an essential ingredient for management design decision-making—will dominate this stage.

The TMB experience in New Brunswick seems to support the validity of the Crain and MacDonald model (see table 1). Initially, TMB's efforts were committed to building their GIS forestry database, i.e., inventory. This involved not only the methodical digitizing of forest cover-type, ownership and base-map data, but the development of data standards and procedures for work-flow, data verification and editing. With the completion of the database in 1987, the proportion of effort dedicated to inventory-type activities decreased and that of analytical application development increased accordingly. However, even before the completion of the database, application development was being undertaken in parallel with inventory activities. A good example of the latter is budworm susceptibility mapping. As early as 1984, TMB personnel had programmed their GIS to map forest areas most susceptible to insect damage, based upon stand condition stored in the database (Erdle and Jordan, 1984). These descriptive maps are now produced annually for use in carrying out New Brunswick's aerial protection programme. A further example involves the digital overlay of insect defoliation maps on the forest inventory. The combination of stand composition and defoliation sets the stage for stand development forecasts necessary for designing forest protection and harvesting plans. These projects are typical second-stage activities characterized by complex spatial data transformations to assist in the implementation of on-the-ground management interventions and the monitoring of forest response. Only recently, in 1987, has TMB exercised GIS capabilities in the management design stage. In designing long-term timber management programmes for 3.5 million hectares of Crown forest, a wood supply forecasting model was linked to the GIS database. After extensive analysis of harvest and silviculture alternatives, the final choices were mapped with the GIS to geographically depict the schedule of activities. These maps provided the base for formulation of detailed implementation activities. In a similar vein, GIS spatial analysis capabilities are being incorporated into wildlife habitat management design. Here, long-term habitat supply is evaluated in much the same manner as timber, but

TABLE 1. AN ACCOUNTING OF GIS INVENTORY, ANALYSIS AND MANAGEMENT DESIGN ACTIVITIES AT TMB (1982-1988)

| *Date initiated* | *Inventory* | *Analysis* | *Management design* |
|---|---|---|---|
| 1982 | Base, ownership and forest digitizing | | |
| 1983 | Forest updating | | |
| 1984 | | Budworm susceptibility mapping | |
| 1985 | | Monitoring | |
| 1986 | | Defoliation overlay | |
| 1987 | | Riparian buffer modelling | Harvest scheduling |
| 1988 | | | Wildlife habitat modelling |

**Figure IV. The mix of GIS applications over time**
*(Adapted from Crain and MacDonald, 1983)*



special consideration is made of the proximity and juxtaposition of vegetation types that are critical factors of habitat quality. While spatial scheduling and analysis of timber and habitat supply mark the start of management design with GIS tools, they capture only a fraction of the potential available. Exploiting this potential fully in support of sound forest management design represents New Brunswick's next and most interesting challenge.

### *GIS impact on forest management*

While much remains to be done in development of management design applications, GIS has already had a qualitative impact on forest management decision-making in New Brunswick. GIS technology and the efforts of TMB have helped to clear away two stumbling blocks that limited forest management endeavour in the past: (*a*) creating and maintaining an up-to-date digital inventory of the present forest: and (*b*) developing a spatial data handling and analysis capability.

Now, for the first time, forest management decision makers in New Brunswick have access to an up-to-date digital forest inventory that describes present forest conditions as well as its geographic distribution. The fact that it is up-to-date reduces some of the uncertainty about the future associated with management decisions. The fact that it is digital offers obvious processing efficiencies and thus hastens the management decision-making process.

In the past, forest inventories have existed, some even in digital form, but any ability to process and analyse the map component has been non-existent. TMB and its GIS have changed the situation in New Brunswick. The ability to transform these spatial data into a variety of prescriptive and/or descriptive map and tabular output products makes for more informed decision-making. Without a spatial data analysis capability a raw forest inventory, whether digital or not, is of limited value in decision-making.

Forest management decision-making requires not only a present forest inventory but, as well, a capability to forecast future forest inventory. In New Brunswick, thus far, forest modelling has been concentrated on forecasting forest conditions over time in response to management interventions (Wang, 1987) and depicting results in map form. GIS offers the more sophisticated approach of incorporating geographic distribution directly into the model itself. In other words, spatial forest models are now a possibility. While none currently exist, they are certainly under discussion and research in New Brunswick. The fact that spatial models could be used to forecast forest condition and geographic distribution addresses the unique time and location-dependent nature of forest management.

While not as obvious, GIS has opened up new areas of forest management endeavour and has triggered intensified efforts in other disciplines so that the management opportunities offered by GIS can be captured. For example, since GIS has created tremendous opportunities in management design for wildlife habitat, substantial effort has been undertaken to develop the biological relationships that determine habitat suitability and population viability. This effort is under way in the Fish and Wildlife Branch of the Department of Natural Resources and Energy under the auspices of Habitat Canada. In a similar response to GIS opportunities, research efforts are under way to develop remote sensing capabilities in detection of insect damage and evaluation of stand growth patterns (Ahern and others, 1988). Research into habitat relationships and remote sensing has been undertaken because GIS has paved the way by which such research results can be used operationally. Spurring research in other disciplines may come to be the most profound impact GIS has on resource management.

### *Organizational repercussions*

A GIS generates organizational as well as forest management impacts. In the case of TMB and company users of GIS in New Brunswick, it has introduced new information gathering procedures, new processing requirements, new output products, new staff responsibilities and new costs.

Obvious organizational impacts are easily observed at the GIS facilities of TMB, J. D. Irving, Ltd., or Fraser, Inc. The contrast with inventory operations of 10 years ago, for example, is striking. While procedures and information processing associated with the field and aerial sampling components of the inventory have remained traditional, the installation of GIS technology has initiated a continuous forest inventory capability. Whereas in the past forest inventories involved a cyclical process of building, aging, and completely rebuilding, GIS permits an inventory to be continuously updated (and extended) thus eliminating the need to completely rebuild at periodic intervals. In addition, GIS-based forest inventory has demanded new procedures and information processing peculiar to database management and digital mapping. A result has been the formation of a new GIS support and development group within each organization. In itself this isn't surprising. What is surprising, on the surface at least, is that in each case the data processing group within the organization has not been assigned principal responsibility nor has the composition of the new GIS group been dominated by computer technologists but, rather, professional foresters. Because spatial data handling associated with GIS for forest management is not even close to running a payroll system or other traditional data processing procedures, data processing personnel have not been in a position to play key roles in GIS implementation. Fortunately, as a result, the evolution of GIS in New Brunswick has been driven by those interested in using information for management and not by those merely interested in managing information.

The decision to acquire and operate GIS technology in New Brunswick consciously excluded a formal cost/benefit analysis. While the start-up cost ($750,000) and annual operating cost ($600,000) are substantial, they pale in contrast to the $20 million annual investment decisions in forest protection and silviculture supported by the GIS forest resource database. They shrink further against the $3 billion the forest sector contributes annually to the provincial economy.

The costs of GIS are concrete and borne today; the benefits are in the form of more effective forest management decisions, the results of which may not be manifested for decades. Further, there is no "experimental control" by which to gauge resource performance under management with and without GIS tools. For these reasons, cost/benefit ratios of GIS use in forestry have not been deemed relevant. Rather, New Brunswick forestry sector has viewed and funded GIS as a legitimate operating cost essential to prudent management of a valuable resource.

## Conclusion

There are undoubtedly many reasons and individuals that share responsibility for the current advanced state of forest management and the role played by GIS in New Brunswick. However, perhaps more than anything else, the so-far successful evolution can be attributed to the fact that from the outset leadership and implementation came from New Brunswick's small but tight-knit community of professional foresters—a group most knowledgeable of forest management decision-making and the potential role of GIS. Its continued evolution will depend upon the creative initiative and perseverance of that same group.

An essential ingredient in forest management decision-making is the ability to model a subject forest and forecast its future development under alternative intervention schedules. The most significant GIS opportunity lies here; specifically, making it possible for the first time to support the construction of models that incorporate a geographic dimension, in addition to one of time, into forest forecasting. Achieving this level of sophistication is a long evolutionary process. After seven years of experience, New Brunswick is just entering that level.

New Brunswick, in particular TMB, together with forest companies such as J. D. Irving, Ltd., and university researchers, are now, more than any other group in Canada, perfectly poised to complete the next, and perhaps most difficult, step in forestry-GIS applications. The province-wide forestry database is complete and procedures for its continued maintenance are daily routine. A wealth of GIS programming and complex spatial data analysis know-how has been accumulated over the course of seven year's experience and research. And lastly, the complexities of forest management are well known in New Brunswick. In the same way that the implementation of the Crown Lands and Forests Act, the introduction of wood supply modelling, the acquisition of a GIS, and the completion of a province-wide digital forestry database were each milestones of achievement, the next step, using the GIS as a tool in management design decision-making, will represent a milestone in the evolution of forest management and GIS.

New Brunswick's experience clearly indicates that the purchase of GIS technology does not buy solutions to any problems of forest management, but rather, provides a tool that, in the hands of innovative users, can be used to generate solutions.

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## THE DEVELOPMENT OF GEOGRAPHICAL INFORMATION SYSTEMS IN INDONESIA*

*Paper submitted by Indonesia*

### RÉSUMÉ

C'est dans le cadre du projet d'évaluation et de planification des ressources foncières que l'Indonésie a mis en place des systèmes d'information géographique (SIG), afin de faciliter la planification physique aux niveaux provincial et national. L'actuel Plan de développement national donnant la priorité au secteur agricole et au programme de transmigrations, les objectifs de ce projet sont axés sur la création de bases de données sur les ressources foncières (topographie, sol, eau, occupation du sol, climat, etc.) et l'intégration des informations qu'elles contiennent en vue de la planification, en tenant compte comme il se doit de l'impact sur l'environnement.

Dans ce document, on explique comment s'est déroulée la phase I du projet (1985-1990) et l'on décrit la mise en place des SIG en Indonésie.

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#### THE LAND RESOURCE EVALUATION AND PLANNING PROJECT

The Land Resource Evaluation and Planning (LREP) project has a number of objectives, but ultimately its purpose is to improve the quality of the planning and decision-making process. This objective can be achieved by enhancing the capabilities of the provincial planning agencies (BAPPEDA).

LREP, Phase I (1985-1990), was designed to introduce a system of physical planning at the eight BAPPEDAs of Sumatera, taking into account the availability of topographic base maps and soil maps fundamental to the development of the system.

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To establish the necessary integrated database, the project was aiming at strengthening the institutional capability of concerned agencies to enable them to collect and collate available data, to coordinate individual databases relating to such subjects as climate, soil and topography into a single information network, and to facilitate ready access by the users of the data.

## Project components

The project components can be described as follows:

(*a*) *Land Resource Data Centre and Information Network.* The Government of Indonesia has established a land resource data centre at BAKOSURTANAL. The agency was strengthened by providing additional professional and support staff, space for computer equipment and also space for storage, display and distribution of maps, airborne and spaceborne imgaery, and reports;

(*b*) *Soil database management.* As one of the key providers of data for land resource planning, the Centre for Soil and Agro-climatic Research was strengthened in its capability to collect and manage data by providing additional professional and support staff, space for computer equipment, as well as space for storage, display and distribution of maps and reports. Methods of soil survey were introduced that would provide data in a format fully compatible with the computerized data management system, and funding was made available to cover reconnaissance soil mapping of the whole of Sumatera during the period of the project;

(*c*) *Land resource evaluation and physical planning systems at BAPPEDAs.* The Government strongly supports the need to improve planning procedures at the provincial level. This component supplied resources for strengthening this activity in the eight BAPPEDAs of Sumatera. Improvement in the planning process was provided by training the provincial planners in modern techniques of data storage, retrieval, and processing (GIS and IPS);

(*d*) *Training in data interpretation and management.* BAKOSURTANAL's existing capacity was strengthened by expanding the agency's training unit to provide training in the utilization and management of digital data on land resources. The need for professional and support staff, additional offices, lecture rooms and GIS workstations at which trainees could gain experience in computer use for purposes of land resource evaluation and physical planning were identified. In addition, this component developed the requisite capability to produce distance learning materials by using tutored video instruction, computer-aided learning and tape-slide equipment;

*Project management office.* In view of the number of concerned agencies and the need to integrate the relevant aspects of their current programmes, the project provided for setting up a project management office (PMO) to monitor and coordinate project activities. The PMO was established at BAKOSURTANAL.

## Hardware/software development

The hardware/software package procured for the Database Centre of BAKOSURTANAL has five major components: this partition is rationalized by functional needs and required outputs. No available hardware/software system provided the complete range of data processing functions. However, independent solutions from several manufacturers permitted an integrated package. The software fulfilled all the functional requirements while the hardware provided a compatible platform for the support of the software. The general description of each of the five components are as follows:

(*a*) *One mainframe-based custodial to store and manage all digital maps.* The hardware component of this facility is a CISC (complex instruction set computer) based minicomputer (VAX 8350) system with a graphic workstation (Textronix). The software component is a vector-based GIS (ARC/INFO) package. The GIS facility is restricted, in part, to the following activities:

- (i) Storage of digital map data from the digitizing workstations;
- (ii) Integration of digital map data from the related agencies;
- (iii) Hardcopy output of digital map data to the plotters;
- (iv) Database management and distribution;

(*b*) *One mainframe-based IPS to store and process all digital satellite images.* The hardware component is the same as the one used by the GIS facility with an image workstation. The software component is a raster based IPS (ERDAS) package. The capacity of this IPS facility is dedicated to the production of enhanced and classified data both in digital and hardcopy format. The minicomputer system of the IPS facility has been partly used to interchange information regarding data;

(*c*) *Four workstations to digitize all mapped data.* The hardware component of these four workstations is an 82086-based microcomputer system with two monitors and a large digitizer. The software component is a vector-based GIS (PC ARC/INFO) package. The workstations are used to capture mapped data in point, line and polygon format. Appropriate feature codes and attributes of each geographic feature are entered;

(*d*) *Four stations to edit all the digitized map data.* The hardware component of these four stations is a Textronix (4111/4105)-based graphic terminal with an alphanumeric monitor and a small digitizer. The software component is a vector-based GIS (ARC/INFO) package. The workstations are used to edit the map data and their associated feature codes and attributes. Automated and visual checks are performed to ensure topological integrity of the digitized data;

(*e*) *Three stations to retrieve the climate, hydrology and infrastructure data from related agencies.* The hardware component of these three retrieval stations is a 80286-based microcomputer system with a printer and a modem. The mainframe systems and the workstations are connected via an Ethernet-based local area network (LAN). The data transfer operations were performed through the LAN facilities. The peripherals attached to the mainframe system consist of two fixed disks, two removable disks, two magnetic tape units, three terminal servers, five microcomputers, two operator consoles, six alphanumeric terminals, one map scanner system (Textronix 4991), three high-speed pen-plotters (Calcomp 1044/1023), one high-speed pen printers, one dot-matrix printer and one colour ink-jet printer (Textronix 46966). The network configuration is shown in figure I.

The existing aerial photo-library and the photographic laboratory were supplied with a large amount of furniture, one high-speed printer, one aerial film processor (b/w), two dodging printers (b/w and b/w or colour), as well as photographic materials.

The hardware/software package purchased for the Soil Database Centre of the Centre for Soil and Agro-climatic Research (CSAR) is similar to that provided to

**Figure I. Integrated Geo-information Production System**

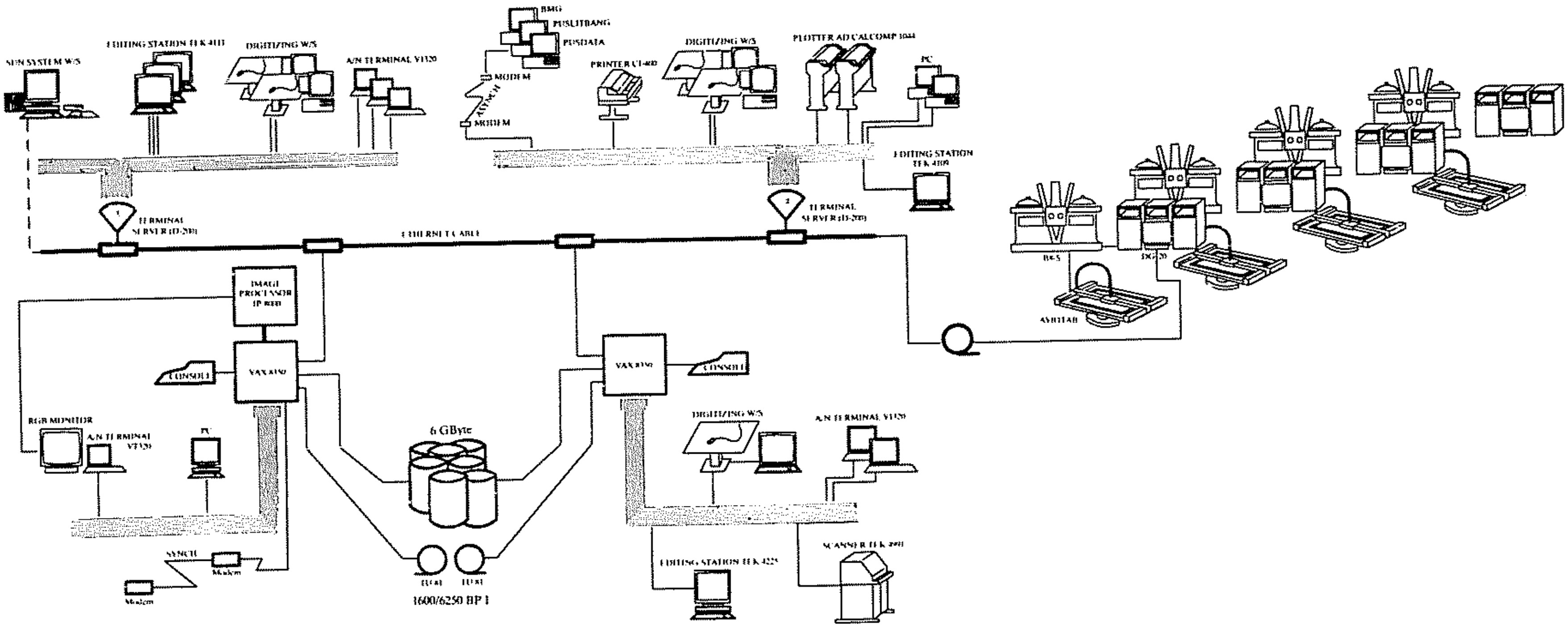
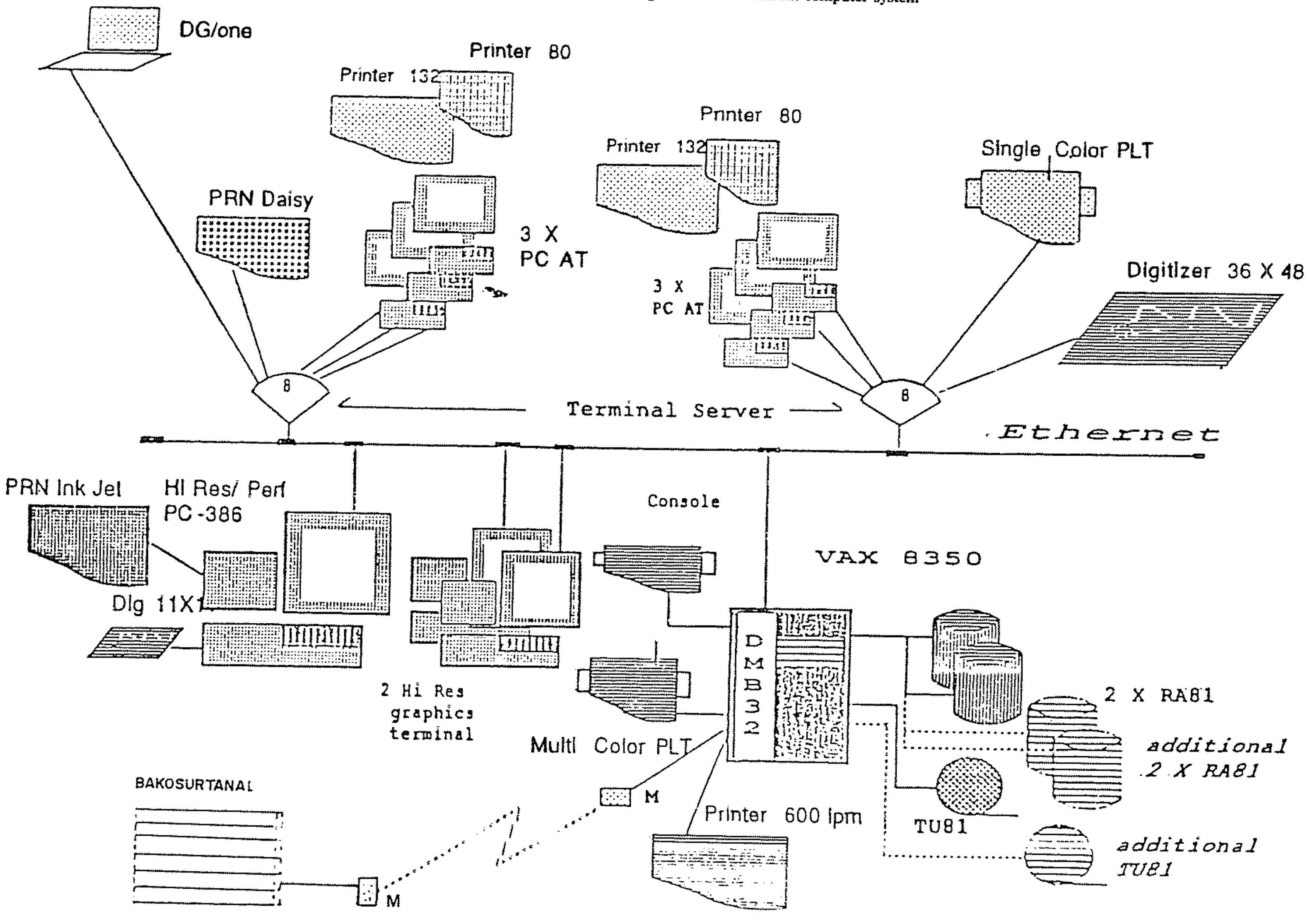


**Figure II. Centre for Soil and Agro-climatic Research: computer system**



BAKOSURTANAL. Its main objectives are to compile a Land Unit and Soil Map at scale 1:250,000; to construct a soil digital database; and to make these data accessible and available to the planners at the provincial levels.

The package has seven components:

1 mainframe-based GIS to store and manage all digital

1 microcomputer-based IPS to store and process all digital satellite imagery

1 workstation to digitize all mapped data

3 stations to edit all digitized map data

8 stations to enter the data collected from field surveys

1 workstation to perform the statistical analysis and regionalization of climatic data

10 laptops (a 80186-based laptop system with a printer) to digitize all field observations and measurements of soil characteristic parameters. The network configuration is shown in figure II.

The hardware/software package purchased for the 8 BAPPEDAs of Sumatera provided computer equipment to be used as tools for implementing the planning system. The general description of this system comprises one microcomputer-based GIS to store, retrieve, process and output all maps, images and statistical data related to planning activities.

The hardware component of this facility is a 80386-based microcomputer system with an image station (No. 9 512 × 32). The software component is a raster-based IPS (PC/ERDAS) package

The workload of this GIS facility is dedicated to the storage and retrieval of spatial and non-spatial databases, the digitizing of maps, the spatial analysis of resource database, the production of hardcopy output and analysis of satellite data.

The data transfer operations are performed through computer tapes/diskettes. The peripherals attached to the microcomputer system consist of one digitizer, one dot-matrix printer and one colour ink-jet printer (Textronix 4696).

In addition, the provincial data centres were supplied with a large amount of office furniture, audio-visual and mapping equipment, and archiving facilities.

The hardware/software facilities of the Training Centre of BAKOSURTANAL are to provide training in data interpretation, GIS operation and management. At the beginning of the project a two-story building was erected to house the following facilities: storage room, administration and staff offices, library, language laboratory unit, TVI studio and editing rooms, lecture rooms, GIS/Image-processing laboratory, and meeting room.

The TVI studio and editing rooms contain video equipment for producing and editing TVI learning programmes, such as electronic news gathering (ENG) video cameras, fixed and portable sound and lighting systems, Portapak production facilities, recording and duplication video recorders, high-band video recorders, monitors, dubbing suite and sound production unit.

The GIS/Image-processing laboratory has PC computer systems for training in geographic information and image analysis: three ERDAS system, one ILWIS system, one TYDAC/Meridian system, one PC ARC/INFO-MicroBRIAN system and one HUNTER/Image PRO system. The restricted number of systems causes problems with large classes since it is not practical to have more than three trainees per system.

## Planning methodology in the provinces

As a first step, provincial data centres (PDCs) were established within each BAPPEDA office to store all maps, statistics, imagery and reports that were relevant to macroplanning in the province.

The role of the PDCs is: (*a*) to provide immediate access for BAPPEDA planners and members of the physical planning team (PPT) to all the data needed for the planning process; and (*b*) to grant all BAPPEDAs of Sumatera with a central office so that all provincial agencies interested in planning can consult when data are required.

In addition to the implementation of data centres in all BAPPEDAs, a micro-based GIS system was installed within each BAPPEDA. The system was designed to assist the PPT in the complex analysis of spatial and statistical information. Database creation and operational procedures were developed for storage and retrieval of data. Furthermore, data transfer and conversion programmes were also generated and a methodology was set to implement manual and automated physical planning systems.

The technical work-plan for physical planning included problem identification, data identification, data collection and interpretation and plan formulation. The task of the PPT is to advise on the design of a master plan for the spatial distribution of development activities within each province. In addition, this team had to screen proposed sector projects and programmes and propose new options for the optimal use of land resources. These options are then forwarded to the Provincial Technical Committee (PTC) for final selection and detailed planning by the sectoral agencies.

Sectoral agencies in this context are land (cadastral and land-use), agricultural, forestry, public works and transmigration agencies.

## Conclusion

The Geographic Information Systems in Indonesia have been developed through the Land Resource Evaluation and Planning (LREP) project, one of whose objectives is to strengthen the planning system at national and provincial levels. The success of the GIS requires the development of databases at national and provincial levels to support planning. For this effort strong coordination is needed for standardization, comprehensiveness and accessibility of data provided by all sectoral resource producing agencies.

The ultimate goal is to establish a National Land Resources Information System (NLRIS) by means of decentralization of data collection, processing and storage at the land resource producing agencies and access to these data through information networking.

The role of BAKOSURTANAL is to coordinate the above activities and provide the central node for networking through national database development. That was, indeed, the mandate of BAKOSURTANAL when it was established in 1969 at the start of the first five-year national development plan: to provide all kinds of maps on the national territory, with due consideration for the advancement of technology and to set up an archive of basic data.

The first phase of LREP was completed at the end of 1990. The Government is negotiating with the Asian Development Bank for a second phase of the project to cover at least 15 provinces for the coming five years, with improvement based on lessons learned from LREP I. A similar project for marine resources has been envisaged, called MREP (Marine Resource Evaluation and Planning).

## (e) *Specifications and standards*

# A NEW AUSTRALIAN STANDARD FOR SPATIAL DATA TRANSFER*

*Paper submitted by Australia*


## RÉSUMÉ

La norme australienne de transfert des données spatiales est actuellement la norme AS 2482 ("Interchange of Feature-Coded Digital Mapping Data"). Cette norme vieille de dix ans ne convient plus aux bases de données modernes ni aux applications des systèmes d'information géographique. Standards Australia propose de la remplacer par une copie de la norme américaine "U. S. Spatial Data Transfer Standard", modifiée en fonction des besoins de l'Australie.

Dans le présent document, on décrit l'élaboration de la norme AS 2482 et les problèmes qu'elle pose, la mise au point et les bases conceptuelles de la norme américaine, et les raisons d'être de la proposition faite par Standard Australia. On aborde également les questions que cette proposition pose pour la communauté australienne des données spatiales.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### THE NEED FOR A STANDARD

A key economic benefit of geographic information system (GIS) technology arises from the ability it provides to share spatial data among users. Data sharing reduces costs by avoiding duplication of data capture and maintenance. However, realization of this benefit is dependent on the wide availability of an efficient and effective method for transferring spatial data between agencies and systems with different GIS hardware and software. The two key issues are communications technology and data formats. The current status of Australian standards for transfer formats is reviewed in this paper. The term "format" here includes the data model and dictionary, and the data encoding method.

There are two approaches to transferring data between the two systems A and B which have different data formats: using a direct translator which converts data from the A format to the B format, or using a third format X as the transfer form, which involves translating A to X then X to B. If the A and B formats are not similar, the direct translator may still involve an intermediate format embedded in the translation software.

If the number of systems is small and the frequency of transfer and volume of data are high, then direct translators may be the most efficient approach. However, where the number of different systems to be supported is large, the intermediate form offers advantages. For N systems with all translations implemented the number of direct translators required is $N(N - 1)$, whereas with an intermediate form the number required is $2N$.

Adoption of a public-domain *standard* intermediate format for spatial data transfer has a number of other advantages. It provides a standard model for spatial data, it provides a structure for the transfer of information about the data being transferred, and it avoids reliance on vendor-specific formats. The only mandatory compatibility requirement between systems and agencies is to support the standard.

#### *Standards Australia*

Standards Australia (formerly the Standards Association of Australia) is the national organization for the promotion of standardization in Australia. It is an independent non-profit organization administered by a Council comprising representatives from government, industry, professional groups and the community. Standards Australia is the Australian member of the International Standards Organization (ISO).

Standards Australia has published over 4,000 Australian standards on a diverse range of topics, and has about 1,600 technical committees which prepare draft standards. Each committee is formed on a national basis with a balanced representation from all interested sectors of the relevant industry. New standards are initiated by authoritative sources external to Standards Australia, such as industry associations and professional societies. Technical committees either draft a new standard or adapt the work of the external body to the required format. Drafts are circulated for public comment and consensus must be reached within a committee before a standard can be published. Australian Standards are not compulsory *per se*, but they are frequently referenced in statutory regulations and contracts making their use mandatory in specified situations.

The Committee relevant to spatial data is Information Technology Committee Number Four (IT/4), Geographical Information Systems. IT/4 has representatives from government agencies, academia, industry associations, professional societies and research bodies involved in surveying, mapping and land information. Development of spatial data transfer standards is the responsibility of subcommittee IT/4/2, Geographic Data Exchange Formats.

### AUSTRALIAN STANDARD 2482

#### *Development*

The development of the current Australian standard format for spatial data transfer, AS 2482, is summarized in the following chronology of events.

*1974*: The National Mapping Council (NMC) formed a working party to develop a standard for the exchange of digital topographic information. A key factor was the increasing use of consultants to produce digital mapping data for government mapping authorities. The resulting "NMC Standard on Exchange of Topographic Information on Magnetic Tape" was completed in 1978.

*1979*: NMC submitted its standard to the Standards Association of Australia (SAA, now called Standards Australia)

*The original text of this paper prepared by Andrew L. Clarke, Standards Australia, appeared as document E/CONF 83/INF 8 for consideration as an Australian Standard. SAA constituted a more broadly-based committee to develop an Australian Standard based on the NMC work.

*1981*: SAA published AS 2482-1981 "Interchange of Feature Coded Digital Mapping Data". The Australian standard was substantially different from the 1979 NMC standard.

*1982*: A NMC Working Party developed a subset of AS 2482, "Recommended Procedures for the Interchange of Digital Mapping and Charting Data on Magnetic Tape". The subset defined preferred options in places where the standard allowed for alternatives.

*1984*: SAA published a revised version of the standard AS 2482-1984. This was an extension of the 1981 standard, adding more feature codes and improving the scope and content of various record types.

*1985*: NMC revised its recommended procedures document to reflect AS 2482-1984 and the experience of members in the use of the standard. The NMC document was titled "Recommended Procedures for the Interchange of Small and Medium Scale Digital Vector Topographic Mapping Data" to reflect the NMC view of the narrow scope of AS 2482.

*1987*: SAA formed Committee IT/4, Geographical Information Systems. This was partly in response to a request from the NMC to change the title of AS 2482 to reflect its narrow application. Key outcomes from the initial meeting of IT/4 were to produce a third version of AS 2482 by incorporating the NMC subset, and to assess the United States Draft Standard for Digital Cartographic Data with a view to adopting it as a basis for development of a new Australian standard to supersede AS 2482. Subcommittee IT/4/2, Geographic Data Exchange Formats, was formed to undertake these tasks.

*1989*: Standards Australia published AS 2482-1989 (Standards Australia 1989). AS 2482-1989 is compatible with AS 2482-1984 and includes an appendix based on the 1985 NMC subset. The description of the scope was changed and other minor changes were made to reflect developments relating to the Australian geodetic system and to enable identification of versions of AS 2482.

As 2482 has been a successful standard. It is widely used by government mapping agencies who acquire data from digitizing consultants, and who distribute data to users.

### *Concepts*

AS 2482 specifies a file and record structure for the interchange of point and vector digital mapping data. It is not intended to be used for the transfer of polygon, raster or topologically structured spatial data, nor for attribute data which may be associated with the spatial data. It is designed for interchange on magnetic tape and makes use of existing national and international standards for tape labelling and encoding. A hierarchical system of four-digit feature codes defines about 750 cultural, hydrographic, relief and vegetation features. Users may also define four-digit feature modifiers to further specify map features.

The general structure of an AS 2482 map data file, in accordance with the NMC subset, is as follows:

*Tape label*: Fixed-length header with tape identification information.

*File headers*: Two fixed-length headers containing basic file identification, the creation date, and format information.

*Essential information record*: Fixed-length record defining coordinate systems, scale factors and offsets.

*(Basic) descriptive information records*: Six fixed-length records defining: the map number, name, scale and theme; the owner, agency and contact person; the source, source scale and source date; the date digitized and date last revised; the estimated root mean square error in X, Y and Z; and the camera focal length and flying height (for digital photogrammetric data).

*(Other) descriptive information records*: Fixed-length records containing other descriptive information, if required, such as non-standard feature codes, feature modifiers, or donor-defined coordinate systems.

*Feature records*: Variable length records for each feature. Each record has two or three segments: *header* segment, defining the record length, nature of feature (point or line), feature code and modifier, and number of axes (Z, XY, or XYZ); *detail* segment for line, point or text data, containing the feature coordinate values; and, if required, a further detail segment for identification/name, containing textual data such as the feature name.

*End of file*: Two fixed length labels defining the end of the file.

### *Problems*

AS 2482 represents the state-of-the-art in the late 1970s for computer-assisted map production. The technology then was for data acquisition through digital photogrammetry or table digitizing, followed by production of map reproduction material on precision vector plotters.

Initial criticisms of AS 2482 were that the options provided in various parts of the standard made it difficult for users to write comprehensive and robust transfer software, and that the specified feature codes did not satisfy large-scale mapping applications.

The NMC subset partially addressed these criticisms. However, with the development of large spatial databases and analytical applications of spatial data, based on GIS technology, AS 2482 was also seen to have some serious conceptual problems. These include:

(*a*) It does not support polygon, grid or raster data types;

(*b*) It does not support topologically structured data;

(*c*) It has minimal provision for data quality information;

(*d*) It has minimal provision for attribute data.

These problems merely reflect the original purpose of the standard, which was to facilitate data transfer for digital topographic map production. It is therefore not a criticism of those involved with its development to say that it is not suitable for use as a general-purpose spatial data transfer standard for GIS and related applications.

## United States Spatial Data Transfer Standard

### *Development*

The development of the United States Spatial Data Transfer Standard (SDTS) is summarized in the following chronology of events (Morrison, 1988; Rossmeissl, 1989):

*1980*: The United States Geological Survey (USGS) signed a memorandum of understanding with the National Bureau of Standards (now the National Institute of Standards and Technology (NIST)), resulting in the USGS assuming leadership in developing and maintaining earth science standards for use in federal Government agencies.

*1982*: USGS contracted the American Congress on Surveying and Mapping to establish the National Committee for Digital Cartographic Data Standards (NCDCDS), headed by Prof. Harold Moellering. NCDCDS published nine reports over the following five years. Report 8 "A Draft Proposed Standard for Digital Cartographic Data" was published in January 1987.

*1983*: The United States Federal Interagency Coordinating Committee on Digital Cartography (FICCDC) was established. A FICCDC Standards Working Group commenced development of a data exchange format, resulting in publication of a report titled "Federal Geographic Exchange Format" in December 1986.

*1987*: USGS established a Digital Cartographic Data Standards Task Force (DCDSTF) to meld the work of the NCDCDS and FICCDC into a single standard.

*1988*: DCDSTF published "The Proposed Standard for Digital Cartographic Data" (DCDSTF 1988). A maintenance authority was established within the USGS National Mapping Division to test the proposed standard, conduct educational workshops, disseminate information and coordinate promotion of the standard to NIST as a federal information-processing standard (FIPS). A Technical Review Board with representation from the government, academic and private sector spatial data communities was established to oversee the process.

*1989*: The proposed standard was tested in two phases between January 1988 and April 1989 (Rossmeissl and others, 1989), resulting in a number of proposed changes and simplifications to the content and presentation. The name was changed to "Spatial Data Transfer Standard". Further testing was then performed.

*1990*: The standard was submitted to NIST in July 1990 and was then subjected to a format and structure review. NIST is expected to release the resulting document as a draft FIPS in January 1991 for a formal comment period of 120 days. After review of the comments and any necessary revisions, a final FIPS should be approved in late 1991.

After approval by NIST for the SDTS to become a Federal Information Processing Standard (FIPS) it will be submitted to the American National Standards Institute for promotion as an ANSI standard.

### *Concepts*

The conceptual basis of the proposed United States standard was reviewed by Moellering (1988) and its content was described by Morrison (1988). The three parts of the SDTS are briefly outlined below

#### *Logical specifications*

Part 1 provides a general model for spatial data, a specification for data quality reporting, and specifications for various data transfer modules. The data model has three parts: a model of spatial phenomena, a model of the spatial objects used to represent phenomena, and a model of spatial features that explains how spatial objects and spatial phenomena are related. The data quality specification utilizes a "truth in labelling" approach, requiring users to report what is known about the lineage, positional accuracy, attribute accuracy, logical consistency and completeness of the data. The transfer specification provides modules for global information, for primary and secondary attribute data, for vector, raster and composite objects, for graphic representations and for data quality information.

#### *Spatial features*

Part 2 provides a non-hierarchical and extendible model for a spatial data dictionary, comprising entity, attribute and attribute value definitions. Some initial definitions are given (for topographic and hydrographic features) and more will be developed by the maintenance authority. Users may supply their own entity and attribute definitions within the transfer set.

#### *ISO 8211 encoding*

Part 3 defines the transfer mechanism, which is implemented in an existing general-purpose interchange standard ISO 8211 "Information Processing Specification for a Data Descriptive File for Information Interchange". The variable length records of ISO 8211 may be written on magnetic tape, floppy disk, magnetic tape cartridge and cassette, and compact disk read only memory (CD-ROM).

## A NEW AUSTRALIAN STANDARD

### *Proposal*

Two approaches were available to Standards Australia for the development of a new standard to supersede AS 2482: either start from scratch and write a new standard in consultation with the Australian spatial data community, or adapt an existing standard to suit the Australian requirements. The first approach would involve many years of effort by many people and could only be justified if no suitable existing or proposed standards could be identified.

At a meeting of the ICA Working Group on Digital Cartographic Data Exchange Standards in Budapest in August 1989, presentations were given on the development of standards in Australia, Canada, Federal Republic of Germany, Finland, France, Hungary, Japan, Norway, Sweden, United Kingdom, Union of Soviet Socialist Republics, and the United States of America. Other countries, including the People's Republic of China, New Zealand, South Africa and Switzerland, military organizations such as NATO and the United States Defense Mapping Agency, and agencies such as the International Hydrographic Organization, are also interested or involved in spatial data transfer standards. The Canadian, United States and NATO standards will all use ISO 8211 as an exchange syntax.

While each of these competing standards may have particular advantages, none has yet emerged as dominant or as a *de facto* international standard. When Standards Australia Committee IT/4 reviewed the future of AS 2482 in 1987, adaption of the proposed United States SDTS was considered to be the most appropriate method of developing a new Australian Standard. It overcomes all the conceptual problems of AS 2482 and has been developed with extensive user and vendor consultation. Economic benefits of adapting the United States standard include:

(*a*) It will be supported by the major North American GIS vendors who are active in the Australian GIS market;

(*b*) Implementation by Australian GIS vendors will assist their penetration of the United States GIS market;

(*c*) It is more likely than others to be adopted by Australia's Asian and Pacific neighbours.

Technical benefits of adapting the United States standard include:

(*a*) It will be applicable to most of the spatial data community, particularly GIS, LIS, remote sensing and computer-assisted cartography users;

(*b*) It will enable transfer of all spatial data types (topologically structured and unstructured vector data, raster data) and the associated attribute data;

(*c*) It will assist all levels of communication between spatial data users through definition of a general spatial data model;

(*d*) It provides a structure for data quality reporting;

(*e*) It provides a structure for the development and maintenance of Australian entity and attribute definitions.

Standards Australia therefore proposes to clone the United States Spatial Data Transfer Standard, with the minimum necessary modifications to make it suitable for Australian use.

### *Modifications*

Three areas of modification to adapt SDTS to Australia have been identified: referenced standards, coordinate systems, and spatial feature definitions.

Some of the existing standards referenced in SDTS may not be applicable or valid within Australia. Alternative standards may need to be substituted, or the referenced standards may be adopted for Australia or incorporated within the new Australian standard. ISO 8211 has already been cloned as AS 3654-1989.

The Australian version must refer to the Australian map grid, the Australian height datum and to other relevant coordinate systems.

The United States definitions for topographic and hydrographic features are not generally applicable to Australia. Australian definitions for these and other types of geographic entities and attributes will be required, in accordance with the model structure included in SDTS. Subcommittee IT/4/4, Entity and Attribute Definitions, has been formed by Standards Australia to coordinate this work. Working groups are being formed for the following data types:

Topographic and hydrographic
Geological and geophysical
Land use
Natural resources
Cadastral
Street addressing
Utilities

The existing draft standards and coordinating mechanisms of groups such as the Australian Land Information Council and the Inter-Governmental Advisory Committee on Surveying and Mapping will be utilized in the development of the Australian definitions. Note that introduction of SDTS is not dependent on the availability of Australian definitions, as users can define their own data dictionary within a transfer.

### *Process*

After the draft FIPS has been released in the United States in early 1991, Standards Australia will prepare a draft Australian standard by making the necessary modifications for referenced standards and coordinate systems. Public comments will then be sought on the question of cloning rather than on the technical detail of the standard.

Assuming that there is consensus on the question of cloning, Standards Australia will attempt to synchronize release of the new Australian standard with release of the final FIPS SDTS in the United States in late 1991. AS 2482 would remain as a valid Australian standard for an overlap period of some years.

## Issues for the Australian Spatial Data Community

### *Limitations of SDTS*

The spatial data transfer specification within SDTS is complex, reflecting the complexity of structured spatial data. Software development by users may not be practicable, so there is a need to encourage local spatial software vendors to support the standard. Some industry sectors may consider that the effort required to conform with a general-purpose spatial data transfer standard exceeds the benefits for their specialist applications. Subsets or "profiles" of SDTS may therefore be required to simplify implementation for particular applications. A federal SDTS profile is being developed in the United States specifically for the transfer of topologically structured vector data.

The overheads in creating a conforming set of files may inhibit use of the standard for small data volumes and for transfers involving primarily attribute data.

SDTS will not be applicable to all Australian spatial data agencies. The Royal Australian Survey Corps and Royal Australian Navy Hydrographic Service have international obligations which require support of alternative data transfer standards.

While SDTS could be used for on-line data transfer over communications networks, its design is not optimized for that media. Further, there is no explicit provision for incremental transactions involving updates or extensions of previously transferred databases. However, SDTS could be readily extended to support these applications.

### *Description, not prescription*

SDTS does *not* prescribe standards for spatial data structure, data quality or feature definitions. Rather, it provides a model within which users must describe the topology, quality and meaning of the spatial data being transferred. Producers of spatial data must therefore define their own standards for structure, quality and definitions, or refer to other existing standards for these characteristics.

### *Support*

Ongoing support of the new Australian standard will require a software validation facility, user education, implementation support, modification of the United States documentation, assessment and introduction of developments made to the United States version, maintenance and dissemination of a database of Australian spatial feature definitions, promotional activities, and research and development of extensions to the standard.

Standards Australia does not have the resources to offer these support services and has therefore asked the Australian Land Information Council (ALIC) to establish a SDTS support group to undertake the full range of support activities. ALIC has accepted the request and will be calling for expressions of interest from appropriate institutions to establish and operate the support group, for an initial period of three years, commencing in early 1991.

## Conclusions

Australia was ahead of most countries in the adoption of a national standard for spatial data transfer when AS 2482 was first released in 1981. However, a new standard is now urgently required. The Standards Australia proposal to clone SDTS offers significant economic and technical benefits. However, much work still needs to be done to ensure successful implementation of the new Australian standard. Potential users should now be addressing their need for prescriptive standards for spatial data structure, quality and feature definitions, their priorities for further technical development of SDTS, and the support that will be provided by their GIS vendors.

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# STANDARDS AND SPECIFICATIONS OF SURVEYING AND MAPPING IN CHINA*

*Paper submitted by the People's Republic of China*

## RÉSUMÉ

Dans ce document, on présente les normes et spécifications chinoises en matière de levés et d'établissement de cartes : organisation et administration, processus d'élaboration, classification et caractéristiques. On indique également les normes et spécifications formulées et révisées au cours des dernières années.

Survey and mapping standardization in China is a task of national significance; it is carried out on the basis of the Standardization Law adopted by the National People's Congress Standing Committee, the highest legislative body of the People's Republic of China.

Standardization is an indispensable part of surveying and mapping undertakings, and thus it has an important role in the administrative function of the National Bureau of surveying and mapping (NBSM) of China. Standardization is necessary in organizing modern survey and mapping products, guaranteeing their quality, as well as being an important component of scientific management. In China, standardization has developed along with survey and mapping undertakings. In the last forty years, great advances have been made. According to statistics, in 1990 more than 120 standards and specifications of all kinds concerned with surveying and mapping (including state standards, trade standards, and ministerial standards were issued.

### DEVELOPMENT OF STANDARDIZATION

In general review, the developing process of standardization can be divided into three stages.

First, was the initial stage, after the founding of the People's Republic. In the early 1950s, survey and mapping works were carried out nation-wide in order to meet the demands of economic restoration and construction. Survey and mapping products urgently demanded standards, therefore some standards were introduced from abroad, and some national bases were started, e.g. the astronomical base-point was set up in 1953; the Beijing Coordinate System 1954 was established in 1954; and the system of heights, Yellow Sea 1956 was founded in 1956. These establishments provided the foundation on which survey and mapping standards were constructed later.

The second stage was the formulation of technical standards of survey and mapping through our own technical forces and experience. The National Bureau of Surveying and Mapping (NBSM) was founded in 1956, after which the planning and administration of national survey and mapping undertakings were strengthened, and standardization was strengthened as well. On the basis of the actual conditions of the country and the needs of survey and mapping production, NBSM, with the cooperation of some other survey and mapping organizations, starting from 1958, in just a few years worked out a number of specifications and rules for geodetic survey, photogrammetry (including both field and office work), plane-tabling, mapping and toponym transcription, which ensured the unification of the technical specifications of surveying and mapping products (results and maps) and improvement of their quality. Among them, "Norms of geodesy in the People's Republic of China (draft)" and "Basic mapping principles of topographic maps, scales 1:10,000, 1:25,003 and 1:100,000 (draft)" issued in 1959, laid the foundation for unifying the procedures of geodetic survey and accuracy of topomaps at all scales in China.

The third stage began in 1984 with the establishment of the Research Institute of Standardization of Surveying and Mapping of NBSM, which is focused on the study, formulation and revision of standards and specifications for survey and mapping. Since then, China has acquired a specialized force for survey and mapping standardization, and scientific research and experiments have been much strenghtened thereby. Formulation and revision of standards and specifications are accelerated. Meanwhile, survey and mapping standardization, as part of national standardization, began to be incorporated into the national standards. The State standards of survey and mapping are issued and provided to the International Standardization Organization (ISO) for international exchange by the State Bureau of Technical Supervision, the national Department responsible for standardization.

### CHARACTER AND CLASSIFICATION OF CHINA'S STANDARDS

Standards of survey and mapping may be roughly divided into basic standards and method standards. Taking into consideration different working procedures, they fall into different groups in accordance with specialties, namely:

General survey and mapping

Geodetic survey

Photogrammetry and remote sensing

Engineering survey

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Cadastre survey

Marine survey

Cartography and map printing

The characteristics of China's survey and mapping standards are:

(*a*) They fit tightly the needs of production;

(*b*) They have accuracy targets, clear descriptions and strict rules. Accuracy targets set up in the technical standards of geodetic survey and photogrammetry are almost the same as those used in developed countries.

STANDARDS AND SPECIFICATIONS FORMULATED AND REVISED, 1986-1990

According to demands for survey and mapping products in the last several years, 14 State standards of survey and mapping were formulated and about 30 trade standards and ministerial standards were revised. These are listed in the annex.

Under the guidance of the general policies of the country, still further efforts will be made for the improvement of China's surveying and mapping standardization.

**ANNEX**

**Categories of State standards for survey and mapping: formulated and revised, 1986-1990**

| *Classification* | *Serial number* | *Code* | *Title* |
|---|---|---|---|
| Geodetic survey | 1 | GB Remain to be ratified | Specifications of national first- and second-order levelling |
| | 2 | GB Remain to be ratified | Specifications of national third- and fourth-order levelling |
| | 3 | GB Remain to be ratified | Specifications of long distance range-measurement |
| Photogrammetry and remote sensing | 4 | GB 6962 1986 | Specifications of aerial photography for topomaps at scales 1:500, 1:1.000. 1:2,000 |
| | 5 | GB 7930 1987 | Specifications of photogrammetry office work for topomaps at scales 1:500. 1:1,000, 1:2,000 |
| | 6 | GB 7931 1987 | Specifications of photogrammetry field-work for topomaps at scales 1:500, 1:1,000 1:2,000 |
| | 7 | GB 12340 1990 | Specifications of photogrammetry office work for topomaps at scales 1:25,000. 1:50,000. 1:100,000 |
| | 8 | GB 12341 1990 | Specifications of photogrammetry field-work for topomaps at scales 1:25.000, 1:50,000, 1:100,000 |
| Cartography and map printing | 9 | GB 5791 1986 | Cartographic symbols for topomaps at scales 1:5.000, 1:10.000 |
| | 10 | GB 7929 1987 | Cartographic symbols for topomaps at scales 1:500. 1:1,000 |
| | 11 | GB 12342 1990 | Cartographic symbols for topomaps at scales scales 1:25.000, 1:50,000 |
| | 12 | GB 12343 1990 | Cartographic specifications for topomaps at scales 1:25.000, 1:50.000 |
| | 13 | GB 12344 1990 | Cartographic specifications for topomaps at scales 1:100,000 |
| | 14 | GB Remain to be ratified | Colour standard for map printing |
| Marine survey | 15 | GB 12317 1990 | Cartographic symbols for marine charts |
| | 16 | GB 12318 1990 | Cartographic specifications for marine charts |
| | 17 | GB 12319 1990 | Cartographic symbols for navigation charts in Chinese sea area |
| | 18 | GB 12320 1990 | Cartographic specifications for marine charts in Chinese sea area |
| | 19 | GB 12327 1990 | Specifications of marine survey |

# NORMALISATION DES ÉCHANGES D'INFORMATIONS GÉOGRAPHIQUES EN FRANCE*

*Document présenté par la France*

## SUMMARY

French activity in exchange formats is conducted in two main directions. The first is strategic: the CNIG working group must be recognized as the only group in France where geographical information exchange systems are discussed taking into account the European context. The second is technical: the work deals with data model (theoretical concerns), content definition (semantic concerns) and exchange systems (syntactic concerns).

The National Council for Geographic Information (CNIG) is a governmental organization attached to the Ministry of Planning. This consultative organization is concerned with the development of geographic information uses in France taking into account the needs of public and private users. It is mainly involved with the study of the capture and identification of spatially-referenced data, their analysis and processing, and the definition, production, conservation, and distribution of all derived products. Under the CNIG Standing Commission on geographic research, a working group, now known as the commission "Normalisation des formats d'échange", is involved with the definition and conduct of an exchange format standard for digital geographic data.

Six commissions have been set up:

(*a*) Commission on large-scale topo-cadastral mapping;

(*b*) Standing commission on geographic research;

(*c*) Commission on evaluation of the economical and social utility of geographic information;

(*d*) National commission on toponymy;

(*e*) Commission on the "national digital ground survey";

(*f*) Commission on exchange formats standardization.

The Standing Commission on geographic research is involved with the evaluation of what is going on in the research programme of the French organisms dealing with geographic research, with the definition of general objectives of that research, and with a mutual information and coordination between partners.

An inquiry upon the geographic information community (2000 samples, 622 answers) was done in 1987. Its purpose was to get remarks on a draft definition of the "large scale topo-cadastral mapping". One of the main conclusions was the general need for the definition of a standard exchange format.

During the first symposium organized by this commission, held in Paris (13-04-88), all the 15 speakers were more or less claiming the importance of the definition of a suitable way to exchange geographic data.

This context led the CNIG to set up, in May 1988, an exchange format working group.

*La commission "Normalisation des formats d'échange"*. One of the working groups of the permanent commission on geographic research was involved with the definition and the proposition of "an exchange format standard for digital geographic data".

The work was essentially to develop a system of exchanging digital geographic data which is able to give intercommunicability, interoperability and compatibility within the producers and users of geographic data in France. This includes the documentation of the whole standard.

It was set up in May 1988 and during 1988-summer an enquiry among professionals concerned with geographic information was undertaken to establish a list of the formats in use in France. Following discussions by that group it was decided to charge the group with defining a standard according to the following steps:

Definition of the final document
- Digital Geographic Information (DGI) logical structure
- physical structure
- annexes (coding system, glossary, etc..)

Definition of the DGI logical structure

Definition of the standard

Definition of a coding system

Study of the means of diffusion and approval of the standard.

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*The original text of this paper, prepared by François Salgré, Institut géographique national, appeared as document E/CONF 83/L 47

This Working Group is composed of some 20 representatives of various organisations of that domain and is assisted by a group of 7 experts involved in the technical tasks.

It has been clearly identified to study the existing standards in the world in order to learn from other experiences, and to avoid the known pitfalls. The first lemma is that the data models for geographic information are scale-and-nation-independent. The second one is that the way to apply models are nation-independant even if the results are nation-and-scale-dependent. The third one is that the exchange standard documentations have to be fully understood (French texts are mandatory). The last one is that there will be in the future a need for international standards. Those lemma imply to work within the knowledge of what is going on in an international basis.

Actually the elaboration of a French exchange standard cannot be separated from the one of an European exchange standard, and both actions have to be led at the same time.

This working group is now known as the commission "Normalisation des formats d'échange" and is seen as a separate body. (April 1990 decision of the CNIG plenary assembly).

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### Objet et objectif de l'effort national

Pour l'essentiel, les travaux du conseil national d'information géographique (CNIG) consistent à élaborer un système d'échange de données géographiques assurant un degré nécessaire d'intercommunication entre systèmes informatiques, et de compatibilité entre les différents centres producteurs et utilisateurs français de ces données. Simultanément, il produira un document de synthèse permettant au lecteur de comprendre et d'utiliser aisément le système en question.

Ces objectifs imposent cinq conditions :

*a*) Une telle norme doit échanger toutes structures de données possibles (DAO-spaghetti-topologique-maillé);

*b*) Les échanges physiques doivent pouvoir être faits par bandes magnétiques, disquettes, RNIS, etc.;

*c*) La documentation doit être lisible;

*d*) La méthode de présentation des données doit être commune (mêmes concepts de base) tout en acceptant des variantes (souplesse);

*e*) Dès l'en-tête sont intégrées des informations permettant d'interpréter automatiquement et sans équivoque la structure des données.

Le cahier des charges de l'élaboration de la norme comporte six contraintes :

*a*) Rapidité de mise en œuvre;

*b*) Economie de moyen impliquant en particulier l'analyse de normes existantes ou en cours de mise au point;

*c*) Modernité impliquant la prise en compte de modèles de données validés sur le plan théorique et permettant de suivre les évolutions du génie logiciel;

*d*) Dimension internationale et tout particulièrement européenne;

*e*) Maîtrise du produit : participation active de la France à l'élaboration et l'évolution d'une norme européenne;

*f*) Prise en compte des rôles respectifs du CEN, de l'ISO et de l'AFNOR.

### Description de l'état d'avancement

#### *Volet stratégique*

*Organisation française*

Au sein du conseil national de l'information géographique, la commission a été organisée en un comité de pilotage et une équipe de spécialistes.

Le comité de pilotage est composé de représentants officiels des ministères ou organismes concernés[1]. Il est chargé de fixer les objectifs pratiques à atteindre, de suivre l'avancement des travaux, d'en évaluer les résultats, d'assurer l'ensemble des relations avec les organismes concernés, d'informer la communauté géographique française (et européenne) de l'avancement des travaux par le biais des salons, colloques et revues, et de coordonner les actions de la France dans les instances internationales.

L'équipe de spécialistes de l'information géographique numérique, mise à disposition par certains des organismes[2] de l'équipe de pilotage, est chargée de réaliser les tâches techniques définies par le comité de pilotage au cours de sessions.

Dans la mesure où la promulgation de normes est en France du ressort de l'AFNOR (Association française de normalisation), un rapprochement avec celle-ci a été dès le début pris en compte. Au sein de l'AFNOR, une entité spécifique disposant d'un budget propre a été créée en 1990 (EDI-France). Elle a pour but de favoriser l'échange de données informatisées et donc de faire avancer les travaux de normalisation touchant à l'EDI au sens général.

La commission du CNIG est de facto le lieu de rencontre de tous les utilisateurs d'informations géographiques numériques et doit devenir à terme le point de convergence de tous les travaux français, voire de certains travaux européens. Toute prénorme d'échange d'informations géographiques numériques en provenance d'autres nations, tout avis sur ce type de prénorme et toute proposition française doivent passer par la commission du CNIG.

Ainsi le but spécifique de l'organisation française est de faire reconnaître la commission sur les formats d'échanges du CNIG comme groupe opérationnel d'EDI-France afin de devenir ce point de passage obligé.

*Orientation européenne*

L'organisme européen officiel de normalisation est le Comité européen de normalisation (CEN). La particularité de ce dernier est que toute norme adoptée par lui devient obligatoire pour les pays de la CEE. Les organismes normalisateurs des pays doivent alors annuler ou modifier les normes nationales qui viendraient en contradiction. Ainsi au-delà des normes adoptées par l'ISO, celles du CEN ont un enjeu stratégique important.

L'Europe de 1992 en particulier et l'Europe au sens géographique sont deux réalités de la communauté géographique européenne. Quelques exemples viennent illustrer cet état de fait. En premier lieu les efforts dans le domaine de l'assistance à la conduite automobile (Prométheus dans le cadre EUREKA [Conseil de l'Europe] et DRIVE [CEE]) consistent entre autres à concevoir des bases de données routières par nature "Pan-européennes". En second lieu le projet CORINE de la CEE où la constitution d'un système d'information sur l'environnement pose le problème d'une base de données européenne. On peut citer également les efforts du CERCO dans ce domaine.

Le groupe de travail, à rattacher vraisemblablement au CEN, est chargé de faire émerger une norme d'échange européenne à l'horizon 1995 qui soit acceptable (et acceptée) par tous les intervenants de l'information géographique numérique (producteurs, équipementiers, utilisateurs).

### *Volet technique*

#### *Modèle conceptuel des données*

Dans le contexte français l'état de l'art conduit à envisager l'échange de données maillées, CAO/DAO, spaghetti et topologique structurée. Ainsi un modèle de données "universel", permettant de caler tout modèle de données spécifique, est à mettre au point. Pour un échange donné entre deux systèmes, la mise en correspondance respective de chacun des modèles de données avec le modèle de référence permet d'envisager un interfaçage avec le format d'échange qui soit indépendant des conditions d'échange.

L'étude faite a conduit à proposer un modèle de données général ("universel") qui puisse modéliser tout type de jeu de données géographiques. Ce modèle, mis au point en tenant compte des connaissances au niveau recherche et des besoins clairement exprimés, a été confronté aux principaux modèles existants : CAO/DAO, spaghetti, topologique.

Ce modèle théorique repose sur des objets élémentaires (arcs, sommets, faces) portant la géomètrie, formant un graphe planaire et permettant de construire des objets complexes. Des attributs géographiques peuvent être associés aux objets complexes et des liens sémantiques permettent d'exprimer des informations de type "relation entre objets".

Dans la mesure où la géographie recoupe de nombreux domaines techniques, pour chacun d'eux on peut définir une façon spécifique de modéliser les données en se basant sur le modèle "universel". Pour chaque domaine technique identifiés (réseau routier, ville, agriculture...), des règles d'utilisation peuvent être dégagées qu'il faudra mettre au point.

#### *Nomenclature*

La définition d'une nomenclature d'objets géographiques susceptibles d'être échangés est une tâche importante. Différents organismes producteurs et/ou utilisateurs ont mis au point de tels catalogues pour leurs propres besoins et qui ont été rassemblés par le CNIG. Dans l'esprit de la séparation du particulier et du général, une nomenclature commune à tous les intervenants de la géographie doit être mise au point, ainsi que des nomenclatures propres à chaque domaine technique.

Il s'agit dans un premier temps de mettre au point une méthode de classement des objets des différents catalogues en fonction de leur importance sémantique relative et de leur emploi plus ou moins généralisé (structuration de connaissances).

Dans un second temps la méthode ainsi définie sera appliquée sur les catalogues recueillis par le CNIG, en séparant les objets en différentes catégories d'utilisation de façon à produire une nomenclature provisoire informatisée.

#### *Format d'échange : comparaison des propositions étrangères*

L'enjeu de la comparaison de NTF et de DIGEST est d'établir, sur le plan institutionnel, théorique (modèle conceptuel de données), informatique (modèle de transmission), et organisationnel, laquelle des deux normes il serait préférable d'adopter pour remplir le cahier des charges précédemment fixé.

L'hypothèse du développement d'une norme française a été rapidement écarté eu égard aux aspects coût, délais et "européanisation" qu'une telle solution imposait.

La comparaison des aspects institutionnels de NTF et de DIGEST fait préférer la solution DIGEST en raison de sa dimension internationale, et particulièrement européenne, de la participation active de la France à son élaboration et à ses tests, et sa disponibilité imminente ne présente plus d'obstacle.

L'aspect théorique de la comparaison porte sur l'adéquation du modèle conceptuel de données sous-jacent avec le modèle de données théorique "universel". Sur ce plan-là, DIGEST s'est révélé plus performant d'autant plus que la documentation technique associée est apparue plus claire. Toutefois DIGEST ayant été créé pour des applications militaires à petite et moyenne échelle, il sera nécessaire d'enrichir sa nomenclature d'objets pour l'adapter à la diversité des applications civiles et de le tester sur des applications civiles à grande échelle.

L'intérêt d'avoir une norme reposant sur des standards existants a conduit ici encore à préférer DIGEST dans la mesure où le réemploi de la norme ISO 8211 permet de laisser aux informaticiens les problèmes de transmission et de respecter une architecture en couches.

Le problème de l'échange de données géographiques se posant en France surtout en terme de transfert de fichier, l'adoption de ISO 8211 comme couche de transmission a été retenue. L'autre norme de transmission étudiée (ISO 9735-EDIFACT), plus adaptée à l'échange de message, a été écartée du fait de l'importance du travail à réaliser pour interfacer la couche géographique de DIGEST avec la norme 9735.

Le format DIGEST sous ISO 8211 est le plus performant vis-à-vis des contraintes techniques et des obligations imposées par le cahier des charges. La commission propose donc de retenir ce format, d'enrichir sa nomenclature, de la tester, et d'attribuer à sa version civile le nom de Echange de données informatisées GEOgraphiques (EDIGEO).

#### *Format d'échange : amorce de solution française*

La demande des utilisateurs d'information géographique numérique est relativement pressante et la préconisation par le CNIG de DIGEST doit pouvoir se traduire dans les fait dès 1991.

Ainsi tester, répandre l'utilisation et préparer l'évolution de EDIGEO sont les tâches principales à accomplir.

Convaincre que EDIGEO convient, c'est réaliser des tests d'utilisation de cette norme montrant son adéquation aux usages projetés. Ils doivent impliquer les principaux intervenants. C'est aussi réaliser une francisation de la documentation. Basée sur un glossaire franco-anglais des termes et concepts tant théoriques que pratiques, sa traduction permettra d'être accessible aux utilisateurs futurs de la norme. C'est enfin de proposer d'ores et déjà des amendements à DIGEST pour l'améliorer.

L'accessibilité de la norme et son utilisation effective passe par la formation des utilisateurs, à différents niveaux de responsabilité.

C'est aussi accumuler et synthétiser une expérience nationale pouvant peser de tout son poids dans le cadre de travaux à l'échelle de l'Europe.

Convaincre que EDIGEO convient, c'est enfin montrer que, au-delà des considérations purement théoriques, son cadre permet d'intégrer des études antérieures et de fédérer les solutions déjà entrevues.

Le programme de test en cours de mise au point devrait être terminé avant la fin 1990, de façon à pouvoir proposer la version finale de la norme CNIG en mars 1991.

Les contacts en cours avec les constructeurs automobiles (projet Prometheus et Drive) devraient permettre de faire une bonne synthèse entre les résultats de GDF et ceux de DIGEST, en jouant sur la complémentarité des études et en séparant nettement ce qui relève du domaine technique, de ce qui relève de la couche géographique et de ce qui relève de la couche de transmission.

*Echange de messages*

L'intérêt de l'échange de données et de la distribution interactive d'informations urbaines entre les collectivités territoriales et leurs partenaires publics et privés réside dans l'amélioration de la gestion en optimisant l'utilisation des informations urbaines. Il s'agit pour des situations d'échange prédéfinies (déclaration de travaux, permis de construire...) d'automatiser les échanges de données informatiques.

La distribution interactive de données urbaines est permise par l'échange d'ordinateur à ordinateur, grâce à des moyens électroniques, de données structurées regroupées en messages normalisés. Reposant sur le modèle conceptuel de données "universel" implémenté dans EDIGEO, la normalisation des messages, et la gestion interactive de ces échanges, par la mise en réseau de SI urbains existants améliorera la diffusion d'information géographique à l'intérieur d'une ville.

NOTES

[1] Ministères : finances (cadastre), agriculture et forêts, défense, équipement, intérieur

Organismes : IGN, CNIG, AFNOR, EUREKA-FRANCE, Service hydrographique et océanographique de la marine, Bureau de la recherche géologique et minière, Association des ingénieurs des villes de France, Centre national de la recherche scientifique, GIP-RECLUS, Electricité de France, URBA2000, FRANCE-TÉLÉCOM

Privés : Ordre des géomètres experts, Chambre nationale syndicale des topographes photogrammètres, Chambre nationale syndicale des photogrammètres privés

[2] Ministères : finances (cadastre), agriculture et forêts, défense, équipement.

Organismes : IGN, BRGM, CNRS, GIP-RECLUS

Privés : OGE.

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## MAPPING, CHARTING, AND GEODETIC STANDARDIZATION ACTIVITIES WITHIN THE UNITED STATES DEPARTMENT OF DEFENSE*

*Paper presented by the United States of America*

### RÉSUMÉ


En tant qu'organisme responsable de la technologie de la cartographie et de la géodésie au sein du Département de la défense des Etats-Unis, la Defense Mapping Agency a entrepris un programme global de normalisation. Celle-ci se rapporte au cadre d'utilisation et aux logiciels utilitaires, y compris les normes en matière d'échange, d'affichage et de manipulation de l'information numérique relative à la cartographie et à la


*The original text of this paper, prepared by Mel Wagner, Defense Mapping Agency, appeared as document E/CONF 83/L 30 géodésie pour les usagers du Département de la défense des Etats-Unis. Le document décrit les initiatives actuelles du Defense Mapping Agency System Center dans le cadre du programme de normalisation

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The Defense Mapping Agency (DMA), as the responsible agency within the United States Department of Defense for Mapping, Charting, and Geodetic Technology, has established a comprehensive programme of standardization. The goal of this research and development initiative is to develop a comprehensive suite of standards for the exchange, manipulation and display of digital data. The purposes of the programme are to assure the compatibility and interoperability of digital mapping, charting, and geodesy databases supporting a wide variety of simulators, command and control, navigation and weapon systems; to assure that data from different sources and from different collection techniques can be combined, processed and displayed in a common geographic reference frame; and to assure that two users performing the same or similar functions will get comparable results.

## New products on compact disc–read only memory (CD-ROM)

There are a number of current research and development projects which support these goals. For example, in 1989 DMA produced 460 CD-ROMs containing ARC digitized raster graphic products, including rasterized versions of operational navigation charts, tactical pilotage charts and 1:50,000-scale topographic line maps. 850 new CD-ROMs were produced in 1990. The current schedule is to produce 1,000 new CD-ROMs per year. World vector shoreline, formerly available only on magnetic tape, is now available on CD-ROM. A production capability for digital terrain elevation data has been established. All available digital terrain elevation data should be published on CD-ROM by April of 1990. In 1991, we intend to prototype on CD-ROM, the electronic chart update manual, tactical terrain data, interim terrain data, and digital navigation publications.

## Digital products study

In May 1990, the Deputy Director for Management and Technology of DMA commissioned the "Defense Mapping Agency Digital Products Study" to look at the Agency's standardization activities. The goal of this study was to provide a "framework for development of mapping, charting, and geodetic standards". Phase 2 of this study, begun in November and expected to last for 3 months, will provide an implementation plan for execution of this framework within an integrated environment. The scope of the study addresses the United States Department of Defense weapons and system requirements, an assessment of commercial geographic information systems capabilities, data compression, media, ongoing map, chart, imagery and formatted text projects, as well as the mapping, charting, and geodesy needs of the intelligence community. The framework that evolved from this study is a mapping, charting, and geodesy hierarchy of standards.

At the very top of this architecture is the "Environment Level". Within this level are the protocols that enable the algorithms and software at the lower levels to operate within the users environment. Included will be such things as standard operating system environments, standard query languages, presentation manager interfaces and graphics interfaces. This level represents standard platforms and operating system environments such as VAX, MacIntosh, PC and Sun workstations, standard languages such as FORTRAN and C, presentation managers such as X-Windows and standard query languages such as SQL. DMA will not drive these standards but we must ensure that lower level standards which are developed are compatible with these standard environments.

The "Exploitation Level" will contain user-oriented standard algorithms for such things as datum transformations, grid and projection generation, coordinate conversions, thinning and generalization, contouring, panelling and merging. This level is very important, for it is here where DMA can have a tremendous impact. We must provide not only standard algorithms and software, but guidance on the proper applications, expected accuracies and selection criteria to choose the proper algorithms to satisfy user-specific applications.

The "Data Directory Level" contains global information common across all product forms: tiling, indexing and cataloging schemes, recording history, spatial referencing schemes, accuracy, currency and legend information, as well as indices to aid the user in rapid access techniques.

At the "Product Level", the content, extent (coverage) and accuracy of specific products will be defined. Product Level standards also include delineation rules, capture and inclusion conditions, relations, procedural constructs and symbolization rules.

The "Data Dictionary Level" defines the spatial data structure (i.e. raster versus vector), and the feature coding scheme (i.e. glossary and lists of features and their attributes).

The "Format Level" describes the manner in which the physical organization of data is determined. For records, fields and subfields, the format defines the use of fixed versus variable lengths; the use of tags and delimiters versus constant position; the use of ASCII versus binary character coding; and the imbedding of the format description within the data set versus separate documentation.

The "Media Level" standards describe the volume labelling and physical characteristics of the transport media (i.e. magnetic tape, CD-ROM, etc.). DMA will not influence standards at this level but will adopt pertinent industry standards such as ISO 9660 for volume labelling and Philips Yellow Book for the physical characteristics of CD-ROM.

### *Digital Chart of the World*

The Defense Mapping Agency's flagship effort for the development of vector product standards is called "Digital Chart of the World". The goals of this initiative are: the development of exchange standards for all DMA vector products; the demonstration of those exchange standards on a broad range of prototypes; development of software to display and manipulate data using the standards; and the production of a 1:1 million scale product, suitable for geographic information systems applications. The Digital Chart of the World product is based on the existing 1:1 million scale Operational Navigation Charts. It will be topologically structured, thematically separated and organized relationally. The Digital Chart of the World will be distributed on CD-ROM The final product will be available at the end of 1991.

*Utility software development*

Several initiatives are under way to assist the user in the import, display and manipulation of digital mapping, charting and geodetic information under the mapping, charting and geodesy utility software development program. The Common User Interface project will standardize the look and feel of interactive menus and standardize terminology used.

The Software Design project will establish conventions for the design, documentation and development of mapping, charting, and geodesy utility software.

The goal of the Symbol Development and Display project is to establish a mechanism for creation and exchange of standardized symbol libraries for display in a softcopy environment.

The current Department of Defense *Glossary of Mapping, Charting, and Geodetic Terms* is being updated to include definitions of digital and geographic information systems terminology applicable to DMA products.

A handbook on datum transformations, generation of grids and projections and coordinate conversions has been circulated for service review. This handbook provides guidance to users on selection of appropriate algorithms, expected accuracies and performance characteristics. A follow-up to this project is an effort to establish United States military standards software, employing the guidance of the handbook.

An operations concept for a library of utility software is under development which will identify how the software will be maintained and distributed, how configuration management will be performed and how information on available software will be provided to the users.

## Research and Development Initiatives, 1991

All of the previous initiatives represent current activities. The following activities represent new starts for 1991 and beyond.

The goal of the digital map data comparison initiative is to demonstrate the proper application and uses of machine readable products. These demonstrations will highlight the differences, advantages, disadvantages and capabilities of DMA vector, raster and video products. The Digital Products Study, mentioned earlier, identified a number of different compression techniques suitable for use on Defense Mapping Agency raster, vector and formatted text products. The study concluded that selection of a single compression methodology could not be done without a detailed analytical evaluation to test both the metric and visual effects of compression. The services have been invited to participate in this compression study. At the conclusion of the study, a single compression technique will be selected (for each product form) and applied to DMA products.

Development of standards which describe the structure, format, content etc. of new digital products will continue. Transition plans for the application of these standards to traditional Defense Mapping Agency digital vector, raster and formatted text products will be developed.

Efforts will also continue in the development of demonstration and display, translation and utility software for the import, display and manipulation of mapping, charting and geodesy data in the typical user environment.

DMA will also investigate the use of new media technologies, including Write Once Read Many, Very Large Data Storage, rewritable optical media, Videodisc and 8mm cassette.

We will also continue our support, both financially and through participation, to joint efforts within the Department of Defense, other national and international agencies and academia. Some of these include: the Digital Geographic Information Working Group, the National Center for Geographic Information Analysis, the Federal Geographic Data Committee (formerly Federal Interagency Coordinating Committee on Digital Cartography), the National Science Foundation, the National Institute of Science and Technology and the International Geodetic Symposium on Global Positioning Satellite.

## Conclusion

In summary, DMA has been involved in digital product standardization activities for more than a year. A study identifying and addressing major mapping, charting and geodesy issues concerning production, a hierarchy of mapping, charting and geodesy standards, compression, decompression, utility software, computer readable media, packaging and distribution, digital map displays, advanced products concepts and rapid prototyping capabilities will make important recommendations on the optimum uses of DMA digital products. This information will support our participation and coordination with national and international standardization organizations.

For further information of Defense Mapping Agency's Data Standardization program, contact:

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|---|---|---|
| Director | | Director |
| Defense Mapping Agency | or | Defense Mapping Agency Systems Center |
| Attn: PRS | | Attn: SGC |
| 8613 Lee Highway | | 8613 Lee Highway |
| Fairfax, Virginia 22031-2137 | | Fairfax, Virginia 22031-2138 |
| Telephone: (703) 285-9238 | | Telephone: (703) 285-9257 |

# APPROACHES TO SPATIAL DATABASE TRANSFER STANDARDS*

*Submitted by the International Cartographic Association*


## RÉSUMÉ

L'Association cartographique internationale (ACI) a créé un groupe de travail sur les normes d'échange entre bases de données cartographiques numériques. Le présent rapport décrit les activités de ce groupe et présente des conclusions sur les caractéristiques d'un système idéal de transfert de données spatiales. Il évoque également les efforts entrepris dans de très nombreux pays afin d'élaborer de telles normes.


Since the middle of the 1960s various individuals, groups and organizations in many countries of the world have built various kinds of cartographic databases for use with their cartographic software systems to analyse and display their data. In the early years this work was uncoordinated and somewhat haphazard, but as the years progressed it came to be realized that great efficiencies could be gained if the cartographic database built by one group could be used by another on a system that is different from the originating system. It has been further realized that greater efficiencies could be gained if transfer standards could be developed that would facilitate transfers of cartographic databases.

This idea arose in the 1980s among many cartographic and spatial data processing groups and organizations, which had been working on the problem for some years. Other groups and organizations have become interested in the problem more recently. As the work was initiated in various countries, research workers began informally to compare notes and experiences concerning such developments. A number of informal discussions were held at the last few International Cartographic Association (ICA) technical meetings. During the ICA Congress in Morelia, Mexico, in 1987, under the Commission on Advanced Technology the topic was formally examined and discussed.

From those meetings, the ICA Working Group on Digital Cartographic Database Exchange Standards was founded in early 1989 with the following directives.

(*a*) The Working Group will be organized in the 1989 time period;

(*b*) The initial meeting of the Working Group will be held during the ICA meeting in Budapest in August 1989;

(*c*) The goals of the Working Group are:

- (i) To exchange information and reports by the ICA member countries concerning the development of digital cartographic data exchange standards;
- (ii) To collect and distribute in the Working Group copies of all standards published in ICA countries;
- (iii) To serve as a focal point of information concerning digital cartographic data exchange developments throughout the world;
- (iv) To identify research needs that arise from the standards process;

(*d*) A presentation by each member of the Working Group will be made at the Budapest meetings concerning cartographic standards activities in his/her member country.

An effort was made to contact the ICA countries that were engaged in or interested in such work to nominate a member for the Working Group. International organizations that were known to be working on this problem were invited to nominate an observer to the Working Group. The idea was to have a member or observer to represent each active ICA nation and international organization in the world.

The founding meeting of the Working Group was held at the ICA technical meetings in Budapest, in August 1989. Representatives from 16 ICA countries were present. Many Working Group members gave presentations concerning the status of cartographic database transfer standards in their countries. At this meeting in Budapest, the Working Group also added a fifth goal, that of producing an ICA monograph that discusses the present state of development of such standards in the various ICA countries and organizations throughout the world. That desire has resulted in the present monograph. Since the meetings in Budapest the members of the Working Group worked diligently to produce their chapters. The Working Group met in Switzerland in July 1990 to review their draft chapters and finalize them.

This monograph is organized into an introduction by the editor that provides the background for the effort. It also provides an explanation of some of the important concepts underlying the effort, as well as a discussion of the transfer process itself. This preliminary material is important to the reader, enabling him to understand more clearly the individual efforts. It also contains a brief review of each following chapter to succinctly encapsulate each effort in a larger context, and concludes with a brief summary of the introductory material. Following, are about 20 substantive chapters presenting the efforts in progress in each represented country and organization. The whole presents a comprehensive picture of the cartographic database transfer standards development efforts that are active throughout the world. (In one or two cases groups invited to write chapters did not complete them.)

As one reads these individual descriptions of the activities of standards development in the ICA countries and other organizations, it is possible to get the impression that all of the theoretical details are completely understood. This is far from the case. Rather, there are many theoretical concepts that are incompletely understood or in some cases, are not understood well at all. These situations provide a number of interesting research opportunities, as described in Moellering (1991b).

## Basic concepts

In order to efficiently understand the transfer process and the following discussions, it is crucial to clearly comprehend the fundamental cartographic theory underlying the work, i.e. the notions of real and virtual maps, deep and surface cartographic structure, and the notion of cartographic data levels. These concepts, and many others, are emerging from the developing area of analytical cartography, which is a major thrust to develop a more theoretical and mathematical

*The original text of this paper appeared as document E/CONF 83/L.32.

basis for cartographic concepts. A brief review of analytical cartography has recently been written by Moellering (1991a).

The first major concept of interest here is that of real and virtual maps. During the early 1970s there arose many cartographic products such as cathode-ray tube (CRT) images and digital terrain models that went beyond the conventional definition of a map as a fixed hardcopy product. These developments resulted in calls to expand the definition of what constituted a map. This dilemma was crystallized by Morrison (1974) in the lead article of the first issue of *American Cartographer* where he recognized this growing problem and called for an expanded definition of what constitutes a map. Moellering was faced with the same problem and took up the challenge issued by Morrison. After a few years of research the concept of real and virtual maps was proposed (Moellering, 1980).

It turns out that there are two crucial characteristics that differentiate conventional hardcopy maps from other kinds of virtual maps. The first is whether the product can be directly viewed as a cartographic image. Conventional maps and CRT images can be seen that way, but cartographic data files and things like Fourier transforms cannot: they must first be transformed to a state that has direct viewability. The second crucial characteristic is whether the product has a permanent tangible reality. Figure 1 gives a four class diagram that shows the resulting classes of real and virtual maps generated by yes/no answers to the two characteristics. The definitions for these classes (Moellering, 1980) are as follows:

*Real map* is any cartographic product which has a directly viewable cartographic image and has a permanent tangible reality (hardcopy). There is no differentiation as to whether that real map was produced by mechanical or electronic means.

*Virtual map, type 1* has a directly viewable cartographic image but only a transient reality, as has a CRT map image. This is what Riffe called a temporary map. Given the direction of current scientific work, electro-cognitive displays may be possible.

*Virtual map, type 2* has a permanent tangible reality, but cannot be directly viewed as a cartographic image. These are all hardcopy media, but in all cases the products must be processed further to be made viewable. It is interesting to note that the film animation adds a temporal dimension to the cartographic information.

*Virtual map, type 3* has neither of the characteristics of the earlier classes, but can be converted into a real map as readily as the other two classes of virtual maps. Computer-based information in this form is usually very easily manipulated.

Here it can be seen that conventional cartographic products such as sheet maps, atlases and globes that have a fixed tangible reality, and are directly viewable as a cartographic image are called "real maps". The other three classes lack one or both of the two characteristics and are called "virtual

**Figure 1. The four classes of real and virtual maps**

*Directly viewable as a cartographic image*

| *Permanent tangible reality* | *Yes* | *No* |
|---|---|---|
| *Yes* | REAL MAP<br><br>Conventional sheet map<br>Globe<br>Orthophoto map<br>Machine drawn map<br>Computer output microfilm<br>Block diagram<br>Plastic relief model | VIRTUAL MAP, TYPE 2<br><br>Traditional field data<br>Gazeteer<br>Anaglyph<br>Film animation<br>Hologram (stored)<br>Fourier transform (stored)<br>Laser disk data |
| *No* | VIRTUAL MAP, TYPE 1<br><br>CRT map image<br>(a) Refresh<br>(b) Storage tube<br>(c) Plasma panel<br>Cognitive map<br>(two-dimensional image) | VIRTUAL MAP, TYPE 3<br><br>Digital memory (data)<br>Magnetic disk or tape (data)<br>Video animation<br>Digital terrain model<br>Cognitive map (relational geographic information) |

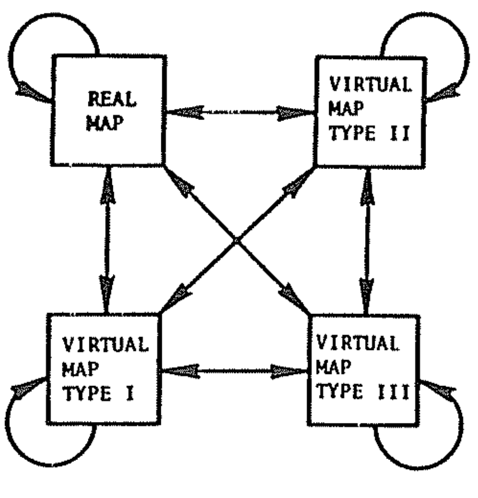
maps''. These three classes provide for the expanded definition of maps that reflects many of the developments in modern cartography. It turns out that virtual maps can contain the same information as a real map, and in the case of cartographic databases, perhaps more. Moellering recognized that even cartographic databases should be considered maps because they can contain the information of a real map and can be transformed into one if necessary. This solution solves the dilemma recognized by Morrison.

It turns out that the information in these various classes of real and virtual maps can be transformed from one to another as shown in Figure II.

Expanding on a notion pioneered by Tobler (1979), transformations between the four classes of real and virtual maps can be used to define all of the important data processes in cartography. As shown in Moellering (1984) these 16 transformations define operations such as digitizing (R ⟶ V3), CRT display (V3 ⟶ V1), making a CRT hard copy (V1 ⟶ R), direct plotting (V3 ⟶ R), or database transfer (V3 ⟶ V3). These transformations can also be used to design cartographic systems (Moellering, 1983) and can also be used to define the field of cartography itself (Moellering, 1987).

The second major concept is that of deep/surface cartographic structure developed by Nyerges in his dissertation (1980). Surface structure is defined as the graphic realization of cartographic information, and when realized in a fixed hardcopy form it is called a real map. Following the precepts of Noam Chomsky in structural linguistics, Nyerges realized that there was a direct spatial analog to the linguistic deep structure. Cartographic deep structure is the set of spatial entities, attributes and relationships between them that may or may not be graphically realizable. This information is always in a virtual state and is usually found in virtual map, type 3, databases. Figure III shows this relationship graphically where the lower part of the figure, the surface structure made up of real maps and virtual maps, type 1, is the area where traditional cartography has been focused for the many centuries of its long and glorious history. However, in the last decade, a new area has been identified, deep structure made up of virtual maps, type 3, that is now the focus of an expanding area of analytical work. Deep structure contains work on spatial data structures, analytical operators, and fractals, just to name a few. For a fuller discussion of analytical map use, see Nyerges (1991). This concept is introduced here because of cartographic database transfers. Further explanation and discussion will follow in a later section.

**Figure II. The 16 real/virtual map transformations**




This concept greatly expands our understanding of cartography and directly reinforces the concept of virtual maps. It can also be seen that analytical cartography largely operates in the area of deep structure and displays its results in a surface representation of some kind, many times in the form of virtual map, type 1, CRT images.

The third major concept of importance here is that of Nyerges data levels (1980), which define the levels of spatial data from the most general level of data reality to the most specific level of machine storage, as the bits and bytes are contained in computer hardware systems. Table 1 lists these levels and provides a short description of them.

It turns out that in early developments in cartographic data structures many researchers tried to define the *data structure*, (Nyerges level 4) directly, without having defined the more general levels of the *information structure* and the *canonical structure* first. The *information structure* is a formal model of the information to be housed and managed in the spatial database, while the *canonical structure* is a model of the data to be coded, structured and housed in the database. The *data structure* is dependent on those two more general levels if it is to be efficiently defined. The *data structure* is then stored in data records in the *storage structure*, which is physically stored as bits and bytes in the computer hardware in Nyerges level 6. This work suggests why so many spatial data structures of the 1970s did not work very efficiently or in some cases failed outright. Hence, this concept is crucial to understand in order to clearly see what is involved in the cartographic database transfer process.

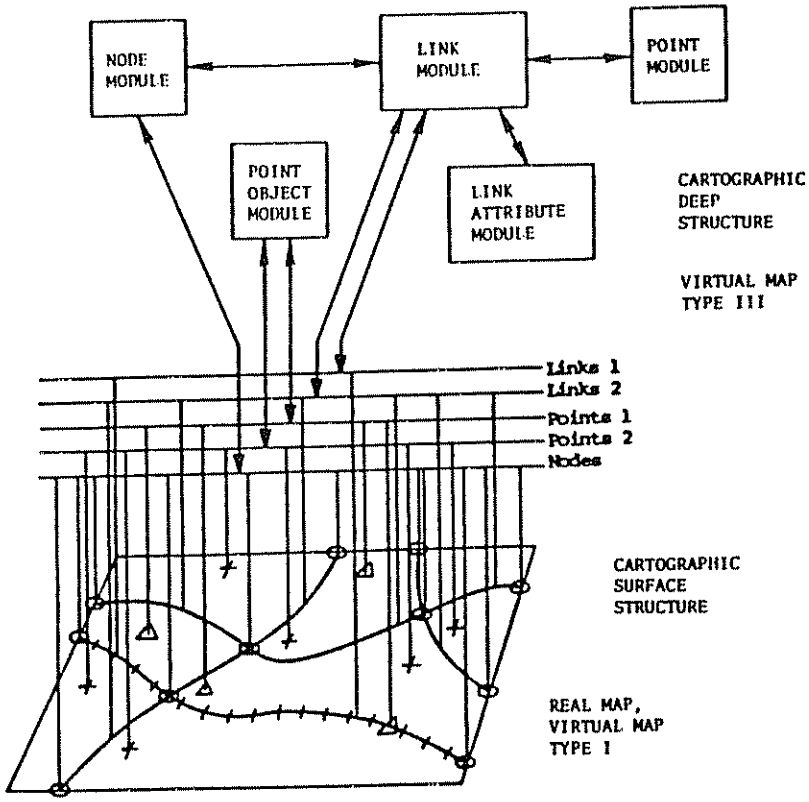
## DATABASE TRANSFER PROCESS

At the outset, one might conceive of this cartographic database transfer process as capturing and moving a real map image from one system to another. In this view such a transfer would be a surface structure transfer. However, the

TABLE 1 NYERGES DATA LEVELS

| *Level* | *Definition* |
|---|---|
| 1. *Data reality* . . . | The real world and data pertaining to it concerning cartographic entities and relationships between them. |
| 2. *Information structure* | A formal model that specifies the organization of information pertaining to a specific phenomenon. It includes data classes and relationships between them and acts as a skeleton for the canonical structure. |
| 3. *Canonical structure* | A data model representing the inherent structure of a data set which is independent of specific applications and systems which manage such data. |
| 4. *Data structure* . . | A logical data organization designed for a particular system in which specific relationships and links are implemented. |
| 5. *Storage structure* . . . | A specification of how a particular data structure is stored in data records in a particular system. |
| 6. *Machine encoding* . | The physical representation of how the structure is held in the physical devices of computer system hardware. |

Figure III. Deep and surface cartographic structure




cartographic world is a far richer place than that. The cartographic information to be transferred must first be organized into a virtual-3 deep structure database. This is because such a virtual-3 deep structure organization allows for the addition of more deep structure information which is associated with the database, but is not of a surface structure (graphic) nature. Such deep structure information can include a wealth of attribute information, for example, that may be used in the database for analytical purposes and not necessarily for graphic rendering. The key idea here is that such a database transfer between systems is a deep structure virtual-3 transfer and not a surface structure transfer. A deep structure transfer facilitates building the transfer file itself as well as the restructuring of the data itself into the spatial data structure of the system to which the database is being transferred. One must realize that when cartographic or spatial data is in a virtual-3 deep structure form, it is much more flexible and manipulatable than it would be in other states.

At this point it is important to understand the difference between the use of pairwise converters for database transfers, the current situation, and the use of a more general metafile transfer, the proposed situation for most national transfer standards. One issue involves the number of database converters that would be required to do the job. Suppose that there are 100 cartographic systems with heterogeneous data structures, software systems and hardware architectures in an open systems environment that are candidates for transferring spatial databases among them. Using the current situation of pairwise data converters as an example, one would need

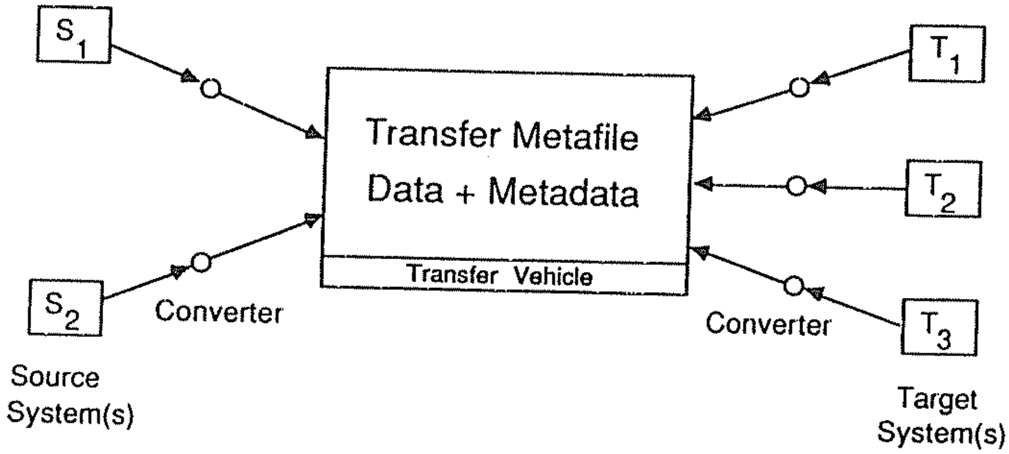
$$\frac{N(N-1)}{2} = \frac{100\,(99)}{2} = \frac{9{,}900}{2}$$

$$= 4{,}950 \text{ pairwise converters}$$

to accomplish the transfer between all combinations of systems. The desired situation is to have a common metafile transfer standard that can be used for almost all database transfers where 2 N+ = 2 (100) = 200+ metafile converters would be required to accomplish the task. It can be clearly seen that the metafile transfer approach is preferred because in theory about 200 metafile converters would be required, whereas 4,950 pairwise converters would be required. This is a tremendous difference. In practice this difference would probably be smaller because in the pairwise case not all combinations would require implementation, and in the metafile case converters would probably be required for general classes of spatial database systems. But even if three times more metafile converters were required, 600 in this example, and only 60 per cent of the pairwise converters were required, the difference would be about 3,000 converters for the pairwise case and 600 for the metafile case. This is still a five-to-one savings for the metafile approach. That is why national standards groups are moving towards this solution for their database transfer requirements. For the long run, the metafile approach is clearly preferred.

Figure IV illustrates the general cartographic database transfer process. On the left is the source database with its own information structure, canonical structure, and data structure, data elements and modules. On the right are several target databases to which one desires to transfer the cartographic database. These cartographic databases are associated with different systems that may have very different data structures and hardware architectures. Therefore the source data structure usually cannot be transferred directly between the two systems. It is usually necessary to take the source database and convert it into the organization of the transfer metafile. This conversion is done by a software converter designed for that purpose that reads the data

Figure IV. The cartographic database transfer process




structure of the source database and converts it into the structure of the transfer metafile.

The transfer metafile has a structure that is specified by the national standard for which it was designed. This transfer metafile is the actual vehicle that carries the data from the source to the target systems. The internal structure of various national transfer standards differ widely in approach and design. They range from fairly straightforward formats to fairly rich transfer mechanisms. This will be discussed later. Many national transfer metafiles have as their base an international transfer standard such as ISO 8211, or others, to act as base transfer vehicle. This vehicle facilitates the actual mechanics of the transfer.

When the transfer metafile arrives at the target system, it must be converted from the organization of the transfer file to that of the target system(s). This is accomplished by a converter that reads the transfer metafile and converts the structure of the data to that of the target system. That system itself will then insert the actual data into its database.

One question that arises from the above description is: What kinds of data components can be transferred with such a process? Fundamentally, one has descriptions of features from the real map and attributes associated with them, cartographic objects that contain the geometry and topology of the features, information on the data quality, and other essential information such as projection, coordinate system etc. The features have been defined by the individual national groups and code such things as mountains, streams, transportation, cities, soil, population and a host of other things that exist in the real world. Associated with these features are sets of attributes that contain information about those features, such as mountain elevations, stream flow, transportation type, city name, soil type, population components and so on. The cartographic objects usually have a set of primitives that begin with the level of spatial dimension, 0-, 1-, 2-, 3- etc. and may contain information about topological properties of the object, such as connectivity or contiguity (neighbour relation). Quality information that relates to the above features, attributes and objects is specified and carried along with the transfer. Depending on how this information is specified, this quality information could relate to large classes of data, or to individual features or objects themselves. Ancillary information, such as projection and coordinate system is usually part of the transfer file and serves an important role in processing the data. Finally, some standards include metadata, which is data that relate to the substantive data being transferred, to aid in the transfer process. Such metadata can be particularly helpful to the decoding converter that receives the transfer metafile and converts into the structure of the target system. The nature of this metadata varies greatly between the various national transfer standards. This above discussion also implies that each national standard has specified things like feature definitions, object definitions, quality levels, and the transfer metafile organization itself.

*Transfer process and data models*

The database transfer process can also be examined from the point of view of the data model(s) involved. At the conceptual level it involves the information structure (Nyerges level 2), and the canonical structure (Nyerges level 3), while at the operational level it involves the data structure (Nyerges level 4) and the storage structure (Nyerges level 5). The information structure is a model that describes how the entities from the real world that are contained in the database are related one to another. In order for a database transfer to take place effectively, the source database and the target database must be compatible with one another. For example, if the source database only contains information pertaining to roadway systems and the target database only information pertaining to streams and waterways, a data transfer is not feasible because the source and target databases are not compatible with each other. If, on the other hand, the target database contains data on streams, waterways, roadways and communication linkages, then a transfer from the source to the target database is feasible. Therefore, at the information structure level, when the subject matter of the source and target databases is compatible, a transfer between them is usually feasible, assuming that the lower Nyerges levels are compatible too.

One can now look at the canonical structure (Nyerges level 3), which specifies the model of the data contained in a database. At the outset one must be clearly aware that three general families of data structures are specified by such a data model: vector, raster and relational. These are treated as distinct classes of data organization which are not compatible with one another. Therefore, it is not feasible to attempt to transfer data from a source database that has some sort of raster structure to a target database that has some sort of vector structure. Going between these three families of spatial data organization is a data conversion problem beyond the sort of spatial data transfer problem being discussed here. Since this discussion focuses on the data transfer question, such conversions between the three families of spatial data will not be further considered here. It is therefore assumed that database transfers of the kind being discussed here will be transfers *within* each of these three fundamental families of spatial data. However, with some of the national efforts, it is possible and feasible to transfer data from these three families within different sections of a transfer file. In that case raster data from the source system would arrive as raster data at the target system, vector from the source system would arrive at the target system as vector data, and so on. No conversions between families could be made. The intriguing question as to whether there may exist a unified theory of spatial data that would permit more general data models and structures has been raised and discussed in Moellering (1991b).

The data model specifies the formal organization of the spatial data for a particular system. When transferring data between two systems that have the identical data model, even when there are differences in the implementation of the data structure (Nyerges level 4), the transfer is straightforward. This current discussion is setting aside the question of hardware architecture differences for the moment, which will be discussed later. The more typical case is when the data models in the source and target systems are different, even though they are in the same data structure family. The general answer to this question is that if the source and target systems contain the equivalent information, even though it may be structured in differing data models, a data transfer can usually be carried out. However, there are limitations to this possibility. For example, if the source system data model contains geometry and topology for the fundamental cartographic objects, and the target system data model only contains geometry for such objects, the transfer can be made, although it will be an information losing transfer. However, if the source system data model only contains geometric information on the cartographic objects, and the target system data model contains both geometry and topology, then a problem arises because the target system requires information that is not found in the source system. Since the data transfer tools described below are not designed to generate new information for the target system, such a transfer cannot be carried out. Therefore, the general principle to be learned here is that these kinds of data transfers can be information-losing, although it is inefficient to do so, but they cannot be information-gaining.

One can then consider the specifics of the data structure, (Nyerges level 4). It is very common for large differences to exist between data structures in the source and target systems even though the data models may be fairly similar. obviously large differences will exist between the two data structures when the data models are also very different. Assuming that the information contained in the source and target systems are equivalent, the transfer process must restructure the data so it is compatible with the target system when they arrive at that end of the process. The transfer process must also overcome differences at the storage structure level (Nyerges level 5), as well. There will almost always be large differences between the storage structures of the source and target systems due to differences of the operating system and hardware architecture differences. These kinds of differences are not inconsequential and must be properly handled by the transfer process.

*Transfer machinery*

One can now begin to turn to the machinery that actually carries out the data transfer. It turns out that the various national standard proposals differ considerably in outlook and approach to this problem. This section provides a conceptual framework of the range of the kinds of transfer machinery that is being proposed in the field. In all cases such transfer machinery must accomplish two major tasks:

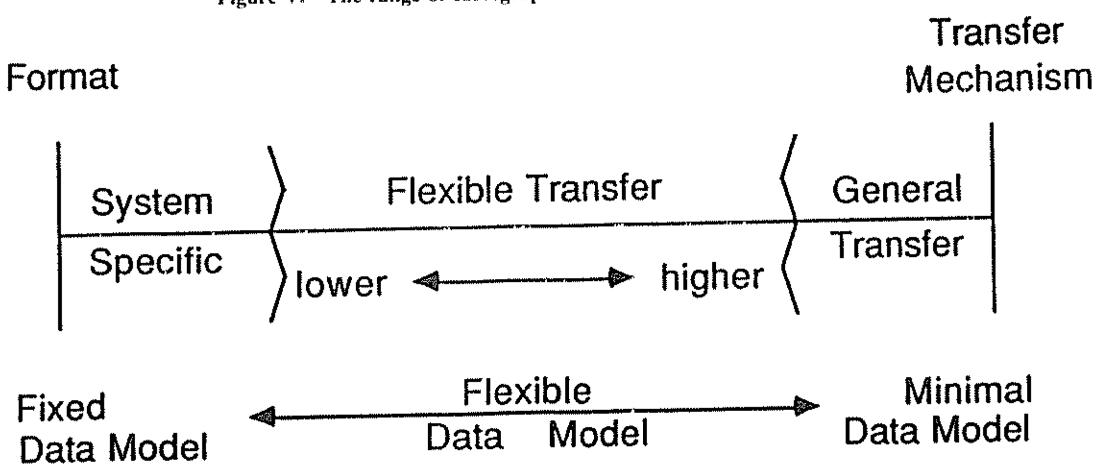
(*a*) It must transfer spatial data from source to target system where there are differences between the data models, data structures, and storage structures of the two systems, as discussed above;

(*b*) It must transfer the spatial data in such a way that the process transcends difference in hardware architecture between the source and target systems.

This second requirement is just as important as the first. Every transfer standard must address this question. In general, approaches to the problem range from using a fairly fixed format to using one of the international standards such as ISO 8211 or EDIFACT as a basic implementation vehicle.

Reflecting back to figure IV, every standard has a transfer file. Those that are more rigid transfer the information in the form of a fairly rigid data model. As the transfer standard becomes more flexible the data model reflected in the transfer file becomes more flexible. The most flexible form of transfer standard can be called a transfer mechanism. Here the transfer data model is a very flexible minimal model that can accommodate a wide range of source/target data models. This range of approaches to the problem can be conceptually viewed as a continuum, as illustrated in figure V. At the

**Figure V. The range of cartographic database transfer processes**



extreme left is the system-specific fixed data model that would be a fixed fairly rigid format. If the source and target systems were the same fixed data model used by the transfer standard, the data transfer would be very simple. However, this level is very inflexible and generally cannot accommodate a wide range of other data models for transfer. It would have fairly limited use between differing systems. Few if any of the national standards proposals are this rigid. More likely is the case where the transfer standard has its own fairly specific data model that has been designed to accommodate a wider range of source and target data models. These more flexible data formats are more widely applicable to the situation where there are wider differences between the source and target data models. These systems require that the source data model be converted into the transfer data model which is then later converted into the target system data model. This also implies conversions in the data structures and file structures as well. The more flexible is one of these transfer formats, the wider the range of source and target data models that can be accommodated. However, this implies increasing complexity of the standard as the flexibility of the format increases. The most flexible kind of a transfer standard tends toward a very flexible data model that is almost minimal in nature. It focuses on a modular primitive object design where the transfer structure is organized around the source data model in such a way that the transfer structure can be decomposed and reconstituted later as the target data model. This sort of transfer standard can be called a transfer mechanism. At the extreme, such a transfer mechanism would have a very minimal data model that can be structured to accommodate an extremely wide range of source/target data models. As the range of the flexibility of such a transfer mechanism increased, the complexity of the mechanism would also increase. The goals here would be to design a mechanism that maximized flexibility and minimized complexity. Since these goals conflict and are trade-offs one with another, the task of designing a national transfer standard that serves the professional community efficiently is not an easy one.

## Desired Characteristics of the Transfer Process

As one looks at this sort of spatial data transfer process, it is possible to identify basic characteristics that such a process should possess. The following discussion provides a listing and brief definition of the desirable characteristics that such a process should have. It is based on an earlier discussion by Moellering (1988) and has been adapted to the more general international situation. The discussion will be carried out in terms of general characteristics, cartographic objects, data quality, cartographic entities and, finally, the transfer machinery.

*Transfer three major families of spatial data structures*

Currently there exist three major families of spatial data structures. A successful database exchange process should be able to transfer vector, raster and relational data structures and associated ancillary information.

*Transfer across different computer architectures*

For proprietary reasons there are many different kinds of internal machine architectures for computers. Many of these architectures are not compatible with each other. A good spatial database transfer mechanism will be able to transcend such architectural differences.

*Transfer databases between non-communicating parties*

Typical database exchanges require prior communication, documentation and sometimes extensive discussion before any data can be transferred. The goal is to specify the standard so that this kind of communication is not necessary, but is built in as part of a standard data exchange mechanism.

*Modular and extendible*

Because of the dynamic developments in the field of cartography and spatial data structures, the standard must be specified in a modular fashion. In this way new developments which need to be included in the future can be added in a modular fashion without disturbing other parts of the standard. Obsolete parts could be deleted in a similar way.

*Robust and reliable*

Any database exchange mechanism must be specified so that it is robust and reliable. This means that it must not be sensitive to some data errors and occasional data corruption so that data perishability during transmission should be very low, thus ensuring that the probability of correct transmission is quite high.

*Media independent*

The exchange mechanism should be media independent so that spatial databases can be transferred by magnetic tape, direct telecommunication, hard or floppy disk, CD/ROM or any other appropriate medium.

*Transfer both syntax and semantics*

A good transfer process with the above characteristics should be able to exchange the syntax, or structure of the data reasonably straightforwardly. However, the capture of the semantics, or meaning of the information transferred is much more difficult to insure. Transfer of the semantics is more difficult to do than is the transfer of syntax.

*Facilitate the transfer of self-describing databases*

Currently such databases are experimental or only a gleam in the designer's eye. However, it is clear that such databases are being developed and that they will be in common use within a decade. A standard must accommodate such exchanges.

*Use best concepts and existing standards available*

Developing an efficiently and comprehensive spatial database transfer standard is not a simple matter. Therefore one must be clearly aware of current research so that the best available concepts are used in the design of the standard. The items presented in the conceptual background form the crucial intellectual basis of a standard. Existing national and international standards that apply to the problem must be sought out and examined. Such existing standards should be utilized whenever possible.

*Awareness of work in cognate areas*

Every discipline such as cartography has interactions with its cognate areas, and therefore one must be aware of what is going on in those areas in the way of standards activities. In this case one must pay attention to four primary cognate areas: geographic and land information systems, photogrammetry and remote sensing, computer graphics and CAD/CAM, and, geodetic and land surveying.

*Involve the user community in the process*

This is a very important and time-consuming activity. However, it is crucial, because as the scientific solution to the standard is developed, a consensus must be developed in the professional community it is intended to serve.

*Maintenance authority*

Developing cartographic standards is not a one-time process. Since such a standard is being built in an area such as spatial data, there is active research taking place in many areas. One must realize that periodically the standard will have to be updated. Therefore, it is clear that the initial effort must be conducted so that future enhancements can be made without disturbing the existing parts of the standard. Hence, the notions of modularity, extendibility and robustness become very important so that the standard can be enhanced as new developments take place. All of this implies the founding of a maintenance authority to supervise the interpretation of the standard and to lead the work of actual maintenance. It is expected that the area with the highest demands on maintenance will be the cartographic entities.

## CARTOGRAPHIC OBJECTS

Cartographic objects are the digital representation of entities and as such are the fundamental building blocks of any spatial data structure. Hence, they must be modular, and be capable of being assembled into more complex and higher dimensional structures.

*Only necessary to define primitive and simple objects*

As with any standard, one must always clearly define the primitives in the system. Here it was also necessary to define some simple objects that are constructed out of primitives from lower dimensions. These simple objects serve as the primitive objects for the higher dimensions.

*0-, 1-, 2- and 3-dimensional objects should be defined*

All four levels of dimensional primitives should be specified, with provisions for building higher-level objects if they become necessary. The standards currently do not explicitly define anything above 2-D primitives because not enough is known about them at the present time. 3-D and higher dimensional objects can be added as a future enhancement as they become better understood and needed by the community.

*Geometry and topology*

When defining cartographic objects, it is necessary to define them so that they include aspects of geometry and topology. How this is done can vary greatly depending the nature of the particular national standard being defined.

*Coordinate systems*

For a spatial data standard, objects must be validly defined for both Euclidean and simple curved surfaces, such as the sphere and the ellipsoid.

*Modular and extendible object set*

Given the above object requirements and general characteristics it is clear that the set of primitive and simple objects must be modular, so that new ones, 3-D for example, can be built out of them.

## DATA QUALITY

Data quality is an essential ingredient to any database transfer because the integrity of the data must be insured throughout the exchange process.

*Truth in labelling*

The fundamental rubric under which the data quality portion of the standard operates is truth in labelling. This means that the producer of the database should be required to provide specified quality information for review by the prospective user. The user would review the quality report and decide whether that particular database is suitable for a particular application. It is anticipated that the better-quality databases will see more frequent use than those of lesser quality and hence the specification of the quality report will create a tendency towards creating databases with improved data quality.

*Flexible quality levels*

In order to function as a national standard with broad application, it is clear that a national standard must have flexible quality levels, as levels are product-specific and therefore outside a national standard; but they may exist as internal quality specifications for particular products produced by individual organizations.

*Various levels of testing rigour*

Because of the necessarily flexible quality requirements, there are also different levels of testing rigour that could be applied in a particular situation. However, the report should explicitly state which level had been applied and what the results are.

## GRAPHIC ENTITIES

Cartographic entities exist in the real world and are the things being represented modelled, analysed and displayed in modern cartographic work.

*Universal set of entity definitions*

Definitions should encompass all entities that may be coded in at the national level. However, a standard should be designed with conceptual hooks on the bottom to which additional entities and attributes could be attached.

*Modular entity definitions*

Entities are defined in a modular fashion with many aliases of analogous terms linked to them. This will serve to simplify the structural complexity of the definitions themselves, and pave the way for a non-heirarchical definition structure for the entities, if desired.

*Extendible set of entities*

Because of the modular definitions of the entities, a maintenance authority could update and modify the entity set as a regular and systematic part of its work.

*Scale independent*

These entity definitions are designed to be scale independent and not related to product specific scales. This is because a database may be used at a range of scales for various purposes, within reason.

*Non-hierarchical definition structure*

It is possible to define a set of entity definitions that are not hierarchically organized. Hierarchical entity definition structures are cumbersome to use, subject to judgemental error and are not very amenable to modern query retrieval systems. Therefore, an entity can be defined with many possible attributes and attribute values that could be assigned, depending on the situation of the actual entity in the real world.

*Designed for modern query retrieval systems*

With the modular definitions, scale independence, and non-hierarchical definitional structure, entities, their associated attributes and attribute values, can be easily entered, retrieved and manipulated in modern database query management systems.

### Transfer Machinery

The transfer machinery is what actually converts the source database to the transfer metafile form and later decodes the metafile into the target database. The transfer metafile is the exchange file that is actually transferred between computer systems. This kind of transfer can occur with magnetic tape, by direct telecommunication, with hard or floppy disk, CD/ROM or almost any other kind of form because a standard should be media-independent, as pointed out earlier.

*Transfer three families of data and ancillary information*

The data exchange mechanism should be designed to transfer data bases from all three of the fundamental data structure families: vector, raster and relational, as well as information pertaining to attributes of the entities and associated quality information.

*Modular forms and modules*

Each of the three families of data structures should have a modular transfer form associated with it. Each of these three forms should be composed of a set of modules that transfer the primitives, attributes, quality information, and other ancillary information. Every module of this kind is composed of a set of records that describes its own contents.

*Preserve syntax and semantics*

In the database transfer between systems, the syntax is preserved in the logical forms and modules. However, the semantics, or meaning, is implicitly preserved in the syntax of the exchange. Clearly, the syntax of the information is easier to preserve than the semantics.

*Minimize external documentation*

A good database exchange process will reduce the need for external documentation, particularly if the software is written to run interactively. Ultimately, such a standard should be designed with the concept of being able to support self-describing databases in the future when they become available.

*Generate export database metafiles*

The transfer converter processes the information from the source database and creates an exchange metafile for the actual database transfer between systems as shown in figure IV. The transfer metafile will then be decoded into the target database by the converter.

*Conform to existing standards*

A particular standard must usually conform to existing national standards. In addition, the International Standards Organization (ISO) standards should be used whenever practicable. These are the same or similar to existing standards used in other countries.

### Overview of Standards Efforts

Currently, there are about 20 ICA member nations and other international organizations working on the question of spatial database transfer standards. This work includes chapters describing 18 efforts in progress, ranging from those that are at the initial stages of examining the problem to those that are nearly finished with a comprehensive effort. The following discussion summarizes each effort for which a written chapter has been received.

*Australia*

Work on a national topographic data transfer standard began in Australia in 1974, a very early effort. The effort focused on developing a transfer format for map data that was codified in 1981 by Standards Australia as AS 2482 Interchange of Feature Coded Digital Mapping Data. The standard was revised in 1984. In the later 1980s the group realized that a more comprehensive database transfer standard was needed. The groups are now evaluating their effort as well as the work of several of the ICA national groups. Currently the United States spatial data transfer standard (SDTS) is a leading candidate for adoption. Further evaluation is proceeding.

*Austria*

Although digital map data processing has been going on for many years in Austria, it is only recently that an initial database transfer standard has been proposed by the Austrian Standards Institute. This standard is called ONORM A 2260, 1990 *Datenschnittstelle für den Austausch geographischer-geometrischer Plandaten* (Interface for digital exchange of geographic-geometrical data). This data transfer format is oriented primarily towards large-scale maps and drawings. As such, it is currently geometry only with topology not explicitly specified. Since the standard was proposed in 1990, it has not yet been extensively field tested.

*Canada*

Canada is in the interesting position of developing more than one spatial database transfer standard, the first in the topographic area, and the second in the hydrographic area. The first effort was begun in the late 1970s by the Canadian Council of Surveying and Mapping (CCSM), now called the Canadian Council on Geomatics (COG). They have developed a standard for the exchange of digital topographic data which was originally proposed in 1982. The proposed standard is a variation of a flexible format, and includes a data model, standard features and attributes, a quality specification, and a file format. Implementation and testing of the standard commenced in 1986. The standard is in its later stages of approval.

The second major effort in Canada is that of a map and chart data interface format (MACDIF) proposed by a group of agencies in the country. Work began in 1985 and is progressing. The MACDIF syntax is based on the abstract notation syntax (ASN) and is intended "to standardize the interface point between two communicating entities regardless of the mapping or charting application".

Work is also continuing to develop a geographic document architecture (GDA). This effort is intended to operate in an open systems interconnection (OSI) environment.

*People's Republic of China*

The challenge of cartographic database transfer is seen as a component of geographic information system (GIS) standardization in China. Work is in the early stages of defining the problem in this context. It includes projects to develop land classification codes, creation of 1:4M geographic database, computerization of topographic symbols, among others

*Finland*

Work on database transfer has been going on in Finland since the 1970s. In 1985 the Ministry of Agriculture and Forestry established a steering committee on the LIS project. The practical part of this work is being carried out by the National Land Survey. This work has resulted in the National Administrative Standards (VHS): VHS 1041 on geographical data representation and VHS 1040 on message description. These standards operate in an EDIFACT (ISO 9735, Electronic Data Interchange for Administration Commerce and Transport) environment. As such, these data transfer standards seem to be fairly flexible transfer mechanism. Additional work has been carried out on a geographical data dictionary system (GDDS), a geographical query language that is a subset of SQL, as well as an EDIFACT interpreter.

*France*

Work on a national transfer standard in France was initiated by the National Council for Geographic Information (CNIG) in 1987. This led to the forming of the Commission for the Normalization of Exchange Formats, which has been working on a database transfer standard in the areas of data model, data definition, exchange files and exchange of messages. This has led to the adoption of the DIGETS data model (see DGIWG below), implemented on an ISO 8211 base that is called EDIGEO. Testing is in progress.

*Federal Republic of Germany*

The effort in the Federal Republic of Germany was begun in the early 1970s by the Working Committee of the Surveying and Mapping Institutes of the Länder (ADV). In 1982 the Uniform Database Interface (EDBS) was published. This work has now become involved with the development of the Authoritative Topographic Cartographic Information System (ATKIS). As part of this work a data model, feature catalog and symbol catalog have been defined. As such EDBS appears to be a relatively fixed format. Current work is being carried out to define a more flexible version of EDBS in cooperation with other European efforts, notably CERCO.

*Hungary*

In the later part of the 1980s digital cartographic data processing became more widely spread and the need for a database transfer standard was realized. Initially efforts were made to review the Canadian, American, British and German standards proposals. Further work has resulted in a proposal for a digital cadastral map standard (DCM). Work on this effort is continuing.

*Japan*

Although digital cartography has been used in Japan for many years, it is only relatively recently that standardization efforts have been actively pursued. In 1985 the Geographical Survey Institute formed the Committee for Digital Mapping Standardization. This group defined the Standard Procedure and Data Format for Digital Mapping in 1988. This specification includes data quality, a feature coding system, and transfer format. As such, this transfer standard is a somewhat flexible format based on fixed length records.

*New Zealand*

In 1987 Land Information New Zealand (LINZ) began closely evaluating possible alternatives for a spatial database transfer standard. After careful study, the United States Spatial Data Transfer Standard (SDTS) has become a leading candidate for adoption. However, LINZ is developing attribute definitions for use in the country. Further work is continuing.

*Norway*

In the late 1970s the Norwegian Ministry of Environment initiated the SOSI (Coordinated Approach to Spatial Information) project. From this project arose a defined transfer format, SOSI, in 1985. Object definitions and attribute codes were defined in 1987. The SOSI format is specified at four levels of use and, as such, is reasonably flexible. An ISO 8211 implementation vehicle is being considered. Currently SOSI handles only vector data, but future plans include handling raster and pictorial data.

*South Africa*

In 1985 a project team was formed at the Centre for Advanced Computing and Decision support to develop a national spatial data exchange standard for South Africa. In 1987 SWISK 45 was published and has now become known as the National Exchange Standard (NES). NES provides for the transfer of vector and raster data. As such it is implemented by a relational transfer format that seems to be rather flexible. Current work on NES includes further enhancement of the standard and production of a user manual.

*Sweden*

In the early 1980s the Swedish Association of Local Authorities developed a simple standard, KF85, for the transfer of vector data. Since 1986 an effort has been under way by the Research and Development Council for Land Information Technology (ULI), to define a more comprehensive data transfer standard. Currently, several working groups are carefully evaluating standards being developed in other countries. Primary interest is focusing on an adaptation of the British NTF format on an ISO 8211 implementation that is compatible with the German ATKIS system in cooperation with CERCO.

*Switzerland*

The Swiss are currently developing a cadastral-data system that will use a data transfer format called AVS (Antliche Vermessungs Schnittstelle). They are also evaluating other national efforts to develop such data exchange standards. There is interest in the possibility of adapting one of these standards as it applies to the situation in Switzerland. Evaluations are continuing.

*United Kingdom*

In 1983 the House of Lords Select Committee on Science and Technology recommended that a set of map data exchange standards should be established to replace earlier, more limited work. In 1986 the first version of the National Transfer Format (NTF) was issued. It is a reasonably flexible format that can transfer vector data with both geometry and topology. Raster and grid data can also be accommodated. NTF is specified on five levels of operation and transfers information on features and data quality. Current work involves evaluating the possibility of using ISO 8211 as the base implementation mechanism for NTF.

*United States*

The need to develop a comprehensive cartographic data transfer standard became evident in the early 1980s. To this end the National Committee for Digital Cartographic Data Standards of the American Congress on Surveying and Mapping (ACSM) was founded in 1982 under the sponsorship of the United States Geological Survey. Shortly thereafter the Federal Interagency Coordinating Committee for Digital Cartography was founded in 1983. Through their cooperative efforts *The Proposed Standard of Digital Cartographic Data* was published in 1988. Further work by the USGS Technical Review Board defined what is now known as the Spatial Data Transfer Standard (SDTS). SDTS is a very flexible exchange mechanism that will transfer vector, raster and relational data. Digital cartographic objects that have a wide variety of geometric and topological properties can be transferred. The standard consists of an object specification, entity specifications, data quality information, and the transfer mechanism. SDTS uses ISO 8211 as the basic implementation vehicle. SDTS has been extensively tested and is currently undergoing its final evaluation and polishing on its way to becoming a Federal Information Processing Standard (FIPS).

### *Commission européene des responsables de la cartographie officielle*

CERCO is an organization composed of the directors of European national cartographic agencies. As such, CERCO is interested in the possibility of defining a European Transfer Format (ETF). The leading contender seems to be a modification of the British NTF format adapted to an ISO 8211 implementation base. Discussions are continuing.

### *Digital Geographic Information Working Group*

DGIWG is an international group with members of several European countries, including the United States and Canada, which was formed in 1983. Most of these countries are NATO members, although the DGIWG leadership has stated that this effort is independent of NATO. DGIWG has recently produced a proposal for a data transfer format called DIGEST, which is intended to handle raster, vector and matrix data. DIGEST is being amended to run on an ISO 8211 implementation base. A feature and attribute coding catalogue (FACC) has also been produced, along with several specifications for raster products. Field testing of DIGEST is continuing.

## SUMMARY AND CONCLUSIONS

As the reader can see, there are currently many cartographic database transfer efforts going on in many parts of the world. The ICA Working Group on Cartographic Database Exchange Standards was founded in order to provide a forum for discussing this work at the international level.

In order to really understand the data transfer process, it is very important to understand the key concepts involved, such as real and virtual maps, their transformations, deep and surface cartographic structure, and the six Nyerges data levels. With those basic concepts in hand, one can begin to more fully understand the database transfer process. It is clear that the transfer metafile approach has advantages over the conventional pairwise converter approach because of the dramatically fewer number of data converters that would be necessary to specify, build and maintain.

It can be seen that it is possible to design and build a variety of cartographic database transfer processes that range from a simple fixed format that has rather limited use, to a more flexible format that has a much wider scope of use, to an exchange mechanism that can transfer most data organizations within the three data structure families in an environment that is hardware-independent. These characteristics, plus many more discussed above provide the specifications for an ideal spatial data transfer mechanism.

Finally, one can review the large number of national efforts to develop such standards as discussed in the following chapters of this monograph. It can be seen that there is a very wide range of activities going on, from some groups that are evaluating the situation to groups that have been working on the problem for many years and are in the final stages of a major transfer standard effort.

The question can also be raised concerning the future of this work, and the Working Group specifically. Clearly there is much more work to be done to continue dialogue between these various groups as the work proceeds. It is also possible to begin work on making comparisons between the standards being developed and proposed. It is possible that commonalities between the various transfer standards can be identified, with the possibility of developing interlinkages between some of them. The question of a world standard has been raised, but this kind of a goal seems very elusive indeed. It seems possible that some of the standards could be adopted on a regional basis for common benefit. However, much more effort is required before this question can be efficiently answered.

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# SPECIFICATIONS FOR THE INTERNATIONAL BATHYMETRIC CHARTS PRODUCED UNDER REGIONAL MAPPING PROJECTS*

*Paper submitted by the Intergovernmental Oceanographic Commission*

## RÉSUMÉ

Ce document présente des spécifications élaborées par le Groupe consultatif sur la cartographie des océans de la Commission océanographique intergouvernementale (COI). Ces spécifications devraient être appliquées par les organismes régionaux de cartographie qui élaborent des cartes bathymétriques internationales.

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This submission reproduces the specifications given in annex IV to the summary report of the second session of the IOC Consultative Group on Ocean Mapping, held in Paris from 12 January to 3 February 1987.

### ANNEX IV

**Specifications for international bathymetric charts produced under regional mapping projects**

*Section 100: General*

101—Introduction

A International Bathymetric Charts produced under Regional Mapping Projects are a continuation and further development of the General Bathymetric Chart of the Oceans (GEBCO), under the general guidance of the IOC Consultative Group on Ocean Mapping. These charts are prepared and published with the cooperation of volunteer hydrographic offices and/or groups of scientists from appropriate institutions.

B For each bathymetric chart series, an Editorial Board will be established by the IOC Assembly or Executive Council, for the purpose of technical direction of its compilation and publication.

*Section 200: Basic specifications*

201—Projection

A. Sheets between latitudes 72 degrees N and 72 degrees S shall be shown on Mercator Projection using an agreed International Ellipsoid.

B. Polar sheets shall be prepared using the Polar Stereographic Projection.

202—Scale

A A scale of 1:1, 000, 000 at a reference parallel to be defined by the Editorial Board shall normally be used.

203—Graticule

A A scaled border of each sheet shall be shown subdivided into 1-minute increments of latitude and longitude.

B. Meridians and parallels shall be drawn every 2°.

C Labelling of the graticule shall be every 1°.

D The tropics of Capricorn and Cancer and the Polar Circles shall be shown.

204—Size

The neat line size of each sheet shall not generally exceed 740 × 900 mm.

205—Numbering

A For each chart a consecutive sheet number shall be used as shown in an Assembly Diagram.

B Sheet numbers shall be printed in 8 mm Arabic figures in the lower right-hand and top left-hand corner of each sheet.

206—Dating

The date of the chart publication to be shown on each sheet shall be the date of going to Press.

207—Units of measurement

Depths and topographic heights shall be shown in metres. Depths should be corrected from the third edition of the Echo-Sounding Correction Tables, published by the United Kingdom Hydrographic Department, and this should be stated on the face of the chart.

208—Marginal information

A All marginal information shall be in English (or bilingual if appropriate).

B. This shall include:

1 The general title of the chart.

2. Sheet number.

3. Projection. ellipsoid and scale (see 201. 202)

4 Unit of measurement used for depths and heights

5 Code of colours used to portray hypsometry

6. Code of colours used to portray bathymetry.

7 An index of areas and names of countries whose hydrographic offices or groups of scientists prepared plotting sheets for the sheet

8 The names of scientific coordinators of the chart series and of scientists responsible for the scientific content of the sheet

9 The logo of the Intergovernmental Oceanographic Commission (IOC) of UNESCO

10. Edition number and date of publication (see 206) followed by the statement: "Published by the .. .. ....... (name of printer) under the authority of the IOC (of UNESCO)"

11 List of the sources of the data used (for the chart series)

*Section 300: Topography*

301—For the land part, topographic maps shall be used.

302—The best available agreed-upon coastline shall be used. The coastline shall be shown as a firm line in black.

303

A. Contours on land shall be at 200-m intervals.

B. The thicker lines shall be at 200- 1.000- 2.000- 3.000-m etc. intervals.

C Additional contours which may be required by the data must be shown.

D A colour change for hypsometry shall be used at the following intervals: 0-200. 200-1000. 1000-2000. 2000-3000 m etc.

E Glaciers shall be shown by contours or by symbols. The significant heights shall be shown.

304—Hydrology of the land

On the chart shall be shown at the discretion of the Editorial Board:

Rivers and channels

Lakes

Lagoons

These should be compatible with the contour information on land and the scale of the chart.

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*The original text of this paper appeared as document E/CONF 83/INF 25

305—Major cities and towns, priority being given to those on the coast

*Section 400 Bathymetry*

401—The 1:250,000 plotting sheets prepared by the participants in the Project, according to their zones of responsibility, shall form the basic bathymetric data to be used for the compilation of the chart

The plotting sheets shall be prepared according to the appendix to these Specifications

402—Soundings

A A sparse pattern of numerical soundings shall be shown to indicate maximum and minimum (and other significant) depths, where known, over major undersea features in such a way as not to detract from the paramount objective of indicating sea-floor relief by means of contours

B The exact position of all numerical soundings shown shall be indicated by a dot. The depth shall be written, as cartographically convenient, against the dot, using 1 5 mm sans-serif figures Where space does not permit the juxtaposition of the figures, they may be offset and linked by a fine line to the dot placed in the exact position

C In order to indicate contour reliability, all soundings used shall be shown as dots representing discrete soundings or lines representing continuously sounded traverses Areas of detailed surveys, where soundings are denser than can be conveniently shown, shall be indicated by numbered boxes referenced in the margin

403—Depth contours and colours

A Basic contours shall be at 200-m intervals

B The 200-m contour line and all contours at 1,000-m intervals shall be drawn using thick lines

C 20, 50 and 100-m contours, if necessary, shall be drawn using thin lines

D A colour change for the bathymetry shall be used at the following intervals: 0-200, 200-1000, 1000-2000, 2000-3000 etc m

*Section 500. Nomenclature and geographical names*

501

A A proposed list of names for inclusion on each sheet shall be forwarded to the GEBCO Sub-Committee on Geographical Names and Nomenclature of Ocean Bottom Features, with a request for guidance on any that might be controversial In preparing this list, account should be taken of the guidelines contained in the GEBCO publication *Standardization of Undersea Feature Names*

B As a general policy, local names (cities, towns, mountain ranges, rivers etc ) shall be in exact agreement with the form prescribed by the most authoritative national source However, in those cases where the national names differ substantially from the normal English usage, the English version shall be shown alongside in parenthesis

C The nomenclature for undersea features shall be shown in the English language

## APPENDIX

**Recommendations for preparation of plotting sheets for international bathymetric charts produced under regional mapping projects**

1 For plotting and contouring purposes the British Admiralty's plotting sheets for oceanic soundings should be utilized

2 Soundings should be in metres corrected using the third edition of the "Echo sounding correction tables"

3 The position of the sounding should be the central point of the group of figures representing it But the position may also be indicated by a dot with the sounding figure alongside, and if necessary, by a thin line drawn to connect the two

4 The soundings figures should be inscribed across the track; the figures should be easily readable, the recommended average size being 1 5-2 m in height

5 The largest possible number of soundings should be shown on the plotting sheets so long as their clarity is not impaired When soundings are very dense, the number may be reduced if care is taken not to eliminate the more important soundings: maxima and/or minima

6 The margin of each plotting sheet should contain the following legend:

"Compiled by

"Last brought up to date on

"Prepared under (name of the appropriate Regional Mapping Project)

7 Each plotting sheet should be accompanied by two overlays:

(*a*) Overlay contour lines with contouring made through each 100 metres Additional contours may be drawn through 50 and 10 metres, where warranted (on the shelf and abyssal plains);

(*b*) Overlay source materials on which should be shown the following:

Areas of soundings and position of isolated soundings with the appropriate legends required to indicate the source and the date of such soundings

Information on the method of navigation and its precision

Information on the type of the echosounder and its precision

8 On each plotting sheet and overlay the date of completion of compilation should be indicated

# AGENDA ITEM 8

## *Management of national mapping and charting programmes*

### (a) *Education and training*

## QUESTIONNAIRE ON THE AVAILABILITY OF TRAINING PROGRAMMES**

*Paper submitted by the Secretariat*


### RÉSUMÉ

En application de la résolution 21 de la onzième Conférence cartographique régionale des Nations Unies pour l'Asie et le Pacifique (janvier 1987) concernant l'enquête sur les programmes de formation existants, le Secrétariat a distribué un questionnaire à remplir par les Etats Membres de l'ONU.


The Eleventh United Nations Regional Cartographic Conference for Asia and the Pacific adopted the following resolution:

"21. *Availability of training programmes*

"*The Conference,*

"*Noting* that there are a number of countries offering education and training programmes in surveying and mapping, including possible funding to obtain such education and training,

"*Further noting* that such information may not be available to all member nations, especially those which may need the education and training,

"*Recommends* that:

"(*a*) The United Nations should compile this information on the type/kind of education and training available in the different countries, the duration, and the possible funding that may be available to support such studies;

"(*b*) This information should be disseminated to member countries."

To implement this resolution and provide better service to Member States, the United Nations Secretariat is collecting information on the availability of such programmes. To assist in this effort, you are kindly requested to complete the attached questionnaire or to advise us of the address(es) of the appropriate authorities and/or institutions in your country.

The Secretariat hopes the dissemination of this information will help developing countries to establish indigenous capabilities in surveying and mapping and in science and technology.

*The original text of this paper appeared as document E/CONF 83/L.1

### ANNEX

**Questionnaire on Training Programmes****

1. INSTITUTION
Name: ______
Address: ______
Telex: ______ Tel: ______
Cable: ______ Fax: ______
Contact person: ______
Principal function(s) of the institution: ______

2. ACADEMIC AND SCIENTIFIC PROGRAMMES
Summary of courses and research activities:
Courses: ______
Research: ______
Duration/frequency/language(s) of instruction: ______
Allocation of time spent in classroom/laboratory/fieldwork/independent research: ______
Facilities: ______
Number of trainees: ______
Entry requirements: ______
Degree/diploma/certificate awarded: ______

**Please complete the questionnaire in English, French or Spanish.

Degree/diploma/certificate awarded: ______________________

______________________

______________________

3 COST OF PROGRAMMES

Cost of tuition, text and related research material: ______________________

______________________

Monthly room and board and incidental expenses: ______________________

______________________

4 SCHOLARSHIP/FELLOWSHIP OPPORTUNITIES

Scholarship/fellowship opportunities for foreign participants: ______________________

______________________

______________________

Other financial support available for foreign participants: ______________________

______________________

______________________

5 COLLABORATION WITH DEVELOPING COUNTRIES

Specific areas of interest: ______________________

______________________

______________________

______________________

Geographical preference: ______________________

______________________

______________________

______________________

## REPORT OF THE NATIONAL WORKING PARTY ON EDUCATION AND RESEARCH IN LAND AND GEOGRAPHIC INFORMATION SYSTEMS*

*Paper submitted by Australia*


### RÉSUMÉ

Ce rapport décrit les travaux d'un organe interdisciplinaire australien qui s'occupe de programmes d'enseignement et de recherche en vue de mettre en place des systèmes d'information foncière et géographique dans la région de l'Asie et du Pacifique.


As the major interdisciplinary body associated with the development of land and geographic information systems (LIS/GIS) in Australasia, the Australasian Urban and Regional Information Systems Association (AURISA) has an obligation to contribute towards a strategy for implementing more effective, responsive and coordinated regional education and research programmes in LIS/GIS.

Consequently, in 1987 AURISA established a National Working Party to examine education and research programmes in LIS/GIS, with the following objective in mind:

> To provide a national strategy for integrating and promoting research and development applications and education in LIS/GIS, and to address the current needs and potential growth of the Australian industry, user community, and educational institutions involved in spatial information technology.

AURISA believes that it will provide an effective contribution towards fulfilling these objectives by satisfying the following goals:

(*a*) Determine the research issues and the research facilities and programmes relating to LIS/GIS in Australia;

(*b*) Determine the educational requirements and document the educational facilities relating to LIS/GIS in Australia;

(*c*) Develop methods towards implementing a national strategy on education and research in LIS/GIS.

In this way, AURISA expects to be in a position to participate both in curriculum development and in the directions taken within industry research and development programmes.

At the same time, it is noted that AURISA is only one of several parties seeking a voice in this area and that it must present a united front with other interested groups—for example, allied industry representatives and bodies, the Australian Land Information Council (ALIC) and the Australasian Advisory Committee on Land Information (AACLI).

Therefore, the intention of this document is to state AURISA's policy and opinions, and to stimulate discussion concerning the implementation of better education and research programmes in LIS/GIS.

### THE AUSTRALIAN LIS/GIS INDUSTRY

LIS/GIS is now established as one of the major market sectors in information technology with a rapid growth rate. A recent survey (by Dataquest, United States of America) indicated that the international market for LIS/GIS will be $US 400 million in 1991. At present, there are about 30 companies offering LIS/GIS products in Australia, although only a few of these provide Australian-developed products. There is considerable activity in implementing these systems in Australia, and already there are departments in federal and state governments, and many local governments, which have installed extensive LIS/GIS.

The future development of LIS/GIS clearly depends upon the advances made in information technology and the growth in the information industries. Strong growth in these industries is essential in order to reduce the expanding national trade deficit, expected to be around $10,000 million in the early 1990s.

In September 1987, the Government of Australia, through the Department of Industry, Trade and Commerce (DITAC), released an "Information Industries Strategy" aimed at expanding Australian capacity to develop new information industries products and services, which to a significant degree incorporates LIS/GIS developments.

The "Information Industries Strategy" contains a number of initiatives, including the "Partnership for Development

*The original text of this paper appeared as document E/CONF 83/INF 10.

Program"; the "National Procurement and Development Program"; and an expanded "Industrial Research and Development Scheme" (IR&D) in information and communication technology. Clearly, the opportunities exist for LIS/GIS companies to participate in these initiatives.

In addition, issues relating to research and development in the information industries were discussed at an IR&D Board Workshop of DITAC earlier this year, where information systems, and LIS/GIS in particular, were seen as an area in which Australian research and development could profitably contribute to the nation's export activities.

However, regardless of the incentives offered by Governments, the lack of trained technical and professional personnel is still seen as the most pressing problem facing the growth of the information industries—a situation which applies equally to the development and application of LIS/GIS.

It is obvious that Australian industry, in both government and private sectors, must display greater commitment and recognition of the urgent need for better educated and trained people in the broad cross-section of technical and professional areas affecting LIS/GIS. Industry must support education and re-training through scholarships, research grants and other funded activities which help to produce more people qualified to fulfil the necessary roles in this emerging industry.

Without appropriately trained personnel, neither Governments nor the information industries can expect to fully achieve their future objectives for Australia.

## Education and research in LIS/GIS

The Australian Government's recent "White Paper on Higher Education" has prompted academic institutions to more closely consider their profiles in education and research. This review has also provided a timely opportunity for institutions to promote the disciplines underlying LIS/GIS—such as geography, surveying, statistics, computing and planning—and to focus on the research necessary to develop and apply LIS/GIS.

The Government's increased emphasis on research is expected to result in considerable rises in Australian Research Council funding over the next few years, and both federal and state governments have introduced measures to encourage and promote research and development in high technology areas such as information technology, which underpin LIS/GIS.

AURISA believes that the time is now appropriate for these new opportunities to be promoted to the LIS/GIS community, in order for it to take full advantage of them.

### *Determining the research issues*

To date there have been few attempts to identify the research issues facing LIS/GIS, and clearly they will not be solely determined by AURISA. Indeed, industry-wide problems must be recognized and solved by the industry as a whole, and in this respect the urban and regional planning (URPIS) conferences represent perhaps the best forum for voicing LIS/GIS concerns and issues, which in turn can be reported via *AURISA News*.

Already, a list of research issues in LIS/GIS has been developed by the University of Melbourne (see annex I), while annex II contains information on how research and development is being dealt with in the United States and the United Kingdom. As a start, the United States National Science Foundation has recently determined that its five basic research priorities in LIS/GIS will be:

(*a*) Improved methods of spatial analysis and advances in spatial statistics;

(*b*) A general theory of spatial relationships and database structures;

(*c*) Artificial intelligence and expert systems relevant to the development of GIS;

(*d*) Visualization research pertaining to the display and use of spatial information;

(*e*) Social, economic and institutional issues arising from the use of GIS technology.

However, this type of list is only a starting point towards implementing a national strategy and must become part of a more formal and systematic programme of basic and applied research. Furthermore, in carrying out such a programme, long-term strategic research objectives have to be defined and clearly distinguished from short-term "brush fire" type of issues confronting systems on a day-to-day basis.

Obviously, industry-wide discussions need to occur on this matter, and it is expected that the major contributors will include:

(*a*) Members of the Australian Land Information Council (ALIC) and the Australasian Advisory Council on Land Information (AACLI);

(*b*) Federal, state, regional and local government agencies developing LIS/GIS;

(*c*) Major educational institutions;

(*d*) the Commonwealth Scientific and Industrial Research Organization (CSIRO);

(*e*) the LIS/GIS private sector;

(*f*) Other practising professionals involved in the development of LIS/GIS.

Given this country's relatively advanced stage of LIS/GIS development, it could be argued that there are perhaps a number of "system-saving" issues which need to be given high priority and investigated immediately, in order not to encumber operational systems with liabilities such as corrupt data and poor performance levels.

Specifically, a number of systems in Australia need to have operational answers to problems such as the updating of graphical data, particularly across networks; quality assurance mechanisms to detect low quality rather than non-conforming data; efficient methods of quality identification on individual data items; and methods of maintaining performance levels and curtailing data volumes as systems grow beyond the capabilities of existing data models and database management systems.

Nevertheless, if research in LIS/GIS is to achieve the impact and reap the benefits that it deserves, it will have to be performed and directed in accordance with some overall research methodology and plan as determined by the LIS/GIS community. AURISA contends that it should take the lead in developing and promoting such a research and development strategy.

Naturally, research priorities will vary with time. However, unless AURISA assists in defining the framework within which this research should be organized and directed, it is likely that much of the research effort will be expended in undertaking needy short-term problems to the detriment of investigating perhaps the more fundamental difficulties that confront LIS/GIS technology and practice.

### *Research facilities and programmes in LIS/GIS*

A good starting point for determining the level of LIS/GIS research activity within Australasia is to consult past proceedings of the AURISA national conferences which, to a large extent, contain the body of knowledge underpinning the LIS/GIS industry in the region. AURISA also maintains past proceedings on microfiche and keeps an index of all papers presented at its conferences.

In general, the LIS/GIS research effort in Australia is shared between four main sectors of the industry, these being:

(*a*) The tertiary institutions;

(*b*) Government departments and instrumentalities at federal, state and local government levels involved in LIS/GIS initiatives;

(*c*) CSIRO;

(*d*) Private companies and particularly LIS/GIS software vendors.

First, as a means of determining the level of research and development activity in the tertiary institutions, AURISA sent a questionaire to each university and college of advanced education within Australia and New Zealand—receiving replies from 52 departments and schools at 38 institutions. The responses are tabulated in annex III.

The results of this survey show that while there is considerable work being done in the areas of natural resource, land use and planning, and parcel-based systems development, few institutions are presently engaged in research into the application of artificial intelligence to LIS/GIS, or the study of utility, transportation, and local government systems.

Secondly, while it was relatively easy to gauge the research and development activity in the education sector, a more difficult task was to quantify the level of research taking place within government and semi-government agencies. The reasons for this are complex, although the lack of publicity is possibly due to the need to keep a low profile until developments are proven and also because, as a general rule, these organizations have difficulty justifying this type of expenditure.

AURISA suggests that the best way to determine the level of research and development within public agencies in each state is to make initial contact through the secretariat of the Australian Land Information Council or to contact the state representative of AACLI (see annex IV) for further information.

With regard to CSIRO, considerable research and development in LIS/GIS is being undertaken by the divisions of Information Technology, Soils, Wildlife and Ecology, Water Resources and Construction and Technology (see annex IV), and it is fairly easy to identify since CSIRO has a strong need to publish the results of its work.

Finally, the activity by software and hardware vendors is, for obvious reasons, hard to assess until new product announcements and releases, although most vendors keep their customers well informed of proposed developments.

### *Determining LIS/GIS educational requirements*

Already, the Department of Employment, Education and Training has initiated a study of the skill and training needs of Australia's computing professionals and para-professionals. This study will assist academic institutions in developing curricula which relate to the needs of industry over the next 10-20 years, and academic institutions should react positively to these results and use them as a foundation for determining the added requirements of LIS/GIS education.

An essential step in determining these requirements is to identify those market areas that need personnel with LIS/GIS skills. These are tentatively nominated as being:

Land administration and management
Local government
Spatial data processing and handling
Environmental and natural resource studies
Defense systems
Social and economic research
Education
Urban/Regional planning
Utilities/Facilities management
Surveying/Mapping
Health services
Market research
Retailing/Finance/Banking

From these market areas, subjects can be derived which should form the core of any education programme designed to provide students with a background in LIS/GIS skills, regardless of their major disciplinary interest.

In addition, it is AURISA's view that the aims of such programmes should be:

(*a*) To provide an understanding and awareness of the real world and existing structures;

(*b*) To develop a knowledge of methods of representing the real world;

(*c*) To understand the characteristics of technology;

(*d*) To provide students with the skills necessary to use technology.

However, while educational institutions are already capable of addressing the first two aims, the latter two present difficulties due to the rapidly changing technological environment. Therefore, strategies will also be needed, in the education of technology, to maintain our educators' knowledge base as well as the standard of software and hardware required for training.

One possible solution to this last point is to place emphasis upon cooperative education and training through the help of industry support schemes. This would be more economical for the country as a whole, since the latest technology would be placed in industry rather than in institutions where it would have to be continually updated at public cost.

As a means of bringing the academic and industrial worlds closer together, several programmes are already successfully in progress, satisfying the needs and aims of both Government and the parties concerned. These programmes include Teaching Companies, the federal Government's Civil Offset and Partnerships Program, and the 150 per cent R&D tax incentive scheme.

In other disciplines, computer science for example, state governments are already providing funding for industry-supported courses which require students to spend part of their time working with major companies. In addition, schemes such as the government of Victoria's Education Foundation offer support in high technology areas through "seed funding" for new courses.

The need for education and training in LIS/GIS was recently highlighted in an excellent study by the Western Australian Land Information System (WALIS) Executive Policy Committee, and undertaken by Arthur Young Management Consultants (*WALIS Training Needs: Final Report*, published by the WALIS secretariat, Perth, 1988).

Even though the study was primarily directed towards government needs, the findings have a general application. The study confirmed that there are a large number of people requiring education and training in LIS/GIS. Training needs were categorized into 14 subject areas ranging from an understanding of the Western Australian land data environment, to skill-training on specific software packages. Proposed courses were identified from this analysis of needs. Some of the major recommendations of the report are:

(*a*) Establishment of a real-life multidisciplinary project ("pilot project") to apply modern techniques in LIS/GIS and give staff realistic project experience;

(*b*) Possible establishment of a research chair in GIS applications;

(*c*) The WALIS secretariat to become involved in the curriculum activities of tertiary institutions;

(*d*) Public service scholarships to be instigated for study in LIS/GIS;

(*e*) The WALIS secretariat to appoint a training Coordinator for LIS/GIS.

*Educational facilities in LIS/GIS*

Finally, in order to determine the extent to which educational institutions are already responding to the needs of LIS/GIS, it was necessary to identify which major institutions had relevant education programmes in place.

The list, given in annex V, has identified only formal courses in LIS/GIS-related areas, and it should be noted that other forms of industry education may cover a much broader range of activities, including seminars, conferences, workshops and short courses—services that are already provided by many institutions.

It should also be noted that AURISA and other professional societies often run continuing education courses, and some state government departments are also taking an active role in the sponsorship of short courses, workshops, and the funding of international speakers at LIS/GIS seminars.

### Methods towards implementing a national strategy in education and research in LIS/GIS

As a means of contributing towards the implementation of a national strategy in education and research in LIS/GIS, AURISA intends to formally engage in the promotion of its policies in education and research in land and geographic information systems, at all levels consistent with the aims and objectives embodied in its Charter of incorporation, and in conjunction with other interested parties.

The areas of LIS/GIS with which AURISA is concerned are:

Research and development
Education and training
Information exchange
Advisory services

*Research and development policy*

With regard to research and development in LIS/GIS, AURISA will:

(*a*) Maintain a Working Party tasked with deriving methods for addressing the research and development issues highlighted in this report (this Working Party will also deal with education and training);

(*b*) Encourage both public and private sector agencies to support industry-related research and the provision of scholarships at the tertiary level;

(*c*) Reward innovative research by annually awarding a "best research paper" at the URPIS conference.

*Education and training policy*

As a means of encouraging increased education and training, AURISA will:

(*a*) Support programmes for general and specialist short courses dealing with relevant matters in education and training in land and geographic information systems—either in its own right, or through its regional affiliates, or in association with other professional societies and bodies;

(*b*) Include, as a matter of course and in conjunction with future national URPIS conferences, specialist education and training workshops in land and geographic information systems;

(*c*) Encourage both public and private sector agencies to become more actively involved in and aware of the need for LIS/GIS education, which includes staff re-training.

*Information exchange policy*

In adopting the role of an information exchange agency, AURISA will:

(*a*) Include information on education and research developments in *AURISA News* on a regular basis;

(*b*) Facilitate the maintenance and use of LIS/GIS research and development databases among its membership;

(*c*) Include, as a formal part of the URPIS programme, sessions devoted to discussion of education and research issues;

(*d*) Coordinate the provision of materials to assist with education and awareness of the importance of LIS/GIS (e.g. annotated bibliographies, digital data sets, classroom exercises).

*Advisory Services policy*

As a professional association, AURISA has an inherent body of expertise in LIS/GIS within its membership which is unmatched in the region. Therefore, as a service to both its membership and to the community, AURISA will assist with the establishment of a register of experts who can be approached for advice, not only in education and research in LIS/GIS, but also in other aspects of the industry.

*Promotion of AURISA's policies*

As a means of promoting AURISA's policies in LIS/GIS education and research, the following organizations should be advised:

*Government (Industry, Trade and Education)*

Federal ministers
Funding agencies
AIDAB/IDIP
AVCC/ACDP
Australian Research Council
Department of Education, Employment and training
Department of Industry, Trade and Commerce
ASTEC
State Education Departments

*Information industry*

Information Industries Council (export ties)
Australian Information Association

*Others*

Other professional bodies associated with LIS/GIS
Allied Industry Council, e.g. Survey and Mapping
Corporate members of AURISA
Academic Association

Local government associations

The media

Clearly, the initial thrust should be aimed at Governments, emphasizing that:

(*a*) LIS/GIS are important new areas of the national economy;

(*b*) Australia is one of the world leaders in the field;

(*c*) LIS/GIS have excellent export market potential, especially in the Pacific region.

With these particular areas in mind, it is recommended that the style of document to be distributed to each group should be tailored accordingly for maximum impact. For example,

(*a*) A document intended for ministers and AVCC/ACDP members (there may be several versions);

(*b*) A summary document/policy statement, tailored for industry, outlining AURISA's position;

(*c*) An advisory document designed to assist institutions in starting their courses. (This could be a "getting started kit" and might only concentrate on establishing low-cost course packages.)

## Summary

While AURISA is only one of several groups having an interest in research and education programmes in LIS/GIS in Australasia, it is recognized that coordination and cooperation are the essential keys (as they are with the establishment of LIS/GIS) in ensuring that a single voice on this matter is presented to those parties that can have the most effect on changing this aspect of the industry.

AURISA views its role as that of a facilitator and coordinator, which implies close working relationships with other parties in working towards the implementation of a national strategy.

The challenge rests with all people and parties involved with the industry, and AURISA believes that it can make a valuable contribution to the debate and hopefully act as a catalyst for promoting the establishment of a strong education and research base in LIS/GIS in Australasia, for the benefit of the whole community.

## ANNEX I

### Developing a LIS/GIS research agenda at the Department of Surveying and Land Information, University of Melbourne

In order to focus its research strategy, the Department organized a symposium on Land Information Systems in Victoria in May 1987. The forum was designed to bring LIS/GIS organizations and users together, and was jointly sponsored by major government and professional organizations involved with LIS/GIS in Victoria.

A detailed review of LIS/GIS activity was given by 31 federal, state and local government authorities and organizations, each of which were requested to highlight present and future issues and problems in LIS/GIS in Victoria. Papers concerned with parcel-based LIS were grouped and presented in five sessions: planning, local government and community services, natural resources and environment and utilities. Issues were categorized under the following headings:

Data standardization/classification/structure

Parcel-based (cadastral) databases

Topographic databases

Coordination arrangements/timetabling

Cost/payment arrangements and user requirements

Information and education

A summary of issues related to research identified by the LIS/GIS Symposium included:

Data quality considerations

Data classification, formats and exchange standards

Data to be included in databases (including the role of image data)

Topological data structures and expert systems

Updating of databases (especially cadastral boundary information)

Coordination of LIS/GIS development between organizations

Data ownership, legal responsibility, confidentiality and marketing

Need for expertise development and relevant education

Relevant research and development

The significance of these issues is that they come from a broad cross-section of users and system developers.

In addition, in order to get a more focused input to the research agenda, in November 1987 the Department ran a Seminar on Land and Geographic Information Systems Research Directions. The Seminar brought together a wide cross-section of experts from government, private and academic sectors, and included selected LIS/GIS hardware and software vendors.

The following research issues were identified by the participants, and an approximate measure of the perceived relative importance of the issues is given by the number of asterisks (*) against each item.

**** Data interchange standards/networking processes (especially with respect to topology)

**** State implementation strategy for LIS/GIS

*** Educational requirements and outreach

*** Role of "intelligent" data and expert systems (pilot studies)

*** Privacy/security/ownership/legal responsibility

** Costs of data/data acquisition

** Data quality; reconciliation of data

** Spatial analysis/statistical output

** Joint research/coordination of ventures/pilot studies

** Community needs vs wants/societal issues

* Incremental updating

* Integration of parcel based/natural resource/socio-economic data

* Data modelling in LIS/GIS; methodology for understanding systems

* Economic value of databases to the community

* Introduction of LIS/GIS into an organization; corporate view/operational requirements

* Priorities for data capture programmes and who is responsible

* Multidisciplinary communication coordination

Topological data structures

Spatial relationships and database structures Institutional arrangements/organizational coordination

Role of private sector in LIS/GIS for local government

Integration of spatial and commercial (text) data

Common framework for LIS/GIS development

Inclusion of spatial operators in query languages

Role of cadastre in LIS/GIS

Human information processing aspects

Resource priorities in education (public and private sectors)

Access/marketing/neutrality of data

Temporal data and LIS/GIS role of image data (including video and raster)

## ANNEX II

### International trends in LIS/GIS research and development

With such a rapid growth in both the market and technological change, considerable international research and development activity has taken place in LIS/GIS In the United States, the National Science Foundation (NSF) has funded a National Center for Geographic Information and Analysis which aims to:

(*a*) Advance the theory, methods and techniques of geographic analysis based on geographic information systems in the many disciplines involved in GIS research;

(*b*) Augment the nation's supply of experts in GIS and geographic analysis in participating disciplines;

(*c*) Promote the diffusion of analysis based on GIS throughout the scientific community;

(*d*) Provide a central clearing-house and conduit for disseminating information regarding research, teaching and applications

The Center was awarded in August 1988, to a consortium of the University of California at Santa Barbara, the State University of New York at Buffalo, and the University of Maine at Orono Funds of about $US 7 million have been allocated by the NSF for the Center over five years, although matching funding from the academic institutions and private sector is expected to follow

Similar importance has been attached to GIS in the United Kingdom, although developments have taken a different course than in the United States The Select Committee on Science and Technology of the House of Lords recently completed an enquiry into remote sensing and digital mapping, and has made a number of important policy-oriented recommendations for national policy in spatial data handling to which the Government is now responding Among these was a recommendation that a Government committee should be appointed to enquire specifically into the handling of geographical information in the United Kingdom The Committee, which was subsequently established in 1983 within the Department of the Environment, reported in 1987 and has made many significant recommendations about future developments in GIS

Of particular relevance to this document was the fact that the Committee viewed the development of technology as a necessary, but not sufficient condition for the effective exploitation of the potential of GIS A rapid adoption of new technology, it was argued by the Committee, also depends upon the extent to which the general level of public awareness of the importance of the new technology is raised, and particularly on the provisions made for the training of skilled personnel needed to operate the new systems

Without adequate consideration of educational and training needs, together with the general problems of increasing public awareness of the significance of GIS and related technology, decision-makers in the public and private sectors would not be able to make the most effective use of spatial information

On a parallel front, the British Economic and Social Research Council established, in February 1987, four multi-disciplinary regional research laboratories This is the nearest British initiative to that of the National Science Foundation in the United States The regional centres, when fully developed, will have four main functions, all of which relate either directly or indirectly to GIS—namely data management by computer, software development, spatial analysis, and research training

**ANNEX III**
**Research Activity in LIS/GIS in Educational Institutions**

| State | Institution | Department | Cat 1 | Cat 2 | Cat 3 | Cat 4 | Cat 5 | Cat 6 | Cat 7 | Cat 8 | Cat 9 | Cat 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACT | Australian National University | Centre for Resource and Environmental Studies | | * | | * | * | * | | | | |
| ACT | Canberra CAE | School of Applied Science | * | * | | * | | | | | * | |
| NSW | Kuring-gai CAE | | | | | * | | | | | | |
| NSW | Macquarie University | Centre for Environmental and Urban Studies | * | * | | * | * | | | | * | |
| NSW | Sydney Institute of Education | | * | | | | | | | | | |
| NSW | University of New England | Department of Geography and Planning | * | * | | * | * | | | | | |
| NSW | University of Newcastle | Department of Civil Engineering and Surveying | * | * | | | | | | | | |
| NSW | University of NSW | School of Landscape Architecture | | * | | * | * | | | | | |
| NSW | University of NSW | School of Surveying | * | | | | | | * | | * | |
| NSW | University of Sydney | School of Crop Sciences | | * | | * | * | * | | | | |
| NSW | University of Sydney | Department of Geography | | | | * | * | * | | | | * |
| NSW | University of Technology, Sydney | Faculty of Architecture and Building | | | | | * | | * | | | * |
| NSW | University of Woollongong | Department of Geography | | * | | * | * | * | | | | |
| NSW | University of NSW | School of Geography | * | * | | * | * | * | | | | |
| NZ | Massey University | Department of Property Management and Valuation | * | | | | | | * | | | * |
| NZ | University of Auckland | School of Architecture | * | | | | | | * | | | |
| NZ | University of Auckland | School of Commerce | * | | | | | | | | | * |
| NZ | University of Canterbury | Department of Geography | * | * | | * | | | * | | | |
| NZ | University of Olago | Department of Geography | * | | | * | * | | | | | |
| NZ | University of Olago | Department of Surveying | * | | | | | | * | | | |
| QLD | CIAE | Maths and Computer Department | * | | | | | | | | | |
| QLD | Griffith University | School of Australian Environmental Studies | | * | | * | * | * | | | | |
| QLD | James Cook University | Department of Electrical and Electronic Engineering | * | * | | * | | | | | | |
| QLD | James Cook University | Department of Geography | | * | | * | * | * | | | | |
| QLD | Queensland Agricultural College | Department of Agriculture | | | * | * | * | * | | | | |
| QLD | Queensland Institute of Technology | Department of Information Systems | * | | | * | | | | | | |
| QLD | Queensland Institute of Technology | Department of Surveying | * | | | | | | | | | |
| QLD | University of Queensland | Department of Geographical Sciences | * | * | * | * | * | * | * | * | * | * |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA | Roseworth Agricultural College | Department of Land Resources Management | | * | | * | * | | | | | |
| SA | SA CAE | School of Pure and Applied Science | | | | * | | | | | | |
| SA | SA Institute of Technology | School of Surveying | * | | | | | | * | | | |
| SA | University of Adelaide | Department of Computer Science | * | * | | | | | | | | |
| SA | University of Adelaide | Department of Geography | | * | | * | * | * | | | | * |
| SA | University of Adelaide | Department of Soil Science | | | | * | * | * | | | | |
| Tasmania | TSIT | School of Architecture and Landscape Architecture | | | | * | * | | | * | | |
| Tasmania | University of Tasmania | Centre for Environmental Studies | | | | * | * | | | | | |
| Tasmania | University of Tasmania | School of Surveying | * | * | | * | * | | * | | * | |
| Victoria | Bendigo CAE | Department of Social Sciences | | | | * | * | * | | | | |
| Victoria | Deakin University | Department of Occupational Hygiene | | | | | | | | | | * |
| Victoria | Gippsland Institute | Civil Engineering | | | | | * | | | | | * |
| Victoria | La Trobe University | Computer Science Department | * | * | | * | * | * | | | | |
| Victoria | Monash University | Department of Geography | | * | | * | * | | | | | |
| Victoria | Phillip Institute of Technology | Seismology Research Centre | | | | * | | | | | | |
| Victoria | RMIT | Department of Land Information | * | * | * | | | | * | | | |
| Victoria | University of Melbourne | Department of Surveying and Land Information | * | * | * | * | * | | * | * | * | * |
| Victoria | University of Melbourne | Faculty of Agriculture and Forestry | | * | | * | * | * | | | | |
| Victoria | University of Melbourne | School of Environmental Planning | * | | | * | * | | | | | * |
| Victoria | University of Melbourne | School of Information Technology and Elec. Eng. | * | * | * | | | | | | | |
| WA | Curtin University of Technology | School of Computing Science | * | * | * | * | * | * | | * | * | |
| WA | Curtin University of Technology | Department of Surveying and Cartography | | | | * | * | * | * | * | * | * |
| WA | Curtin University of Technology | Centre for Information Technology and Systems Research | * | * | * | * | * | * | * | * | * | * |
| WA | Murdoch University | Biological and Environmental Sciences | | | | * | | | | | | |
| WA | University of WA | Department of Computer Science | * | | * | | * | | | | | |
| WA | University of WA | School of Agriculture | | | | * | * | * | | | | |

*Category codes:*
1. System principles
2. Image analysis
3. Artificial intelligence
4. Natural resources
5. Land use and planning
6. Agriculture and forestry
7. Parcel-based systems
8. Utility and transport systems
9. Local government systems
10. Socio-economic systems

## ANNEX IV

### Members of the Australian Land Information Council

**Commonwealth**
General Manager/Surveyor-General
Australian Surveying and Land Information Group

**New South Wales**
Secretary
Department of Lands

**South Australia**
Director of Lands
Department of Lands

**Australian Defence Force**
Vice Chief of the Defence Force

**Victoria**
Director-General
Department of Property and Services

**Western Australia**
Executive Director
Department of Land Administration

**Tasmania**
Secretary
Department of Lands, Parks and Wildlife

**New Zealand**
Surveyor-General
Department of Survey and Land Information

**Northern Territory**
Secretary
Department of Lands and Housing

### Divisions of the Commonwealth Scientific and Industrial Research Organization involved in LIS/GIS Research

CSIRO Division of Information Technology
P.O Box 1599
Macquarie Centre
NORTH RYDE NSW 2113

CSIRO Division of Wildlife and Ecology
P.O. Box 84
LYNEHAM ACT 2602

CSIRO Division of Soils
G.P.O Box 639
CANBERRA ACT 2601

CSIRO Division of Water Resources
Floreat Park Laboratories
Private Bag,
P.O. WEMBLEY WA 6014

CSIRO Division of Construction and Engineering
PO Box 56
HIGHETT VIC 3190

### Members of the Australasian Advisory Committee on Land Information

**Commonwealth**
Director
Commonwealth Land Information Support Group
P O Box 2
Belconnen, ACT 2616
Ph: (062) 526 984

**New South Wales**
Director
State Land Information Council Directorate
Department of Lands
GPO Box 39
Sydney, NSW 2001
Ph: (02) 228 6448

**Australian Defence Force**
SO 1 Intelligence-Environmental
Department of Defence
Room F-3-36
Russell Offices
Russell, ACT 2600
Ph: (062) 653 704

**Victoria**
Acting Surveyor-General
Division of Survey and Mapping
Department of Property and Services
2 Treasury Place
East Melbourne, VIC 3002
Ph: (03) 651 2912

**South Australia**
Manager
Land Information Branch
Department of Lands
GPO Box 1047
Adelaide, SA 5001
Ph: (08) 227 0046

**Tasmania**
Director of Land Information
GPO Box 44A
Hobart, TAS 7001

**New Zealand**
Project Director
LINZ Support Group
PO Box 12-271
Wellington, NZ
Ph: NZ 710 380

**Western Australia**
WALIS Coordinator
WALIS Secretariat
Department of Land Administration
533 Hay Street
Perth, WA 6000
Ph: (09) 325 8444

**Northern Territory**
Assistant Director
Mapping and Information Division
Department of Lands and Housing
GPO Box 1680
Darwin, NT 5794

## ANNEX V

### Institutions teaching courses in Land and Geographic Information Systems

| *Institution* | *Department/School* | *Level** |
|---|---|---|
| Curtin University | Computer science, | UG, M, PhD, Grad Dip |
| | Surveying and cartography | UG, M, PhD, Grad Dip |
| QIT | Surveying | UG |
| RMIT | Land information | UG, M, PhD, Grad Dip |
| SAIT | Surveying | UG, M |
| University of Christchurch | Computer science | UG, M, PhD |
| University of Melbourne | Surveying and land information | UG, M, PhD |
| University of Newcastle | Civil engineering and surveying | UG, M, PhD |

| | | |
|---|---|---|
| University of New South Wales | Geography | UG, M, PhD |
| | Surveying | UG, M, PhD |
| University of Otago | Surveying | UG, M, PhD |
| University of Queensland | Geographical sciences | UG, M, PhD, Grad Dip |
| University of Tasmania | Surveying | UG, M, PhD, Grad Dip |

**Terminology*

| | |
|---|---|
| UG | Undergraduate course containing at least one, and in most cases two or more semester units dedicated to teaching the principles and application of LIS/GIS |
| M | Graduate Masters degrees where the thesis or project is directed towards research in the field of LIS/GIS, their use, design, implementation and application May involve some coursework One to two years full-time |
| PhD | Graduate Doctoral degrees where the thesis or project is directed towards research in the field of LIS/GIS, their use, design, implementation and application At least three years full-time |
| Grad Dip | A one year full-time or its part-time equivalent post-graduate qualification combining course and project work in LIS/GIS |

## GIS IN SURVEYING AND MAPPING EDUCATION IN CANADA*

*Paper submitted by Canada*


### RÉSUMÉ

L'inclusion des systèmes d'information géographique (SIG) à titre de sujet d'enseignement et de recherche dans le domaine des études en levés et en cartographie est en pleine croissance au Canada. Plusieurs universités et collèges ont établi, ou sont en train d'établir, des programmes d'ensemble en SIG, alors que d'autres incorporent des cours de SIG à leurs programmes réguliers de levés et de cartographie. Les universités ont établi des centres et des instituts pour les travaux de recherches en SIG. Des programmes de formation continue et de formation spéciale sont aussi disponibles dans les universités ou en dehors des universités. En effet, tout est en place pour le développement de la formation en SIG des années 90.


Although geographic information systems (GIS) is a relative newcomer to surveying and mapping education, it has strong roots in subjects that have been part and parcel of our curricula for many years. Indeed, studies that would now be labelled as traditional were embracing land information and its systematization quite some time ago in ways that are now identified as activities in GIS. Incorporation of GIS into our curricula is therefore a perfectly natural step in the continuing evolution of surveying and mapping education.

What made it possible to establish GIS as a subject in its own right was the dramatic increase in computing power and developments in computer graphics that have taken place in recent years. This is clearly reflected in the many computer-based GIS or GIS-related courses that are now offered at our educational institutions. But while a strong relationship between GIS and computer technology is necessary, if we are to be realistic in its application, it should also be recognized that education in GIS must embrace much more than the computer connection. The roots of GIS in traditional surveying and mapping education attest to this. Curriculum development must therefore pay attention, not only to those courses that are specifically GIS-identified (and, in all probability, computer-oriented), but also to the components of the curriculum that address the fundamentals of land information in the first place.

Active participation of surveying and mapping faculty in Canada in what is now identified as GIS goes back about 20 years, when the Department of Surveying Engineering at the University of New Brunswick hosted one of the first international symposia on computer-based land information systems. This was followed by participation of the same faculty, in development of the Maritime Land Registration and Information Service.

Institutional activity started to pick up considerably in the early 1980s, when schools such as Sir Sandford Fleming College in Lindsay, Ontario, and the Nova Scotia Land Survey Institute (which is now the College of Geographic Sciences (COGS), in Lawrencetown, Nova Scotia, began to offer comprehensive programmes of instruction in GIS. By 1985 all universities with surveying and mapping programmes and many of the colleges had introduced some level of GIS instruction into their curricula.

Recognizing the evolution that was taking place in surveying and mapping education, Laval University, Quebec, undertook in 1984/85 a very thorough study of its curriculum that led to the creation in 1986 of the undergraduate programme in geomatics. Geomatics is a new term in the surveying and mapping lexicon that was chosen to represent the modern systems approach that integrates the fundamental disciplines used to gather, process, store, analyse, represent and disseminate spatially referenced information. The influence of GIS is obvious.

The 1980s have also seen much university research activity in GIS. The University of New Brunswick, for example, developed the GIS system on agricultural research (CARIS), which is currently being marketed through a private company. The University of Calgary recently completed a five-year contract, funded by the Alberta government Department of Forestry, Lands and Wildlife, supporting a professorship in digital mapping and spatial data management.

Developments in the 1980s have in fact just set the stage for the great expansion in GIS education that is expected to take place in the 1990s. This paper attempts to give an

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overview of the institutions and programmes that are in place, or planned, to meet the challenge of the 1990s.

## GIS PROGRAMMES OF INSTRUCTION IN THE UNIVERSITIES

Undergraduate and graduate programmes in surveying and mapping are presently offered at four universities in Canada: University of New Brunswick, Laval University, University of Toronto, and University of Calgary. Total undergraduate enrolment stands at about 540 students; graduate student enrolment is approximately 150. All undergraduate programmes take professional accreditation, granted by either the Canadian Council of Land Surveyors or the Canadian Council of Professional Engineers, or both. All programmes, undergraduate and graduate, include studies in GIS.

At the University of New Brunswick, the Department of Surveying Engineering offers a complete range of instruction in the geographic information field, including:

(*a*) One-year specialized certificate courses;

(*b*) A comprehensive undergraduate B.Sc. degree programme;

(*c*) A graduate diploma programme in land information management;

(*d*) Graduate programmes at both the master's and Ph.D. levels.

The Department of Geodetic Sciences and Remote Sensing at Laval University offers an educational environment in the field of spatial information systems (SIS) which is unique in Quebec. The teaching activities in SIS are included in the undergraduate and graduate academic programmes that are offered in the wider domain of geomatics. At the undergraduate level, the programme offered is a B.Sc. of applied sciences in geomatics. At the graduate level, the programmes offered are the M.Sc. and Ph.D. in geodetic sciences, with spatial information systems identified as one of six concentrations. All instruction is in French.

At the University of Toronto, the Centre for Surveying Science offers an undergraduate Bachelor's programme in surveying science that includes mapping and land information as one of four elective streams. Students can elect to take the stream by itself, or it can be paired with one of the other three streams. A popular choice is cadastral surveying combined with mapping and land information. The Centre also offers, through the Department of Civil Engineering, programmes at the Masters' and doctoral levels that include GIS as one of five major areas of study.

At the University of Calgary, the Department of Surveying engineering offers an undergraduate B.Sc. programme that includes five streams, one of which is in land studies. Making up the land studies stream are five courses that are in GIS or are GIS-related. Similarly, at the graduate level, one of the five areas of specialization is land information systems, also comprising five courses.

## GIS PROGRAMMES OF INSTRUCTION IN THE COLLEGES

Several colleges across Canada include GIS in their programmes of study. The degree of implementation of GIS in the college curricula varies considerably, from simple introduction of GIS topics into one or two courses, to full development of a comprehensive programme of study in GIS. Some of the colleges have been active in GIS instruction for several years, while others are just beginning. While the programmes are designed basically for students at the technician/technology level, at least three of the colleges have geared their programmes as well to university graduates.

Comprehensive programmes in GIS are in operation at three colleges, and a fourth college plans to begin one this year. Brief outlines of these programmes follow.

The College of Geographic Sciences in Nova Scotia offers a one-year in-depth diploma programme in GIS that is designed to train programming professionals for systems management, software development, applications programming, database management, or geoprocessing. Most of the students enrolled in this programme have had previous post-secondary education in agriculture, forestry, computer science, geography, geology, cartography, or related resource management fields. GIS courses are also included in the college's diploma programme in remote sensing, and system training is provided in support of the programmes in planning, surveying, cartography and mapping. The programmes are supported by a very well equipped laboratory environment.

Since 1981, Sir Sandford Fleming College in Lindsay, Ontario, has offered a two-year diploma programme in GIS that has attracted not only high school graduates but also individuals, including recent university graduates, who are already established in a field of expertise, such as surveying, mapping, geography, geology, forestry and planning. The programme deals with theoretical, technical and application issues, in GIS, and it allows for advanced entry granted on the basis of previous exposure to GIS or experience in a field to which GIS can be applied. The College also offers a programme in Cartography that includes a significant amount of instruction in GIS applications. Several of the school's programmes in natural resources management include introduction to GIS concepts.

The British Columbia Institute of Technology (BCIT) in Burnaby, B.C., offers a one-year post diploma programme in spatial information systems. The programme is intended for graduates of two-year technology programmes or university graduates with background in relevant disciplines, such as surveying, mapping, forestry, mining, geology, geography, environmental studies and urban planning, who wish to upgrade their skills and knowledge with theoretical and practical exposure to the various technologies and disciplines which comprise GIS. The programme has been offered since 1987 and has attracted students from a variety of backgrounds. In addition, some of the two-year technology programmes presently offered at BCIT will phase in an introductory course in GIS. It is anticipated that all of these developments will be coordinated by an internal GIS committee, with representation from all interested technologies.

Algonquin College of Applied Arts and Technology, located in Ottawa, has recently developed a comprehensive diploma in geographic information technology that is planned for implementation this year. The full programme is three years in length, with the first two years of study leading to the technician diploma and the third year to the technologist diploma. This new programme is intended to replace the present Surveying and Mapping Technology programme that the college has offered since 1982.

While not implementing full programmes in GIS at their campuses, several other colleges in Canada have nevertheless introduced GIS courses into their curricula.

Seneca College of Applied Arts and Technology in Metropolitan Toronto, for example, offers a revised programme in Resources Management Technology that includes several courses in GIS and GIS-related subjects. The College also offers a programme in Civil Technology that has a strong GIS component. Several subjects are covered, including GIS concepts and applications, GIS database design, GIS history and evolution, and the problems of and preparation for automation, as well as the usual data acquisition disciplines.

The Cabot Institute of Applied Arts and Technology in St. John's, Newfoundland, is in the process of developing courses in GIS for all of its engineering technology programmes. Surveying engineering technology students will be exposed to a two-semester course; all other engineering technology students will take a one-semester course.

College Ahuntsic in Montreal offers a regular three-year diploma programme in the technology of geodesy that includes GIS-related courses. The instruction at College Ahuntsic is in French.

At Georgian College of Applied Arts and Technology, located in Barrie, Ontario, GIS is treated as a component of the overall surveying process, with strong emphasis placed on data acquisition. The Southern Alberta Institute of Technology, located in Calgary, includes in its Surveying and Mapping Technology programme a specific course in GIS along with companion courses in computer-assisted drafting, cartography and digital mapping. The GIS course was recently (1988) introduced into the curriculum; expansion of this course as well as implementation of new GIS courses are expected to take place in the near future.

### UNIVERSITY RESEARCH IN GIS

All four universities conduct research in GIS, much of it through institutes or centres that are associated with, but separate from, the teaching units.

The research effort at the University of Calgary centres around the Center of Expertise in Land Information Systems (CELIS). This effort has involved contributions from four members of the surveying engineering faculty, supported by research associates, sessional professors and graduate students. Faculty expertise in GIS has been strengthened by the recent appointment of an experienced specialist in the field. Research activity includes studies in optimal revision of positional data in spatial databases and information systems, the topology of geodetic networks and land information, control densification by photogrammetry for GIS, integration of digital map files, phenomena based terrain data modelling, artificial intelligence tools for GIS, design concepts for knowledge-based route guidance systems, and development of intelligent image interpretation system.

At Laval University, the research activities of faculty in the Department of Geodetic Sciences and Remote Sensing are carried out in the Centre for Geomatics, which consists of five laboratories: Cartography, Geodesy/Metrology, Photogrammetry, Spatial Information Systems and Remote Sensing. The research carried out in the Spatial Information Systems Laboratory is mainly oriented toward fundamental studies, methodologies and tools for the development of spatial information systems, applications focusing on urban and forested areas, and the integration of remote sensing data in spatial information systems.

The University of New Brunswick recently established the Canadian Laboratory for Integrated Spatial Information Research (CanLab-INSPIRE) for the purpose of providing a national focus for spatial analysis and information management research. The laboratory was created with extensive support from the Government of Canada and industry. Current work includes development of a knowledge-based image processing system, development of an object-oriented database management system, and an evaluation of the technical constraints to distributed database management.

While CanLab-INSPIRE deals with the problems of spatial information theory and systems development, applications research and information management and policy studies are also carried on at the University of New Brunswick. On the applications side, the university has had a long-standing interest in the role of information in support of natural resources management and land information. Most recently a major new strategic research initiative has been announced in the ocean mapping field. Close collaboration is maintained with a number of other laboratories on campus, including the artificial intelligence laboratory, the geodetic research laboratory, the groundwater research group and the forestry management research group. Currently the focus of the information management group is on the implementation of distributed land information networks, and on the development of marine information systems.

At the University of Toronto, research in GIS is administered through the Institute for Land Information Management (ILIM). ILIM is a multidisciplinary institute with faculty presently drawn from the Centre for Surveying Science and the Department of Geography and planning. Also appointed as associates of ILIM are faculty from other universities, such as the University of Ottawa. Three members of the ILIM faculty are also associated with the National Centre for Geographic Information and Analysis in the United States. Present research, activities include: knowledge-based management of uncertainty and inaccuracy in land-related information systems, modelling consistency-preserving transactions in land database systems, application of expert systems and object-oriented database systems for GIS activities and extrapolation of process models of net primary production of coniferous forests to large spatial scales using remote sensing and GIS.

ILIM is also cooperating with the University of Toronto's Institute for Environmental Studies on development of a GIS in China. And, in cooperation with the Geographic Information Systems Standards Laboratory of the United States Department of Commerce, ILIM is working on research in geographic data dictionary systems, knowledge-based physical database design, object-oriented GIS, and expert systems applied to GIS. This research collaboration is aimed at developing GIS standards.

### CONTINUING EDUCATION AND SPECIAL TRAINING

In addition to their normal teaching and research activities, many of the universities and colleges are set up to provide continuing education and special training.

The University of Calgary offers continuing education in the GIS area. In recent years, courses have been offered both in Canada and Australia, with as many as 70 participants in attendance.

The College of Geographic Sciences puts on short courses, workshops and outreach programmes in support of government and private sector organizations and individuals; works with geomatic organizations and government development groups, and with system vendors and service companies; and provides training to international organizations and to students from developing countries, both at the college and on-site in various locations around the world.

The University of New Brunswick has been involved in training assignments throughout Canada, the United States and around the world, through such organizations as the

United Nations Development Programme (UNDP), the World Bank, the Canadian International Development Agency (CIDA) and the Commonwealth Foundation. The university is also prepared to provide short courses for middle and senior managers, either on or off campus.

The University of Toronto has conducted several seminars and short courses in GIS and GIS-related subjects, attended by professional surveyors and managers of information systems, from government and industry.

At BCIT a new initiative for technology transfer will occur in course offerings to industry, primarily aimed at managers, engineers, planners etc. These will take the form of seminars, workshops and credit courses, and will be scheduled for late afternoon and evening to be attractive to potential participants.

The Cabot Institute of Applied Arts and Technology plans to develop an extension programme that will introduce GIS to the present in-place work force and also to develop an offering for more advanced courses.

Faculty from Sir Sandford Fleming College and the University of Toronto have also participated as instructors in the short course on Geographic Data Management for Integrating Resource Planning, presented by the Banff Centre School of Management and Alberta Research Council.

### *Equipment facilities*

As might be expected, there is considerable variation in the facilities for GIS within the educational community. Equipment resources range from modest, at schools just breaking into the GIS field, to substantial for some of the well established programmes.

At the university level, both instruction and research have to be addressed. In general, equipment is initially installed for one purpose or another. However, much of the equipment that is first acquired for research purposes eventually gets used as well for instruction. At the college level, equipment is purchased essentially for instruction.

Since equipment resources at universities and colleges can change quite quickly as internal funds are made available and new grants and contracts are negotiated, no attempt is made in this overview to list the resources of specific institutions, as reported. Nevertheless, it is useful to give a general indication of how things stand at present. The resources that have been reported are therefore presented collectively.

University GIS laboratories are presently equipped with Sun (e.g., 3/260 and 4/110) workstations, Intergraph (e.g., 220 and 340) workstations, DEC (e.g., VAX 11/750, MicroVax II and PDP 11/60) systems, Tektronix graphics terminals, and microcomputer-based graphics stations. Much of the equipment is networked with other laboratory facilities that include photogrammetric stereoplotting instruments, both analog and analytical, image analysis systems and other digital image processing and printing equipment.

With regard to software, the following GIS programs are in place in one or more of the universities: ARC/INFO, CARIS, Compgrid, GRASS, IDRISI, ODYSSEY, PAMAP, PCARC/INFO, SAGIS, TIGRIS and UDMS. Plans are also being made by at least one university to acquire SYSTEM 9. Other software, such as ARIES II, AutoCAD, EASI/PACE and TOPOS, is used as well in GIS-related instruction and research.

Equipment reported by the colleges includes PRIME (e.g. 750) and DEC (e.g., VAX 11/785 and PDP 11/73) systems, Intergraph workstations, microcomputer-based graphics stations, and Tektronix graphics terminals. One college reports that it will be acquiring Sun workstations in the near future.

GIS software presently in place at the colleges includes ARC/INFO, CARIS, GIMMS, Hunter GIS, MAP, MUNMAP, PAMAP, PC-ARC/INFO and SPANS. Further acquisitions may include Terrasoft and SYSTEM 9. The following GIS-related software is also being used: ARIES II and III, AutoCAD, EASI/PACE, IGDC, MAPS 200/300, MEDUSA, Micro-Survey, RAMS and TOPOS.

Obviously, the schools have acquired quite a variety of hardware and software in the GIS and GIS-related fields. But once acquired, this hardware and software must be maintained if it is to do the job, and year-to-year funding for maintenance can be a major problem for educational institutions that must rely on funding sources that often are not built into the institutions' annual operating budget.

## Conclusion

It should be quite apparent from this overview that the surveying and mapping schools in Canada have taken on the challenge of GIS, and have developed, or are in the process of developing, relevant programmes of instruction and research in this rapidly growing field.

Although we may well be proud of what has been accomplished thus far, those of us in the education community know that we have only begun to wrestle with the subject. Well equipped as some of our schools may be at the moment, or promise to be very shortly, GIS will demand even more resources in the future. If GIS grows the way most of us envision, then many more instructors and researchers will be needed to staff our universities and colleges satisfactorily, and more facilities, with appropriate maintenance, will be needed in support of the instructional programmes and research.

It should come as no surprise that all educational institutions in Canada are determined to expand their GIS capabilities as much as resources will allow.

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# EXCHANGE OF SURVEYING PERSONNEL BETWEEN COUNTRIES*

*Paper submitted by the International Federation of Surveyors*


## RÉSUMÉ

Favoriser les échanges de personnel cartographique entre différents pays est l'un des principaux buts de la Fédération internationale des géomètres (FIG). Pour étudier cette question, le Bureau de la FIG a créé un groupe de travail spécial présidé par le vice-président Seppo Härmälä. Le Comité permanent de la FIG a examiné en juin 1990 le rapport présenté par ce groupe et décidé d'en appliquer les principes directeurs.

Le présent document expose les principales conclusions et recommandations contenues dans le rapport, qui s'appliquent en principe à tous les pays. On espère que tous les gouvernements reconnaîtront l'importance de cette question et joueront un rôle actif dans la concrétisation de ces idées.


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In modern times the need to collect information and experiences from abroad is more prominent than ever before. There are some special aspects that have changed our world in this respect. The development of techniques is very fast. New, amazing methods appear from time to time; electronics, especially, computer techniques and satellite methods have introduced entirely new and revolutionary changes in the different fields of surveying.

On the other hand, the world and the demands of surveying have faced new challenges. The explosion of the world's population requires more and more land information. The information is needed for inventory of land resources and planning for their utilization. Increasing population and heavy urbanization have brought about many problems of habitation along with the different forms of transportation. In coping with them, we are obliged to take into account the preservation of nature and of the environment in general. In all these matters the surveyor has a remarkable role, since he must cope with new duties applying the new tools.

The problems are international today and consequently, international cooperation is necessary to meet the challenges. Therefore the world community must work together. It is true that in different countries the surveyors have different duties, different organizations, different background and different education. Nevertheless, the basic needs for surveying are the same. Even if the methods used in one country cannot be applied directly in another, they almost always inspire new solutions and may lead to a more useful procedure.

Then again the element of time must be taken into account. Problems have become so pressing that we cannot afford to wait for decades, not even years, for the new methods. We have to bring the new knowledge immediately from where it exists to where it is needed.

The exchange of information on an international basis is not a new idea. There are different ways to disseminate information: international congresses, lectures, exhibitions, meetings of technical and scientific bodies etc. Each FIG Congress or meeting of the Permanent Committee has included visits to the institutions of the host country; this, added to special commission meetings, symposia, workshops and working groups, has disseminated ideas tremendously.

While many ideas can be conveyed in this way, not all of them can. Often it is better to see the hardships of the practice, too. Moreover, many methods are so complicated that much time is needed to become familiar with them. Many FIG meetings have formed friendly ties that have resulted in good contacts and profitable visits. The value of exchange of personnel arranged in this way should not be underestimated. However, modern times require that more emphasis be placed on this activity owing to the rapid and great changes faced by the profession. More and more surveyors are needed who have learned international communication in the course of their studies. In general, the exchange of students, trainees, young graduate surveyors and young academic staff builds up the future of our profession.

In order to follow closely the development of surveying, it is important that experienced surveyors, experts and executives see with their own eyes surveying methods in countries where a special branch of surveying stands as a vanguard of development. Frequently, it is impressive to experience practices in completely different circumstances, because this gives more depth to knowledge.

A highly important area of exchange prevails between developing countries and technically developed ones. In developed countries new surveyors gain experience by working among experienced ones. The staff of developing countries is mostly so young and so scarce that they have no such opportunities. In order to educate a competent and sufficient surveying staff in each developing country, much exchange is necessary, and it concerns all levels of personnel.

Certainly many obstacles confront the exchange: some of them will be discussed here.

In the first place, there is the language barrier. It is always useful to learn at least one widely spoken language, and this is usually enough, because most surveying experts know international languages, too. Moreover, why not learn to read the international professional literature on surveying?

One of the worst barriers is lack of information, which may be at the root of lack of interest; ignorance can extinguish interest. One of the main aims of this study is to improve the flow of information.

### STUDENT EXCHANGE

Student exchange in this context can be divided into four categories of students:

(*a*) Those taking the whole examination at a foreign university;

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(*b*) Those taking only part of the examination at a foreign university;

(*c*) Those taking only some elected studies at a foreign university;

(*d*) Those taking some post-graduate studies at a foreign university.

In all these categories the universities have a central role to play. An agreement is needed between universities about the aims and conditions of exchange. Recognition of the validity of the examination is one of the most important points for such agreements. Of course, the needs for national legislation and varying practices have to be taken into account.

A multitude of bilateral agreements already exist, some of which may cover the faculties of surveying. There are also examples of multilateral programmes intended to build up to university network (ERASMUS in European Community countries or NORDTEK in the Nordic countries). Agreement can include a system of financing the studies abroad. The financing can be based also on low interest loans or other systems of financing the studies in the homeland of a student.

*Recommendations to the Member Associations*

1. Foster the system of agreements between universities about the exchange of students.

2. Follow up regional programmes like ERASMUS so that the interests of surveying are taken into account.

3. Promote financing systems for student exchange.

4. Disseminate information about possibilities and conditions of student exchange.

5. Promote the exchange of young university staff, taking into consideration the agreements made by universities and a financing system to be built for this purpose.

*Exchange of trainees*

The International Association for the Exchange of Students for Technical Experience (IAESTE) is obviously the principal organization for the exchange of trainees. However, some restrictions have seriously limited such exchange in surveying. First, all of the member countries have not joined IAESTE. Secondly, there are countries that are members, but the Member Associations and the surveying trainees are not aware of the IAESTE organization.

In addition, the classification of trainees does not cover the surveying profession. Instead, they are grouped under constructors, builders, geodesists, surveyors of architects etc. Consequently, the trainees received are often not students of surveying, which falls short of the intention of the trainee, nor does it meet the need of the surveying field, in general.

The concept of international exchange of trainees is not sufficiently well known among surveying students, nor are the connections and financing of such exchanges. The same is true of employers.

Measures required to reach an adequate level of trainee exchange may be summarized by these necessary steps:

(*a*) Amendment of the IAESTE classification to insert surveying under the subject "surveying";

(*b*) All Member Associations of FIG to join IAESTE;

(*c*) Reliable information to employers annually offering jobs to trainees;

(*d*) Reliable information annually to surveying students about applications for jobs;

(*e*) Adequate mental and material support for the exchange.

*Exchange of academic staff*

Academic staff have great influence on the future. Therefore the relevant exchange is one of the most important parts of the activity.

Nowadays the higher staff of universities and related educational institutions are quite mobile. Professors and other higher staff frequently attend different congresses and other meetings and visit other institutions for shorter or longer periods. Still, the situation can be improved, in particular when extended outside the customary circles.

On the other hand, there are problems involved in the exchange of younger staff, personnel that are most important to the future. They can absorb new ideas and learn new techniques; at the same time they are mostly short of means. For this reason special steps should be taken to ensure an adequate exchange of young academic staff. It is very important to facilitate their visits, and funds should be sought to finance the exchange. When the visit concerns studies, the same methods may be used as for the student exchange. Furthermore, since candidates already have a good basic knowledge, they can be employed full-time or part-time for research or teaching tasks in the host country. Member associations should emphasize the exchange of young academic staff to educational institutions. Existing international programmes should be more intensively used like COMETT (the programme on cooperation between universities and industry regarding training in the field of technology) in EC countries.

*Exchange of graduated and experienced surveyors*

One of the leading principles of modern education is continuous education. Anyone wishing to keep abreast with his profession must repeatedly receive education all through his career. Of course, most of it and frequently all of it may be given domestically, a considerable part even at work. However, it has been verified several times that time spent abroad in professional duties will considerably widen the scope of the surveyor's mind and relationship to society.

A visit to another country brings new ideas, new techniques and new visions. But a visitor also takes along his experiences, and thus discussions with him can be useful to hosts, as it is always useful to view matters from a different standpoint.

Visits of graduated and experienced surveyors may take the following forms:

(*a*) Sequel studies or training of young graduated surveyors;

(*b*) Excursions of surveyors;

(*c*) Short-term visits of experienced surveyors;

(*d*) Long-term visits of experienced surveyors;

(*e*) Visits of experts.

*Sequel studies or training.* Some branches of surveying are not taught in every country; again, some special branches stand very high in particular countries. In those cases it is important, and in all cases useful, to take some follow-up studies or training in another country. In this case the visitor belongs to the category of a "student" or "trainee" in spite of his graduation and can be treated according to the corresponding rules. Then, after graduation, it may be easier to get a fellowship.

*Excursions of surveyors.* An excursion to a foreign country is a convenient way of obtaining a general view of the surveying systems of another country. The participants of an excursion may benefit by the travel experience and knowledge of languages of some group members. A visit to a professional surveying institution is apt to offer some ideas and views. It is true that a group is mostly heterogeneous and time does not allow visitors to go deep into details. However, thanks to the visit it becomes clear where more information is available. Moreover, an excursion provides good opportunities to receive friendly contacts with colleagues.

When the idea of an excursion arises, FIG contacts institutions which can host a visit. While the participants finance at least the bulk of the costs, there should be no serious problems in arranging an excursion.

*Short-term visits of experienced surveyors.* The aim of a short-term visit is mostly very specific. There is a certain technique or a method to be learned, and the goal is known in advance. A visit may last one to four weeks. Generally, the visit is in the interests of the employer, in which case it is quite natural that the employer pays the costs.

When the aim of the visit has been decided, the first question is how to find a proper host for it. Sometimes the answer is clear, but if not, and if, for example, the dealer in equipment cannot help, FIG may provide guidance. The national delegate of the relevant Commission may have ideas and addresses, or they may be obtainable from the Chairman of the Commission. If the planner of the visit has in mind a host country, the Member Association of that country will certainly be able to find a contact.

At first sight, a visitor may be seen as a nuisance and time consumer, by the host country. However, an expert visitor from another country may be a good aid to encourage ventilation of ideas. This may fully compensate the host office for the lost time.

*Long-term visits of experienced surveyors.* The aim of a long-term visit of an experienced surveyor is to become acquainted with the methods of another country and to learn the basic problems and their solutions as well as to become familiar with the general atmosphere of surveying tasks. As a by-product the visitor may acquire good information on the host country and very good exercise of the language. A short stay in the country is not adequate. The length can be 2 to 12 months. In addition, if the host office wishes to take full advantage of the visit, a short visit would not be sufficient, because the work of the visitor could not be made productive enough.

As an example of long-term visits based on an international contact we may mention the special Agreement between North European countries on the Exchange of Civil Servants. The Agreement covers all different governmental activities, including surveying. The visitor is paid like a civil servant of the host country, and the travelling costs are covered either by the home country of the visitor or by the visitor himself, depending on the case. Several surveyors have made visits under this Agreement. As visitors have quite a good knowledge in advance of the other northern countries, the stay has mostly been limited to two months.

In fact, several international long-term visits have been paid without any special general agreements. Actually, it is difficult to include the almost limitless variation of requirements to any agreement. However, since long-term visits should become a firm pattern in the future, an attempt should be made to draft certain general principles, such as:

(*a*) The host organization employs the visitor for the time of the visit;

(*b*) During the stay the employer gives various tasks to familiarize the visitor with different types and stages of the work;

(*c*) The home organization pays the travelling costs;

(*d*) The organization and meetings of FIG serve to make contacts for the visits.

The key word is "contact" between the parties, and there are different ways in which it can come about:

(*a*) Personal contacts obtained through FIG activities;

(*b*) Contacts through the commission administration or the Bureau;

(*c*) Contacts through Member Associations;

(*d*) Direct contacts at congresses, meetings of the Preparatory Committee and other meetings.

An active attitude of the delegates on various FIG occasions may remain the main artery for the flow of exchanges. A great help may be a special *Notice Board of Exchange* at congresses and other meetings. The most important point in promoting exchange is, however, a general attitude in favour of it. The rise or fall of the exchange idea depends on it.

*Visits of experts.* An expert is needed mostly to solve a particular problem, and the visit is initiated by the existence of the problem. The visit is paid by those who have the problem to be solved. The role of FIG is limited: In FIG activities people have learnt where to find the experts.

An increasing number of experts are employed by multinational companies. A problem which concerns FIG and the Member Associations is how to utilize the presence of experts and how experts can become familiar with the surveying and surveyors of the host country. The best way seems to be that the visitor participates in the activities of the Member Association during his stay.

### *Exchange with developing countries*

Surveying is a key to economic and cultural development of a country, especially of a developing country. Surveying and mapping activities produce information for the inventory of natural resources, on the use of land and, in general, on different activities related to land. Surveyors are needed to plan the future use of land for different purposes, to develop and maintain a land register or a cadastre, to evaluate land, to execute land management and their share of land policy.

Developing countries are now short of surveying activities due to the shortage of surveying staff. It is not possible to overcome these shortages without the aid of technically developed countries. Most of the aid received, so far, is concentrated on mapping activities. Fortunately, the educational aspect has been connected with mapping cooperation projects in several cases. Each mapping cooperation should include so strong an educational part that the maintenance of the material and the advancement of national mapping could be guaranteed.

In order to educate an adequate staff of surveying personnel to each developing country, different action is required. They will be dealt with as outlined below.

1. *The educational institutions* should be established, but maybe not in every country. Moreover, it is more important to establish and develop them in such a way that they become effective and competent. At least at the first stage, this requires a collaboration of some developing countries. Still more, some of the developed countries should be connected with the project.

This all means a strong exchange of personnel. It is possible to send some students to the developed countries. However, this is not as necessary as to send members of the educational staff to gain more experience from developed countries. At the same time the staff of the educational institute requires educational experts from developed countries and for such a time that their own staff has been strengthened enough. Therefore a continuous tie to a developed country is desirable to ensure the continuity. In both cases the visits—long-term ones—should be mostly financed from development funds;

2. *The developing projects* have in many cases included the exchange of personnel. There may have been different ways to carry it out.

The education and training of staff has been connected with practical surveying and mapping projects. The persons to be educated have participated in the work with the experts which have been sent. Side by side they have learnt the tricks of the actual work until they have been able to carry out the operations by themselves. In this way the developing country has gained the knowhow to maintain and revise the surveying material they have received from the project.

This type of education is not enough for all stages of the work, a deeper education is often needed. Thus a cooperation project has sometimes been included in additional education, some courses in developing countries and visits to a developed country. The length of the courses depends on the basic education of students, the subjects to be taught and the planned future activity. The length of a stay in a developed country may vary from 6 to 12 months. All the time of the stay should aim to the later duties of the visitor. In addition to the theory, a good practical experience should be emphasized. This results from the need of the experienced surveyors which requires the primary attention.

Care should be taken to connect a suitable amount of education and exchange of personnel to each development cooperation project of surveying.

3. *Continued exchange of experienced surveyors and experts* belongs to vital activities in the future. This concerns universities and other educational surveying institutions as well as institutions of practical surveying duties. Visits are necessary in both directions, e.g. from a developing country to a developed country and vice versa. It should be ensured with continuous ties between the countries and it should be continued until it may be called the normal exchange between two developed countries.

*Summary of measures*

*Educational institutions.* The exchange of students and young academic staff as well as the exchange of senior academic staff belong to the interest of educational institutions. Since international activities are developing quite fast in this field, no extensive measures are directly necessary. However, the promotion of the professional activities cannot be expected without certain steps taken by the FIG Member Associations. They are requested to draw the attention of educational institutions to the faculty of surveying recommending good relations to be tied between different countries with a view to comparing examinations and finding mutual acceptance as well as urging students, young academic staff and senior academic staff to apply for the exchange.

*The IAESTE Office.* As IAESTE is recognized as an intermediary of international exchange of trainees it is advisable to use its services as much as possible. All of the member countries have not yet joined this organization. Moreover, some of the countries have joined but no link has existed with the surveying profession. Therefore national members are requested to promote the relations with IAESTE, on the one hand between faculties of surveying and the survey students, in order to encourage trainees to apply for the trainees' posts, and on the other hand between acting survey organizations and IAESTE, to obtain trainees' posts for foreign visitors.

*National Member Associations of FIG.* These are requested to emphasize an extensive exchange of surveying personnel. There is no other organization to initiate and promote the exchange of graduate surveyors and experts. Member Associations can, without any extraordinary efforts, offer the idea of foreign exchange to their individual members and urge the acting surveying organizations to receive visitors, underlining the advantages the employer can take of the visitors.

A more complicated matter is to get a contact between the visitor and the employer. There seems to be certain alternative means to do it. The delegates of Member Associations have a great responsibility. The information and the relations they have received at FIG meetings may enable them to take a direct contact or they may take along the offers to FIG congresses, PC meetings or other meetings and try to make the ends meet. A good aid to obtain a contact can be a special *Notice Board of Exchange* at congresses, PC meetings and other occasions. The organizers of meetings should be commissioned to set up a *Notice Board.* It is not possible to emphasize too much the importance of personal relations in this matter, especially the responsibility of the delegates.

*Development aid.* As the key to future independence in the field of surveying is an adequate and competent staff of surveying personnel, the use of development funds for this purpose belongs to the most effective ways to promote the economic and social life of developing countries. Consequently, Member Associations are requested to inform the offices dealing with development funds on this subject. The funds may be used:

(*a*) To support surveying faculties of educational institutions in developing countries including the exchange of staff at different stages;

(*b*) To finance educational projects in connection with all development projects of surveying and not forgetting the exchange of surveying personnel;

(*c*) To support the exchange of surveying personnel of surveying organizations in order to further the experience of the staff.

*The key.* In promoting the exchange of surveying personnel the key is to provide a good flow of information to everyone whom it may concern.

GUIDELINES FOR EXCHANGE OF SURVEYING PERSONNEL BETWEEN DIFFERENT COUNTRIES

These are guidelines for the purpose of identifying the role of the Bureau and member associations in promoting the international exchange of surveying personnel. (References to the Statutes; Articles 1 and 31.)

*Guiding principles*

*Surveying personnel*

The exchange between different countries includes the following categories of persons:

Students
Trainees
Academic staff
Graduated and experienced surveyors
Experts

*Bureau*

In promoting this exchange, the Bureau is requested:

(*a*) To maintain information on the advantages and opportunities for exchange to Member Associations and other organizations;

(*b*) To promote opportunities for contacts between parties interested in the exchange, in particular at Congresses and other international meetings;

(*c*) To collect information on the exchange of surveying personnel;

(*d*) To observe particularly the exchange with developing countries.

*Member associations*

Member Associations are requested to promote the exchange at the national level and:

(*a*) To inform the surveyors and students of surveying on the different aspects of exchange;

(*b*) To inform the employers and educational institutions on the requirements of exchange;

(*c*) To act as an intermediary for contact addresses and other necessary details;

(*d*) To be in contract with the IAESTE office to promote the exchange of trainees;

(*e*) To seek the necessary conditions, particularly funds, for the exchange;

(*d*) To notify the Bureau of the development of the exchange.

*Commission 2*

Commission 2 (Professional Education and Literature) is requested:

(*a*) To observe the implementation of the recommendations of the Task Force on Exchange of Surveying Personnel between different countries;

(*b*) To notify the Bureau on the achievements in this field;

(*c*) To initiate actions in order to improve the exchange whenever the need is noticed.

## FIG/IHO INTERNATIONAL ADVISORY BOARD ON STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS*

*Paper submitted by the International Hydrographic Bureau*


### RÉSUMÉ

La Fédération internationale des géomètres (FIG) a tenu son XIII[e] Congrès à Wiesbaden en 1971 et, à cette occasion, sa quatrième Commission (hydrographie) a créé un groupe de travail chargé de définir des normes internationales de compétence pour les hydrographes. En 1972, à la dixième Conférence hydrographique internationale, tenue à Monaco, l'Organisation hydrographique internationale a créé un groupe de travail chargé de recenser les cours de formation en hydrographie offerts dans les Etats membres. En 1974, au XIV[e] Congrès de la FIG, tenu à Washington, il a été décidé que les groupes de travail de la FIG et de l'OHI fusionneraient pour étudier et pour modifier le rapport du groupe de travail de la FIG sur les normes en matière de formation.

Le rapport décrit le mandat de ce groupe de travail commun, désigné sous le nom de "Comité consultatif international FIG/OHI sur les normes de compétence pour les hydrographes", qui a établi un ensemble détaillé de normes de compétence pour les hydrographes et des programmes d'enseignement appropriés, a tenu à jour cet ensemble de normes et a supervisé son application afin que la profession d'hydrographe soit régie par des normes de compétence internationalement reconnues.


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The International Hydrographic Organization (IHO) believes that education and training provide the most essential and long-lasting contribution that can be made in the way of technical assistance. A fundamental objective of the International Hydrographic Organization (IHO) is to set standards for the conduct of hydrography and the hydrographic products of its member States. It is therefore clear that standards should be set for the qualifications of those who practise the profession. A second objective is to tender guidance and advice upon request, in particular, to countries engaged in setting up or expanding their hydrographic service.

With the above objectives in mind, the IHO and the Federation internationale des géomètres (FIG) came together in 1972 and decided that some form of international accreditation for hydrographic surveyors was desirable. FIG was concerned with the need for commercial firms working in the offshore industry, to have some recognized certification of the quality of staff which they might employ. IHO was working towards the objectives stated above and was particularly concerned with providing advice to developing countries interested in acquiring a capability in hydrographic surveying.

A jointly sponsored working group was set up, which later led to the formation of an International Advisory Board. A standard syllabus and recommended levels of experience were established. To date, only individual teaching establishments have been accredited, but the Board is now preparing a document which may provide general directions to allow national accreditation for individuals, based on the international standards.

Courses submitted by educational organizations through national focal points are submitted to the International Advisory Board, which meets each year. These courses are

*The original text of this paper appeared as document E/CONF 83/L. 7

compared against the Standards of Competence for Hydrographic Surveyors. Courses of study meeting the requirements are accredited as either category A or B as either "Full" or "Academic". These terms are explained within the standards.

The Standards of Competence are produced in two volumes MP-005 *Standards of Competence for Hydrographic Surveyors (MP-005)* and MP-006 *Reference Texts for Training of Hydrographic Surveyors (MP-006)*, both published by the International Hydrographic Bureau on behalf of the parent organizations. MP-005 includes a preamble and a detailed syllabus. The standards are "A to minimum" level. MP-006 provides a bibliography of publications of direct relevance to hydrography and its associated sciences.

The standards are reviewed by the Board at its annual meetings. The fifth edition of MP-005 was published in English, French and Spanish in 1987, and in Portuguese in 1989. At its 1987 meeting a significant change was made to make the standards more applicable to commercial surveying. There is now a syllabus with a core of common courses and three specialities: nautical charting; port and nearshore surveys; and industrial offshore surveying. To secure accreditation a course must include the core and at least one of the specialities. MP-006 is at present being reviewed for republication early in 1991.

The International Advisory Board is composed of eight members, four appointed by the IHO and four appointed by FIG. The Chairman and Vice Chairman are elected by the members, alternately from the FIG and IHO members. The term of service is three years, after which the Vice Chairman assumes the office of Chairman.

Up to the present time, 23 courses have been accredited. In Asia and Australasia this includes the Graduate Diploma Course of the Australian Maritime College, Tasmania; the Basic/Long Hydrographic Specialist Course(s) of the Indian Naval Hydrographic School, Goa; and the Group Training Course in Hydrographic Surveying and the Advanced Course in Hydrography, Japan.

In addition, students from Asia and the Pacific are accepted at many of those courses outside the region, details of which are included in the full list of the courses available in hydrography and nautical cartography, as listed in the IHB special publication No. 47, 3rd edition, 1988.

A new course, that is particularly relevant to the needs of developing coastal States, is the IMO Model Course on Hydrography, which is scheduled to be presented for the first time starting in March 1991 at the Trieste Maritime Academy, Italy. This course is being funded by the Italian Government and places are being offered free of charge for 12 students in 1991. Action is being taken at present to develop standards, similar to those developed for hydrographers, for nautical cartographers. Once again, these are expected to be minimum standards but will provide both a standard with which to compare existing courses and a model on which to plan new courses.

Attached to this paper, as an annex, is a complete list of hydrographic courses accredited to date. Copies of all IHO publications may be obtained from:

International Hydrographic Bureau
7, avenue President J.F. Kennedy
B.P. 445
MC 98011 Monaco Cedex

**ANNEX**
**Courses Accredited by the International Advisory Board of IHO/FIG**

| | *Course* | *Category* | *Date* | *Language* |
|---|---|---|---|---|
| 1 | Basic/Long hydrographic courses at the Royal Naval Hydrographic School, HMS *Drake*, Devonport, United Kingdom | A | 1980<br>1983<br>(reaffirmed) | English |
| 2 | Ecole nationale supérieure des ingénieurs des études et techniques d'armement (ENSIETA) of the Service hydrographique et océanographique de la Marine, France | A | 1980 | French |
| 3 | The Royal Australian Navy's course for 4th class hydrographic surveyor, Sydney | B | 1981 | French |
| 4 | Basic/Long hydrographic specialist course of the Naval hydrographic School, Goa, India | A | 1982 | English |
| 5 | 4-year course programme of Hogere Zeevaartschool, Amsterdam, Netherlands | A | 1982 | Dutch |
| 6 | Course submission of Ecole des hydrographes of the Service hydrographique et océanographique de la Marine, France | B | 1983 | French |
| 7 | Specialization course in hydrography of the Naval Hydrographic Institute, Lisbon | A | 1983 | Portuguese |
| 8 | Graduate education programme in hydrographic surveying of the United States Naval Post-Graduate School, Monterey, California | A | 1984 | English |
| 9 | Syllabus of the final examination in hydrographic surveying of the Royal Institution of Chartered Surveyors (RIC), United Kingdom | A | 1984 | English |
| 10 | Intermediate hydrography and oceanography course of the Hydrographic Institute, Lisbon | B | 1984 | Portuguese |
| 11 | Specialization course in hydrography of the Hydrographic Institute, Cadiz, Spain | A | 1985 | Spanish |
| 12 | Specialization course in hydrography of the Hydrographic Institute, Genoa, Italy | A | 1986 | Italian |
| 13 | Graduate diploma course of the Australian Maritime College, Tasmania | A<br>Academic | 1986 | English |
| 14 | Hydrographic course of the Maritime Safety Academy, Japan | B | 1987 | Japanese |
| 15 | Hydrographic specialist programme of the Hydrographic Service, Canada | A | 1987 | English |
| 16 | Hydrographic surveyor training programme of the University of New Brunswick, Canada | A<br>Academic | 1987 | English |

ANNEX (continued)

| Course | Category | Date | Language |
|---|---|---|---|
| 17. Diploma in hydrographic surveying of the Plymouth Polytechnic, United Kingdom | A Academic | 1987 | English |
| 18. Group training course in hydrographic survey, Japan | B | 1988 | English |
| 19. Advanced course in hydrography of the Maritime Safety Academy, Japan | A | 1989 | Japanese |
| 20. Hydrographic training programme of the United States Naval Oceanographic Office | B Academic | 1989 | English |
| 21. Port hydrography course of Bordeaux University, France | B Academic | 1989 | French |
| 22. Specialization course in hydrography of the Hydrographic Institute, Valparaiso, Chile | B | 1990 | Spanish |
| 23. Course in hydrography of the Hamburg Polytechnic, Hamburg, Germany | A Academic | 1990 | German |

## (b) *National programmes*

## THE ROLE OF THE CANADIAN GOVERNMENT IN GEOGRAPHIC INFORMATION SERVICES*

*Paper submitted by Canada*


### RÉSUMÉ

Les systèmes d'information géographique (SIG) servent à organiser et analyser l'information applicable aux lieux géographiques. A ces fins, il faut que toutes les données soient traitées uniformément. Le succès de l'application des SIG au Canada dépend de l'adoption d'une stratégie dans ce sens. Il appartient au gouvernement fédéral de promouvoir une approche uniforme des questions de technologie des SIG au Canada.

L'adoption de normes nationales en matière d'acquisition, de stockage et d'échange d'informations géographiques saura promouvoir leur utilisation, ce qui favorisera l'innovation. La création de la Base nationale de données topographiques (BNDT) formera l'assise sur laquelle pourront s'appuyer de nombreuses applications des SIG au Canada.

Il est possible d'atteindre ces buts par la coopération. La coopération entre les ministères fédéraux, les provinces, l'industrie et les universités pour ce qui est de la collecte et de l'échange de donnés géographiques est la pierre angulaire des efforts de promotion des SIG déployés par le Ministère de l'énergie, des mines et des ressources au Canada.


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There is an increasing demand in Canada for digital, georeferenced information. On a scale ranging from building plans to global monitoring a deluge of information is being collected and made available. If this information is to be managed successfully, leadership and cooperation are needed.

At the same time that the demand for information is increasing, so also is the demand for hardware required to process these data. Today's high technology can provide an individual with a desktop computer with the computing power of a mainframe from two decades ago.

What remains to be achieved is the marriage of the technology to the demand. The development of geographical information systems (GIS) has occurred as a means to solve this problem, but this is only part of the solution. Individual systems cannot function in a vacuum. They need data as input, and these data must be accurate and relevant. Furthermore, data must have integrity internally within a file (e.g., all roads must be connected at intersections) and externally between different data sets (e.g., it should be possible to integrate another agency's data files with the National Topographic Data Base (NTDB)).

The Surveys, Mapping and Remote Sensing (SMRS) Sector is poised to take on the challenge of removing those barriers that hinder fulfilment of the potential of GIS technology in terms of technical issues, as well as in those areas affected by human issues.

The development of the components of our sector has closely paralleled the development of GIS technology. The former Surveys and Mapping Branch was at the forefront of automated cartography in the late 1960s and early 1970s, based on a digitizing system that utilized the PDP10 computer and cartographic monitor called XCM and a Gestalt photomapper. Subsequently the B8-based digital stereocompilation system and the customized scanning system, CARDAPS (Cartographic Data Processing System), were developed, and these have carried us to the present. Currently research and development is under way into the exciting potential of the modern GIS systems.

*The original text of this paper, prepared by J.H. O'Donnell, Surveys, Mapping and Remote Sensing Sector, Energy, Mines and Resources Canada, appeared as document E/CONF.83/INF.41

At the same time that cartography was adopting computers, a new discipline was emerging as a major force in the world of digital geographic information. Remote sensing arrived in the 1970s as a superior technology for many thematic applications. With the new generation of Earth observing satellites being launched, and with new developments in airborne sensors, these areas of application are expanding daily. Throughout all of this, the Canada Centre for Remote Sensing has been a world leader in developing and exploiting remote sensing.

Just as GIS is the union of different forms of thematic or attribute information with positional information, our sector is such a marriage of traditional surveying and mapping capabilities, with the new GIS and remote sensing technologies. The union of the Surveys and Mapping Branch with the Canada Centre for Remote Sensing in 1987 to form the Surveys, Mapping and Remote Sensing Sector reflects the real world trends in data integration. Combined expertise and strong cooperation developed with Canadian industry allows the Sector to best exploit the developing science of geomatics.

## Challenges to meet

### *Efficient data acquisition*

One of the most significant obstacles to the efficient development and use of GIS technology is the repeated collection of the same or equivalent data by different groups. This problem of redundancy leads to much wasted time and resources that could be better used in collecting new data. We cannot afford the effort needed to recompile data that has already been compiled.

In the past, government organizations, utilities and private companies all built their databases independently of each other. The same data were collected repeatedly because user groups did not communicate and each used their own data formats and standards. This lack of cooperation and data consistency is of particular concern to the SMRS Sector since the Department of Energy, Mines and Resources provides digital topographic data to these groups for their applications projects.

### *Standards*

The use of a GIS for a particular application generally involves the integration of different data from several sources. Obviously the lack of standards will hamper this process, or even stop it before it can begin.

Standards apply to many different aspects of data transfer. On the simplest level there is the media on which the data are recorded; the format of the data file; the coding scheme used for individual features; and, of course, the question of which features are included in this data set.

The solution to the question of data standards will enable free exchange of information and also help to meet the first challenge mentioned: efficient acquisition of the data. If we can use somebody else's data through uniform standards then we do not have to collect them ourselves. To extend this one step further, data standards, and hence the free exchange of data, will promote the use of GIS technology since it reduces the initial effort and cost required to set up a database.

### *Accuracy and integrity*

We all want accurate data but it is rare for a single data source to have all of the positive qualities desired: geometric accuracy, temporal relevancy, complete feature discrimination, topologically clean. When faced with poor data it is possible to make do and be wary of the results, or not use them and collect redundant but usable information. It is important that all data be as accurate as possible to maximize their usefulness.

## Tasks of the SMRS sector

The Sector plays several roles on the GIS stage in Canada. Some of these roles have specific goals and objectives, such as the collection of data for the NTDB; others address GIS on a broad front, such as the Inter-Agency Committee on Geomatics (IACG).

### *Problems of standards*

When discussing topographic data standards in Canada, the first place to start is with the Canadian Council on Surveying and Mapping. The CCSM national standards were developed following the recommendations of the Task Force on National Surveying and Mapping in 1987. Elements of these standards address feature coding and classification, quality evaluation, and a file exchange format.

In addition to the issues covered by the CCSM standards, other areas of data exchange must be addressed. The transfer of information through telecommunications is an example of this, and is a subject that has received considerable attention. The Department of Energy, Mines and Resources cooperated with the Department of Fisheries and Oceans on the development of the Map and Chart Data Interchange Format (MACDIF), which is based on international data transfer standards.

There is also the question of raster versus vector data. Canadian industry can concurrently supply systems that allow the use of raster-based data to update a vector GIS database. The goal is to fully integrate vector and raster-based technologies to allow for the transparent manipulation of vector topographic data with raster imagery, digital elevation models (DEMS) and thematic overlays. The Sector encourages development in this critical field through capital acquisitions to support industry, as well as contracting out research and development projects.

### *National Topographic Data Base*

The National Topographic Data Base is one of the cornerstones of Canadian GIS policy. The NTDB will form the topographic frame that all GIS applications in Canada can utilize. The compilation of the NTDB will be a cooperative effort involving federal and provincial governments, as well as industry and universities.

Complete coverage of Canada will be provided by three separate levels of data. The first level will consist of stereo compiled data, and will cover densely populated or economically important areas. The second level of data will consist of scanned 1:50,000-scale map graphics, and will cover much of the middle portion of Canada. Northern Canada will be covered by the third level of data, scanned 1:250,000-scale map graphics.

The compilation of data for the third level of coverage was completed in September of 1989 using the CARDAPS systems. Resources assigned to this task, along with new systems at the Canada Centre for Geomatics and from industry, will now focus on the scanning of 1:50,000 sheets to fill the second data layer. The first data layer currently consists of over 500 sheets that have been stereo compiled within the Canada Centre for Mapping and on contract to private industry. These activities will continue, and will be supplemented by stereo-compilation at the Canada Centre for Geomatics as well as inclusion of provincial and municipal map data.

Completion of the NTDB by the year 2000 exemplifies the type of cooperation that is required in the geomatics industry today. Traditional aerial photogrammetry is being combined with new technologies such as remote sensing and raster scanning in several levels of government and private industry for the NTDB.

### *Cooperation*

In all of this activity one of the key ingredients has been cooperation. The Sector feels that this is a vital point, and has played (and will continue to play) a strong leadership role in fostering this cooperation. Using different mechanisms, cooperation is promoted with four main groups—other federal agencies, provincial mapping agencies, private industry and universities.

#### *Federal departments*

Recently, the Inter-Agency Committee on Geomatics was set up to coordinate GIS activities within the federal Government. The IACG consists of six technical subcommittees: GIS Data Models, GIS Data Communications, GIS Data Bases, GIS Standards, GIS Education/Research, and User Needs and Applications. At present these committees are conducting primary investigations that will define future activities.

An example of how cooperation within the federal Government can operate is a Memorandum of Understanding signed by the Department of Energy, Mining and Resources and Statistics Canada in 1989. This agreement will contribute to the development of the Canadian Online Unified Geocartographical Analysis and Retrieval System (COUGAR). This system will be used in support of the national census, and is based on the NTDB.

To help coordinate GIS activities a GIS division was created within the Sector. The Division's activities are similar to the IACG, but the scope of its work is national, touching on all users of geographical information. Presently GISD research includes data model development, GIS implementation and the evaluation of GIS systems.

#### *Provincial mapping agencies*

In 1989 we announced the Geographic Information Technology Development Program. This is a $16 million plan, over five years, to promote cooperation between the Department of Energy, Mining and Resources and the provincial governments. The goal of the programme is to integrate provincial data into the NTDB to help eliminate the problem of redundant data. Obstacles in the areas of standardization are being addressed to achieve integration of data.

#### *Private industry*

The Department of EMR has supported private industry in the past through capital acquisition, contracting out work and supporting research programmes. It is committed to continuing this close relationship, and to improving cooperation on projects that will advance Canadian technology.

The mechanism used to strengthen these ties is called a Memorandum of Understanding. These agreements formalize relationships with private industry and allow us to work together in a "Team Canada" approach.

A Memorandum of Understanding was signed with the Geomatics Industry Association of Canada, which will allow for many cooperative efforts in the future. A Memorandum of Understanding was also signed with the Canadian Institute of Surveying and Mapping, recognizing it as the national scientific Institute in Canada which encompasses all the surveying and mapping professions.

#### *Universities*

Yet another area where the Sector is encouraging cooperation is with the universities. These institutions have traditionally been a major source of advanced research and it is the thrust of this research that will guide us into the future. The nature of cooperation has been project- and programme-oriented.

## CONCLUSIONS

Even as we grapple with the present technology of GIS we are looking to the future. This technology opens up the possibilities for new data types derived from traditional classes, new means of data exchange and storage, new data models and other developments related to geographic information. Naturally, as the data evolves so do the applications that use this data. New and varied areas of application will be developed, and at the same time many existing applications will merge into the GIS technology.

As the technology advances so must the human element. Education will help to develop this human resource to make available to Canadian industry the expertise they desire. On the other side of the coin the opportunities must exist within industry to allow graduates to work in the GIS field.

Canada is a large country that needs sophisticated geographic information management and analysis. These needs compel us to act quickly to develop GIS technology. The means to do this is through cooperation among all sectors of government and industry in Canada. As the primary agent for geographic information within the federal Government, the Surveys, Mapping and Remote Sensing Sector is committed to provide the most efficient and cost-effective solution in support of natural resources, environmental and land information management.

# LE SYSTÈME D'INFORMATION GÉOGRAPHIQUE NATIONAL DE L'IGN*

*Document présenté par la France*


## SUMMARY

The notion of geographical information is presented here in a very general manner as the relationship between an object or a phenomenon and its position on the Earth's surface. Expressed in digital terms, it is a combination of graphic and alphanumeric data.

The emergence of new requirements for geographical information is largely due to developments in computer science and has led IGN to rethink its response to the mandates entrusted to it.

Seeking to keep abreast of the latest developments in the digitalization of geographical data, IGN has set itself the objective of developing a genuine geographical information system that will give it the widest possible access to descriptive information about the national land surface.

The necessary *modi operandi* and the method selected for the digitalization of geographical information are described, taking as examples three components of the IGN National Geographical Information System.

Since the most accessible way of presenting geographical information is in graphic form, it is essential that computer graphics be able to respond to the geographical problems posed by policymakers.


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On peut définir un système comme un ensemble d'objets et d'activités reliés entre eux et qui interagissent dans un but commun. Dans tout système on distingue, entre les objets et activités qui les composent, des groupes homogènes nettement détachés du reste, que l'on désigne sous le nom de sous-système.

On peut définir les systèmes d'information comme l'ensemble des procédés pour le recueil, la codification, le stockage, l'analyse, la récupération de données ainsi que pour la présentation de l'information qui s'y rapporte.

Les systèmes d'information géographique sont ceux dont l'objectif est de travailler avec une information portant sur la relation entre un objet ou un phénomène et sa localisation à la surface du globe.

Les systèmes d'information géographique traitent donc de toutes ces données physiques ou socio-économiques qui peuvent se rapporter à une unité localisée, à un point, une zone, une limite de la planète.

De par sa mission principale de cartographie du territoire national, l'IGN, comme les organismes dont il est l'héritier, a toujours eu des activités orientées vers le domaine graphique. Ces quarante dernières années ont toutefois été marquées par une évolution considérable de la méthodologie d'établissement des documents cartographiques.

Ce n'est qu'il y a une quinzaine d'années que ces recherches commencèrent réellement à porter leurs fruits et à entrer en production, grâce à l'augmentation des capacités du traitement informatique et surtout à l'apparition de systèmes graphiques interactifs performants.

Cette longue histoire et cette recherche constante du progrès technologique permettent maintenant à l'Institut d'aborder dans de bonnes conditions les grands projets de bases de données localisées et de bâtir son système d'information géographique offrant par là une réponse moderne aux missions que l'Etat lui a imparties.

### Objectif du système d'information géographique national de l'IGN

L'objectif principal du SIGN de l'IGN est d'être un serveur de données dont la vocation est d'une part de constituer et de maintenir une archive des informations géographiques qu'il produit, avec une gestion de l'évolution du paysage qu'elles décrivent, et d'autre part d'assurer une diffusion de ces informations tant en interne à l'IGN pour sa propre production cartographique qu'à l'extérieur.

C'est un service ouvert aux utilisateurs :

*a*) Un contenu défini en tenant compte des besoins des utilisateurs;

*b*) Un maximum de passerelles ménagées entre les données propres aux utilisateurs et les données du SIGN;

*c*) Un soucis de qualité et de renseignement sur la qualité des informations pour permettre à l'utilisateur d'estimer l'adéquation des informations du SIGN à son besoin;

*d*) Une adaptation aux besoins des utilisateurs lors de la fourniture d'extraits des bases de données : libre choix de l'étendue géographique de l'extrait, des thèmes sélectionnés, de la forme de livraison.

Ce sont des informations sur des bases nationales :

*a*) Couverture complète de la France;

*b*) Homogénéité et cohérence des informations : cohérence interne pour chaque base (respect des positions relatives des objets), cohérence entre les différentes bases;

*c*) Garantie de continuité de service en tant qu'élément de la mission de l'IGN;

*d*) Garantie de mise à jour et de compatibilité des différentes versions des BD au cours du temps : chaque objet aura un identificateur unique pour une base donnée et, au cours du temps, cet identificateur est l'identificateur national quand celui-ci existe et n'est pas ambigu;

*e*) Définition de règles de compatibilité entre les bases de données;

*f*) Une politique nationale concernant les formats d'échange : norme unique pour tous les extraits, à court terme alignement sur les standards de fait ou les normes

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*The original text of this paper appeared as document E/CONF 83/L 48.

applicables, à moyen terme alignement sur les normes internationales et nationales (CNIG, CERCO, OTAN).

### Le système d'information géographique national de l'IGN

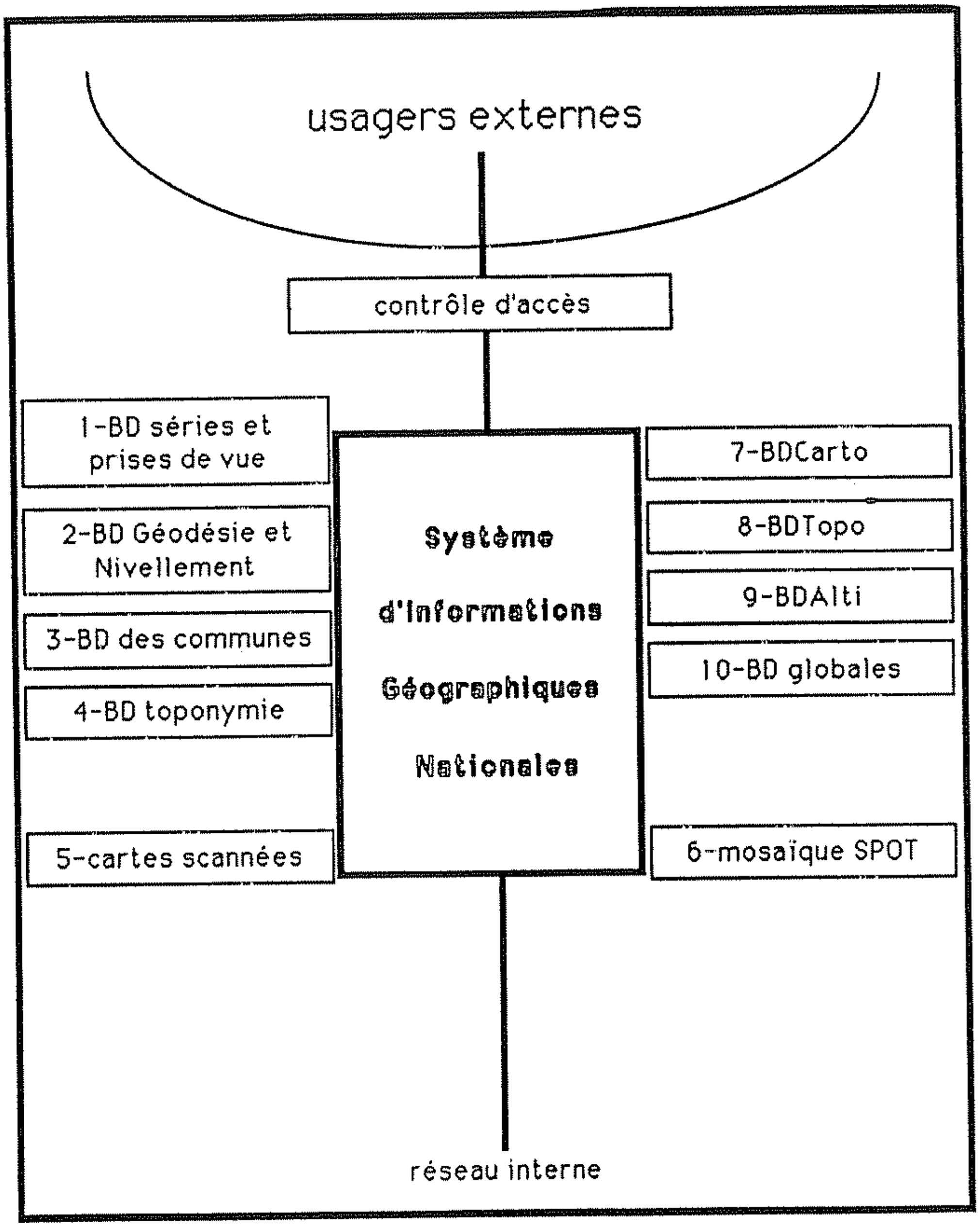
Il est composé de plusieurs bases d'informations (voir figure I).

L'IGN possède un fond cartographique considérable hérité pour une bonne part de ses devanciers et constamment enrichi depuis. L'Institut assure également depuis 1946 la gestion de la photothèque nationale (photographies aériennes et images spatiales). Cette documentation, ainsi que celle concernant les points géodésiques et les repères de nivellement, sera totalement informatisée en vue d'améliorer sa gestion et surtout de faciliter considérablement sa diffusion, notamment par voie télématique.

La base de données des communes comporte les coordonnées des mairies, des "centroïdes" des communes ainsi que de leurs limites. Cette base de données, indispensable pour la cartographie thématique, constitue également la principale clé d'accès aux autres bases; en effet peut nombreux sont les utilisateurs qui formulent leurs interrogations par l'intermédiaire de coordonnées!

La base de données des toponymes contient tous les noms de la carte actuelle à 1/25 000, avec des attributs descriptifs, localisés au kilomètre près. Ultérieurement, au fur et à mesure de la constitution des grandes base de données, chaque

**Figure I. Le SIGN de l'IGN**



toponyme viendra en attribut de l'objet ou entité qu'il désigne.

Les progrès accomplis par les scanneurs permettent également la fourniture de l'information cartographique (ou photographique) existante sous forme numérique maillée et compactée, stockée sur disque optique numérique ou même CD-ROM. Ceci facilite beaucoup l'utilisation des données cartographiques, permettant par exemple des visualisations sur écran graphique avec une définition acceptable. La constitution d'une mosaïque numérique complète sur la France à partir d'images SPOT corrigées des défauts géométriques apporte la vue satellitaire de l'hexagone.

La "base de données cartographiques" vise la gamme d'échelle allant du 1/100 000 à 1/500 000, elle est constituée par traitement des cartes au 1/50 000 existantes (scannage puis vectorisation puis structuration topologique et codage) et par traitement de l'imagerie spatiale SPOT. Son achèvement sur la totalité du territoire national est prévu pour le début de l'année 1992, certains "thèmes" (réseau routier, réseau électrique...)devraient être disponibles plus tôt.

Le projet de "base de données topographiques" vise lui une gamme couvrant les échelles du 1/5 000 au 1/50 000. Cette base sera constituée principalement par exploitation photogrammétrique numérique de clichés aériens, permettant d'atteindre une précision et une richesse compatibles avec la cartographie à l'échelle du 1/5 000 prévue dans le cadre du plan topofoncier national. L'objectif actuel est de

**Figure II. Modèle conceptuel des données géographiques**

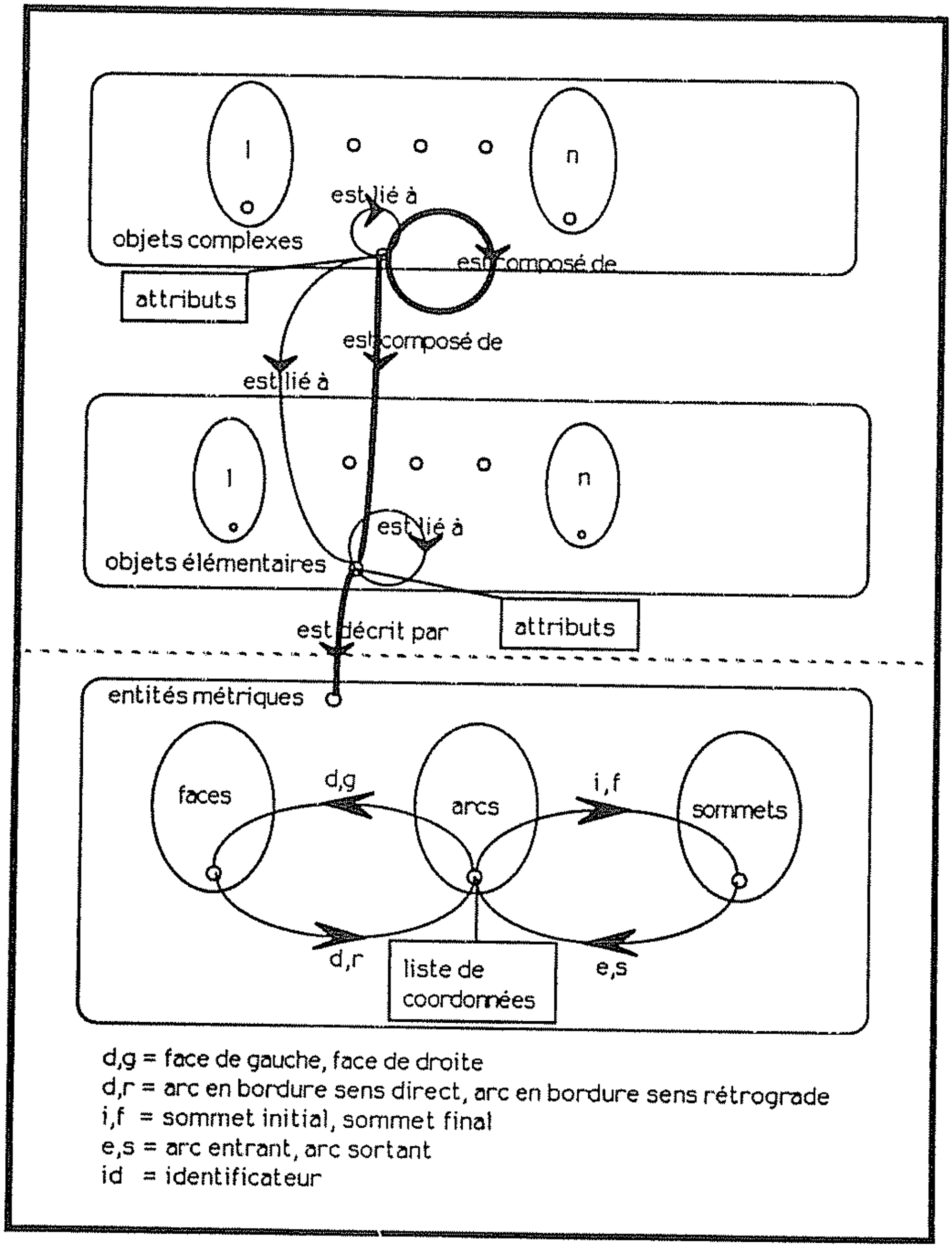
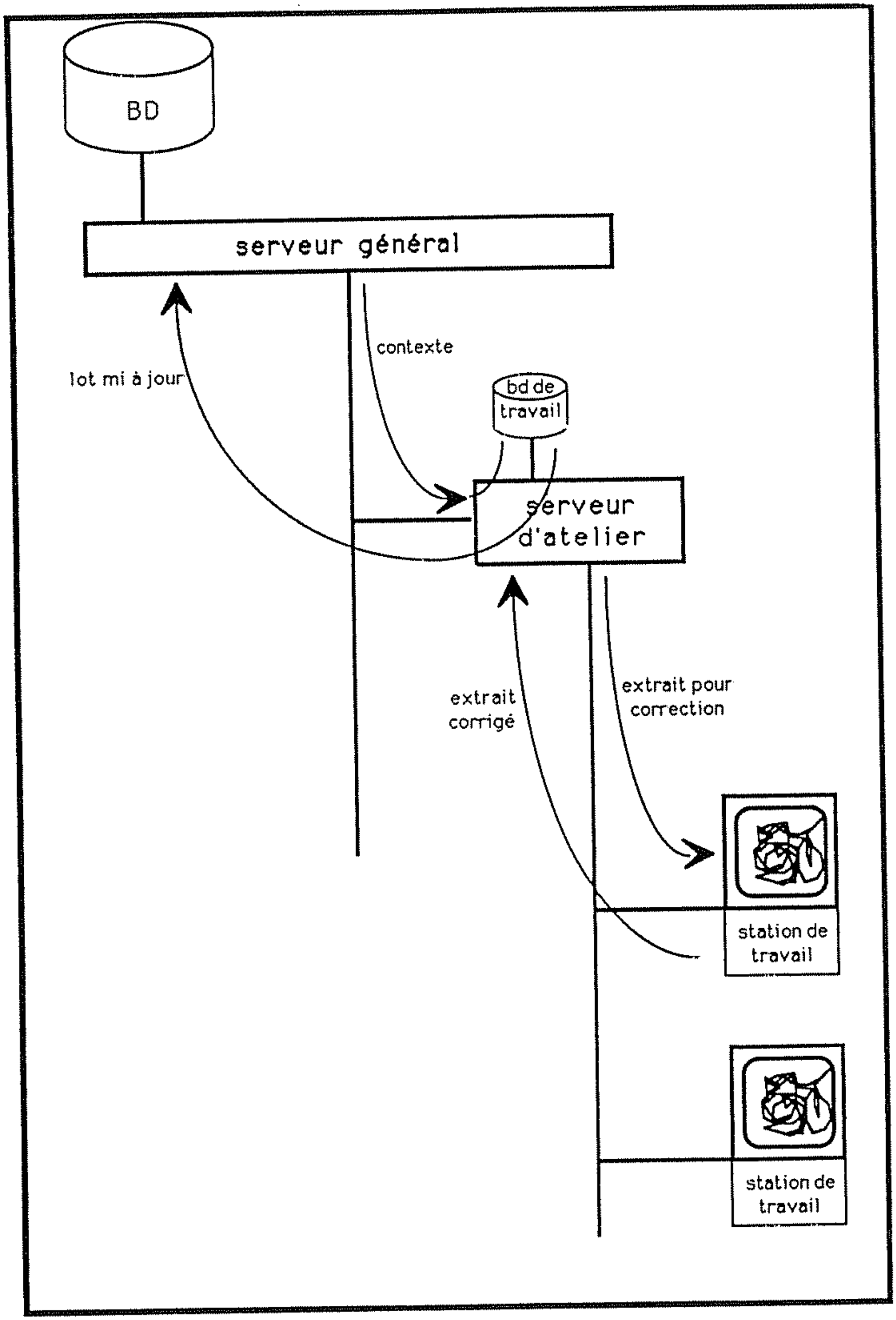


Figure III. Réseau bases de données et flot d'échange



réaliser la couverture complète du territoire d'ici à 2015, objectif très ambitieux quand on sait qu'il a fallu à chaque fois près d'un siècle pour achever les trois précédentes générations de la carte dite "de base (carte de Cassini, carte d'état-major et carte au 1/25 000).

Depuis une dizaine d'années l'IGN a également constitué une base de données altimétriques du territoire national, par numérisation des courbes de niveau de la carte à 1/25 000. Cette base imposante, puisque son encombrement est d'environ 1,4 gigaoctet, permet de nombreuses applications telles que : des calculs de modèles numériques de terrain, de cartes de pentes ou d'ensoleillement, de profils de terrain, de blocs diagramme..., ainsi que la réalisation automatique des matrices des cartes en relief.

Les informations de synthèse sur la France (au 1/1 000 000) et celles plus générales sur le monde (planisphère) sont prévues dans le cadre des bases de données globales.

## Les solutions adoptées

### *Un modèle de données spécifique*

Fort de son expérience et grâce aux contacts nombreux noués avec ses homologues étrangers, l'IGN a pu définir un modèle de données géographiques qui tient compte des avancées les plus récentes du secteur de la cartographie.

La modélisation de la relation entre un phénomène ou un objet géographique et sa localisation se fait grâce à deux concepts principaux : le niveau géométrique, d'une part, qui renseigne sur la forme, la position et les relations spatiales, et le niveau sémantique, d'autre part, qui décrit et défini ce que sont les objets et phénomènes retenus.

Appliqué dans toute sa pureté aux bases de données géographiques structurées (BDTopo, BDCarto, BDZ), ce modèle permet de cerner au plus près les spécificités de l'information géographique.

Dans ce cas, le niveau géométrique repose sur un graphe formé d'arcs, de sommets et de faces (les arcs sont en outre dotés d'une forme graphique), le niveau sémantique est décomposé :

*a*) En objets élémentaires, décrits géométriquement par les éléments du graphe et sémantiquement par des attributs; et

*b*) En objets complexes composés d'autres objets et caractérisés par des attributs, Des liens peuvent unir des objets entre eux pour décrire une relation géographique particulière.

### *Un serveur centralisateur*

Si l'on se réfère à la décomposition classique des SIG, (activités de saisie, activités de gestion-archivage-récupération, activités de traitement et d'analyse, activités d'édition et de génération de rapports), le serveur centralisateur se concentre sur les tâches de gestion, d'archivage et de récupération des données en response à une requête.

L'état de l'art actuel fait que lorsque l'on parle de bases de données géographiques de gros volume le fonctionnement optimal est de réserver les transactions longues au serveur central (extraction sur une zone géographique de certains thèmes) et de n'envisager les transactions interactives que sur des stations de travail œuvrant sur des lots de données thématiquement et géographiquement limitées (voir figure III). Ces transactions interactives concernant la saisie et la mise à jour sont du ressort exclusif des services de production.

## Conclusion

L'information géographique numérique forme un domaine où les possibilités des bases de données classiques sont rapidement dépassées et où les développements des techniques des bases de données généralisées, de systèmes experts et de langages orientés objets devraient trouver un champ d'application important.

L'information géographique a par essence des spécificités qu'il convient de prendre en compte : cette information peut être rattachée à un point du terrain et par voie de conséquence se trouve immergée dans un espace topologique ayant ses propres propriétés (d'où le terme de localisé).

Le travail de structuration, quoique fondamental, est aisé dès lors que sont parfaitement connus les entités pertinentes à prendre en considération, leurs caractéristiques et les liens qu'elles peuvent présenter. C'est généralement cette tâche de collation et de définition qui constitue la pierre d'achoppement de la définition d'un système d'information géographique.

La conceptualisation du niveau géographique n'est pas d'une grande complexité technique, mais se heurte à la difficulté de définir "l'univers du discours", ensemble des informations pertinentes à prendre en considération.

L'examen, non exhaustif, des problèmes que posent les systèmes d'information géographique montre la complexité du traitement numérique de l'information géographique. Cependant, compte tenu de l'évolution de notre société, il semble fondamental que cette information géographique soit disponible, "en temps réel" pour que les décisions d'aménagement, de gestion du territoire, d'intervention consécutive à une catastrophe, etc., soient prises en connaissant précisément l'environnement géographique dans lequel elles s'inscrivent et en évaluant rapidement l'impact des projets ou des solutions envisagées. Seul l'informatique et l'information géographique numérique permettent de satisfaire un tel besoin. Ce n'est que parce que l'information géographique ne peut être commodément perçue qu'au travers de graphiques qu'il est important que l'infographie soit capable d'apporter une réponse graphique aux questions géographiques des décideurs.

La connaissance de cet environnement géographique passe nécessairement par la mise dans un même référentiel des données d'origines diverses repérées par rapport à une même référence. C'est la raison d'être du système d'information géographique national de l'IGN, unique référence topographique, point de passage garantissant l'exacte superposition des informations sur notre environnement.

Les systèmes d'information géographique seront une réalité de demain, une réalité incontournable. La recherche française doit donc se porter sur ce domaine au champ d'application très important amenant de réelles économies pour la société, même si elles sont indirectes et donc difficilement mesurables.

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# MESURE DE LA QUALITÉ DE L'INFORMATION D'OCCUPATION DU SOL DANS UN SIG*

*Document présenté par la France*

## SUMMARY

This study deals with an evaluation of the accuracy of land cover data in the cartographic data base of the Institut géographique national. A typology of errors leads to a definition of land cover data cartographic accuracy. This typology separates the errors into four components: *semantic errors, exhaustivity errors, geometrical errors* and *topological errors*. A method for measuring the first three components is proposed and applied to a sample set representative of the average size of fields in France.

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La qualité de l'information géographique peut, de manière générale, être abordée sous trois aspects : la généalogie des données, qui concerne leur mode de saisie (information à la source, processus...); leur cohérence, qui recouvre l'adéquation des données avec le modèle théorique qui en est proposé; et leur exactitude (terme que nous préférons à "précision"), qui traduit l'écart possible entre les données et la "réalité".

Cette étude se limite au problème de l'évaluation de l'exactitude des données d'occupation du sol. Elle s'inscrit dans le cadre de la production, par l'Institut géographique national français (IGN), d'une base de données géographiques à la résolution du 1/100 000 (base de données cartographique). Cette base de données couvre l'intégralité du territoire national pour des thèmes cartographiques ponctuels, linéaires et surfaciques, et contient en particulier l'occupation du sol (Salgé, 1989).

Dans un premier temps, nous présentons un modèle d'erreurs permettant de définir "l'exactitude cartographique" des données d'occupation du sol et nous abordons brièvement la mise en œuvre de la mesure. La dernière section donne un exemple de mesures effectuées pour l'évaluation d'un système de saisie en cours d'étude.

### L'EXACTITUDE CARTOGRAPHIQUE DES DONNÉES D'OCCUPATION DU SOL

L'évaluation de l'exactitude des données d'occupation du sol a largement été étudiée dans le domaine de la télédétection. Les mesures qui ont été proposées sont dérivées de calculs de matrices de confusions. Elles permettent d'évaluer la fiabilité des surfaces totales mesurées dans chaque classe et sont donc adaptées à une utilisation statistique des données (Rosenfield, 1986).

Une utilisation cartographique des données participe d'un tout autre point de vue. Les parcelles homogènes sont alors considérées individuellement, caractérisées par leur contour (et donc localisées) et leur classe d'occupation du sol, et définissant un "paysage" par leurs formes et les relations de voisinage qu'elles ont entre elles.

C'est le sens de la structuration des données qui a été choisie dans la base de données cartographique (fig. I). Le niveau descriptif porte le contenu thématique des parcelles. Le niveau topologique définit les relations de voisinage sous forme d'une graphe topologique planaire. Le niveau géométrique contient les informations de localisation (et donc de forme) de chaque frontière entre deux parcelles (Salgé, 1989).

La définition d'une erreur cartographique suivra cette structuration. Une erreur d'égale importance en surface n'a pas le même sens si elle peut être interprétée comme une erreur de localisation de la frontière d'une parcelle que si elle correspond à l'attribution d'une classe incorrecte à une parcelle correctement délimitée. Il est donc important, au niveau de la définition de la qualité, de séparer les effets de bords (niveau géométrique de la structure de données) des confusions réelles (niveau descriptif de la structuration de données) [Chrisman, 1990] : le premier cas correspondra à une erreur dite *géométrique*, et le second à une erreur dite *sémantique*, ou *erreur d'attribut*.

De même, certaines confusions de classe peuvent causer la disparition d'un objet ou la création d'un objet inexistant : nous appelons ces erreurs *erreurs d'exhaustivité*. Enfin, des modifications de connexité d'une parcelle ou des relations de voisinage entre parcelles peuvent être induites par les confusions : nous parlerons d'*erreurs topologiques*. La figure II résume cette classification d'erreurs.

Il est évident que ces erreurs sont difficilement séparables. D'une part, parce qu'elles ont essentiellement la même origine (la mauvaise attribution d'une classe à une surface de terrain). D'autre part, parce que l'on peut passer d'un type d'erreur à l'autre par une déformation continue : une erreur géométrique, par exemple, est le résultat d'un déplacement de frontière, qui, s'il devient trop important, sera plutôt interprété comme une création d'objet, et donc comme une erreur d'exhaustivité (Chrisman, 1989).

*The original text of this paper, prepared by Olivier Jamet, Institut géographique national, appeared as document E/CONF.83/L.50.

**Figure I. Structuration des données d'occupation du sol dans la base de données cartographique**

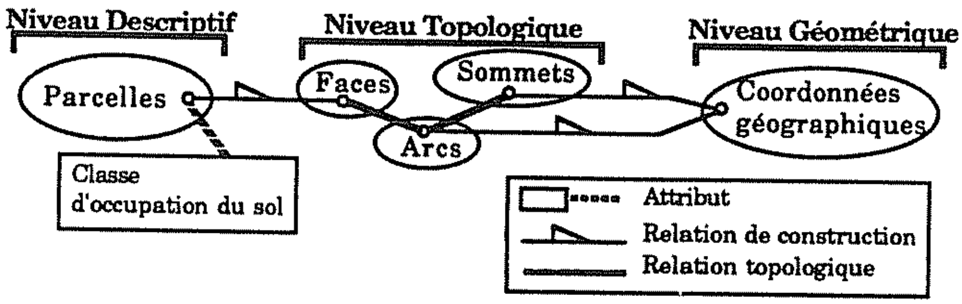



**Figure II. Classification des erreurs**

| | | | |
|---|---|---|---|
| **Erreur Sémantique** | Attribution d'une classe fausse à une parcelle (erreur d'attribut) | | |
| **Erreur d'Exhaustivité** | Omission ou rajout d'une parcelle | | |
| **Erreur Topologique** | Relation de voisinage entre deux parcelles incorrecte | | |
| **Erreur Géométrique** | Erreur de forme et de position d'une parcelle | | |

Ce dernier point montre qu'une phase *d'interprétation du type d'erreur* doit intervenir dans le processus de mesure, et qu'il est donc nécessaire de spécifier les critères qui permettront de classer les déformations dans la typologie proposée. Ceci fait l'objet de la section suivante.

## Mesure de l'exactitude des données d'occupation du sol

L'évaluation de l'exactitude suivant la typologie d'erreur définie dans la section 2 soulève deux questions. D'une part, la mesure de déformations suppose que l'on compare le contenu de la base à un jeu de données exactes, que nous appelerons vérité-terrain ou référence. D'autre part, des techniques de reconnaissance des déformations entre la référence et les données évaluées doivent être élaborées.

Nous n'avons abordé le problème de définition d'une référence que très superficiellement pour l'instant, tout en reconnaissant que c'est une étape clef de la mesure. Cette référence est en fait une représentation nominale du sol dans le modèle géographique utilisé. Nous supposons que cette représentation est accessible par une saisie plus précise que celle de la base de données, et correctement généralisée.

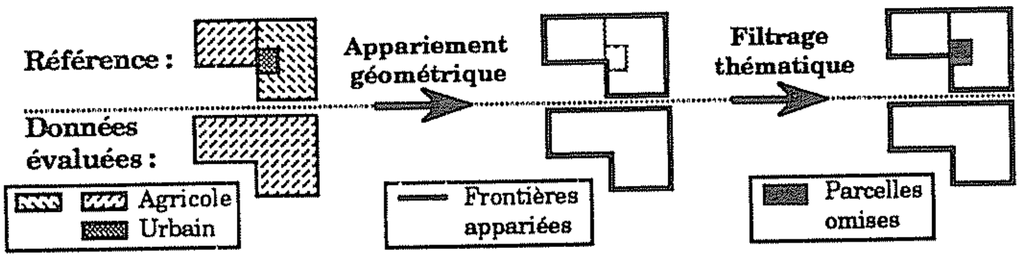
La reconnaissance des déformations, quant à elle, repose sur une identification des objets de la base sur la référence. Nous proposons une solution algorithmique à ce problème de mise en correspondance. Dans un premier temps, des critères géométriques sont utilisés pour extraire les frontières communes aux deux jeux de données : cette opération associe bijectivement les groupes de parcelles (ou agrégats) délimités par les frontières communes de la référence à ceux des données évaluées (Jamet, 1990). Cette correspondance est ensuite filtrée par un critère de contraste thématique : certaines parcelles de la référence, appartenant à un agrégat, peuvent ainsi être reconnues comme absentes dans les données évaluées, et classées comme parcelles omises; symétriquement, des parcelles des données évaluées peuvent être classées comme excédentaires (Le Men, 1990). Ce processus est illustré par la figure III.

La correspondance obtenue en fin de processus donne ainsi directement accès à un décompte des erreurs d'exhaustivité (parcelles omises et excédentaires), dont une mesure sera le nombre et la surface des objets en erreur par thème (*cf.* table 4).

Elle permet par ailleurs une évaluation indépendante des autres types d'erreurs. Les erreurs sémantiques, erreurs d'attribut sur les parcelles reconnues, peuvent être exprimées sous forme de confusions entre classes majoritaires des agrégats appariés, présentées comme des matrices de confusions en nombre de parcelles ou en surface (les surfaces correspondant à la sommation des surfaces des parcelles, et non à des confusions point à point : la mesure s'affranchit ainsi des confusions dues aux déplacements de frontières) [*cf.* table 3].

Les erreurs géométriques peuvent être évaluées par calcul de distance entre frontières appariées. On évalue, pour chaque couple de classes, le déplacement maximal et la moyenne des déplacements maximaux sur l'ensemble des frontières entre ces deux classes, ainsi que la moyenne

Figure III. Processus de mise en correspondance de la référence et des données évaluées




quadratique des déplacements sur tout les points des frontières entre ces deux classes (*cf* table 5).

L'évaluation des erreurs topologiques n'a pas encore été abordée.

## EXPÉRIENCES CONDUITES

Nous avons conduit de premières expériences sur un jeu de données élaboré au laboratoire COGIT à l'aide d'un logiciel d'interprétation d'images SPOT en cours d'étude (Le Men, 1990). La zone de test est située dans l'Est parisien, sur une région représentative du parcellaire moyen français (taille moyenne des parcelles : environ 7 hectares) et couvre une dizaine de kilomètres carrés. La légende d'interprétation compte 14 classes, dont 7 effectivement présentes dans l'image (landes, feuillus, vergers, prairies, labours, cultures, urbain).

L'interprétation a été conduite en utilisant le logiciel en mode interactif : les frontières des parcelles sont obtenues par segmentation automatique et l'opérateur intervient dans la phase d'interprétation des segments, pour réaliser un apprentissage et corriger ensuite les interprétations qui lui sont signalées comme douteuses.

La référence a été établie par interprétation visuelle à l'écran de l'image SPOT; cette saisie, recouvrant environ 60 % de la zone d'étude, a ensuite été contrôlée par une enquête de terrain.

Ces données ne sont pas représentatives des méthodes de production actuelles de la base de données cartographique. Les évaluations présentées dans la suite n'ont donc pas valeur de jugement sur sa qualité. Outre la disponibilité d'enquêtes de terrain sur les zones actuellement saisies, la connaissance *a priori* des artefacts du processus d'interprétation nous a paru importante pour la validation des mesures proposées. Les données issues d'une interprétation semi-automatique (limitant l'intervention de l'opérateur) étaient en ce sens plus adaptées à notre étude.

Les tables 1 et 2 reproduisent les matrices de confusion point à point calculées entre données évaluées et référence. La table 1 est une matrice de confusion brute. La table 2 est obtenue en calculant les confusions après masquage d'une bande d'environ 50 m autour des frontières de la référence. La comparaison entre ces deux tables montre d'ores et déjà que les effets de positionnement des frontières sont relativement importants : l'élimination des pixels voisins des frontières divise le taux d'erreur par 3. Cette technique de calcul ne permet cependant pas une séparation complète entre les effets de frontière et les confusions réelles.

Les tables 3, 4 et 5 présentent les résultats de mesures proposées. Ces mesures permettent d'avoir une analyse beaucoup plus complète de la qualité des données : on constate que le taux d'erreur de la table 4 provient seulement pour une part négligeable d'erreurs d'interprétation (table 3 : 0.48 % de la surface totale). Une faible part des erreurs est due à la création de parcelles excédentaires (table 4 : 0.96 % de la surface totale), et la majorité des erreurs sont donc à considérer comme erreurs de positionnement des frontières. Les mesures de distance permettent en outre de juger que les erreurs de frontières sont en grande parties inhérentes à la

TABLE 1. MATRICE DE CONFUSION POINT À POINT

| | *Land.* | *Feuil.* | *Prai.* | *Lab.* | *Cult.* | *Urb.* | *Verg.* | *% fiab* |
|---|---|---|---|---|---|---|---|---|
| Land | 40 | 104 | 1 | 78 | 3 | 92 | 0 | 12 58 |
| Feuil | 1 | 57 526 | 452 | 351 | 652 | 103 | 1 | 97 36 |
| Prai | 0 | 610 | 11 156 | 206 | 619 | 183 | 0 | 87.33 |
| Lab | 0 | 686 | 260 | 46 857 | 619 | 183 | 0 | 95 06 |
| Cult | 0 | 1013 | 163 | 1 150 | 48 710 | 120 | 10 | 95 20 |
| Urb | 0 | 484 | 43 | 172 | 248 | 3 090 | 0 | 76 54 |
| Verg | 0 | 0 | 0 | 11 | 6 | 0 | 710 | 97 66 |
| % rec | 97.56 | 95 21 | 92 39 | 95 97 | 94.76 | 82 22 | 81 14 | 94.75 |

TABLE 2. MATRICE DE CONFUSION POINT À POINT APRÈS ÉLIMINATION DES PIXELS FRONTIÈRE

| | *Land.* | *Feuil.* | *Prai.* | *Lab.* | *Cult.* | *Urb.* | *Verg.* | *% fiab* |
|---|---|---|---|---|---|---|---|---|
| Land | 9 | 21 | 0 | 37 | 0 | 19 | 0 | 10.47 |
| Feuil | 0 | 39 806 | 56 | 3 | 104 | 51 | 0 | 99.47 |
| Prai | 0 | 119 | 5 077 | 0 | 212 | 57 | 0 | 92 90 |
| Lab | 0 | 79 | 38 | 28 770 | 202 | 74 | 14 | 98 61 |
| Cult | 0 | 267 | 6 | 135 | 28 029 | 8 | 0 | 98 54 |
| Urb | 0 | 212 | 0 | 35 | 54 | 1 488 | 0 | 84.07 |
| Verg | 0 | 0 | 0 | 0 | 0 | 0 | 481 | 100 |
| % rec | 100 | 98 28 | 98 07 | 99 28 | 98 00 | 88 37 | 97 17 | 98 29 |

TABLE 3. ERREURS SÉMANTIQUES (MATRICE DE CONFUSION EN SURFACE)

| | *Land.* | *Feuil.* | *Prai.* | *Lab.* | *Cult.* | *Urb.* | *Verg.* | *% fiab* |
|---|---|---|---|---|---|---|---|---|
| Land. | 47 | 64 | 0 | 0 | 0 | 0 | 0 | 42.34 |
| Feuil | 0 | 59 117 | 0 | 0 | 0 | 0 | 0 | 100. |
| Prai. | 0 | 0 | 12 186 | 0 | 0 | 0 | 0 | 100. |
| Lab | 0 | 61 | 0 | 48 805 | 277 | 0 | 167 | 98 98 |
| Cult | 0 | 0 | 0 | 157 | 50 556 | 0 | 0 | 99 69 |
| Urb. | 0 | 0 | 0 | 114 | 0 | 3 479 | 0 | 96 83 |
| Verg | 0 | 0 | 0 | 0 | 0 | 0 | 722 | 100 |
| % rec | 100 | 99 79 | 100 | 99.45 | 99.46 | 100 | 81 21 | 99 52 |

TABLE 4 ERREURS D'EXHAUSTIVITÉ

| *classe* | *nbre* | *surf.* | *% nbre* | *% surf* |
|---|---|---|---|---|
| Excédents | | | | |
| Land | 3 | 185 | 0.30 | 0.10 |
| Feuil | 3 | 74 | 0.30 | 0.04 |
| Prai | 9 | 588 | 0.90 | 0.33 |
| Lab | 6 | 299 | 0.60 | 0.17 |
| Cult | 7 | 247 | 0.70 | 0.14 |
| Urb | 6 | 322 | 0.60 | 0.18 |
| TOTAL | 34 | 1 713 | 3.40 | 0.96 |
| Omissions | | | | |
| Prai | 1 | 16 | 0.13 | 0.01 |
| TOTAL | 1 | 16 | 0.13 | 0.01 |

Nombre de parcelles (nbre),
Surface totale en erreur (surf),
Pourcentage par rapport au nombre total de parcelles évaluées (% nbre).
Pourcentage par rapport à la surface totale évaluée (% surf)

TABLE 5 ERREURS GÉOMÉTRIQUES

| *Frontière* | | *Sup* | *Moy. Sup* | *Moy. Quad.* |
|---|---|---|---|---|
| Feuillus | Urbain | 5.39 | 1.95 | 1.68 |
| Prairies | Urbain | 4.24 | 1.80 | 1.12 |
| Feuillus | Feuillus | 6.40 | 1.67 | 1.20 |
| Cultures | Urbain | 5.00 | 1.52 | 1.10 |
| Urbain | Urbain | 3.61 | 1.75 | 1.27 |
| Feuillus | Labours | 4.47 | 1.10 | 0.69 |
| Cultures | Vergers | 1.00 | 1.00 | 0.50 |
| Prairies | Cultures | 5.00 | 1.16 | 0.85 |
| Landes | Labours | 1.00 | 1.00 | 0.50 |
| Feuillus | Vergers | 1.00 | 0.53 | 0.26 |
| Landes | Feuillus | 1.00 | 1.00 | 0.41 |
| TOTAL | | 7.07 | 1.17 | 0.83 |

Déplacement maximaux (sup)
Moyenne sur les frontières des déplacements maximaux (moy. sup.)
Moyenne quadratique sur les points frontières des déplacements (moy quad.)

précision des données de départ : les frontières sont en effet *a priori* localisées au pixel près, et la valeur de 0.83 (table 5) prixels d'erreur quadritique moyenne n'a donc rien d'étonnant.

Cet exemple montre les possibilités d'analyse offertes par l'évaluation proposée. Elle permet, dans le cas présent, de cerner l'origine des erreurs de façon précise : la présence d'excédents provient d'une sursegmentation de l'image, produisant de petites parcelles (la surface moyenne des excédents est de 50 pixels, soit 2 hectares) difficilement interprétables; l'examen de la table 5 des distances montre que les erreurs les plus fréquentes dans le positionnement des frontières interviennent sur la classe urbaine dont la difficulté de segmentation est connue.

## CONCLUSIONS

L'évaluation de l'exactitude des données d'occupation du sol d'un SIG ne peut faire l'économie d'une analyse cartographique de la notion d'erreur. La mesure séparée de l'exactitude sémantique (confusion de classe d'occupation du sol sur une parcelle), de l'exhaustivité (omission ou rajout d'une parcelle), et de l'exactitude géométrique (erreurs de localisation des frontières des parcelles) ouvre des possibilités de diagnostic des sources d'erreurs. Par ailleurs, l'adéquation entre la description des erreurs et le modèle de données permet une évaluation indépendante de chaque niveau d'information de la base.

Un effort de recherche reste cependant nécessaire pour rendre de telles mesures opérationnelles. D'une part, au niveau algorithmique. La qualité des mesures effectuées est intimement dépendante de la qualité de l'appariement entre les données de la base et la référence. Les algorithmes que nous avons développés devront donc être validés sur un jeu de données plus vaste : les saisies de l'occupation du sol de la base de données cartographique nous fournirons les éléments nécessaires à la poursuite de l'étude dans ce sens.

D'autre part, au niveau de la méthodologie : le concept de référence doit être précisé, de même que le processus de sondage qui permettra de valider des jeux de données étendus.

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# MANAGEMENT OF NATIONAL MAPPING AND CHARTING PROGRAMMES*

*Paper submitted by New Zealand*


## RÉSUMÉ

En Nouvelle-Zélande, l'évolution rapide des conditions de fonctionnement a incité les institutions de cartographie du secteur public à examiner leurs opérations et à procéder à une réforme substantielle des structures administratives, de la politique d'établissement des prix et de la commercialisation. On est donc passé d'une approche qui privilégiait la réalisation de produits à une conception davantage orientée vers la commercialisation, ce qui suppose une meilleure prise de conscience des besoins des utilisateurs actuels et potentiels en matière d'information cartographique. Les frontières traditionnelles entre les diverses disciplines qui contribuent à la cartographie se sont estompées à mesure qu'émergeait la notion d'une approche commerciale uniformisée fondée sur l'établissement de bases de données cartographiques intégrées. Les institutions de cartographie sont devenues des entreprises qui doivent être gérées comme des entreprises commerciales de façon à pouvoir exécuter les programmes nationaux de cartographie.


A paper submitted by the Secretariat under this agenda item at the Eleventh Conference drew attention to the fundamental reason why the United Nations accepts the furtherance of cartography as an integral part of its operations (E/CONF.78/4/Add.1). Mapping provides a means to achieving better living standards, full employment, and improved conditions of economic and social progress and development, both internally and internationally, thereby positively contributing to the United Nations' ultimate objectives.

In New Zealand, a struggling economy has forced the application of severe budgetary restraints on Government expenditure and has required a substantial increase in the level of costs recovered. This has had a considerable impact on the operations of Government mapping agencies but, in spite of numerous difficulties, innovative management has enabled essential mapping programmes to be maintained. This paper explains how user needs and government requirements are being achieved in the Department of Survey and Land Information (DOSLI), New Zealand's principal survey and mapping agency.

### OPERATING ENVIRONMENT

New Zealand has moved rapidly to a "user-pays" philosophy in the provision of many products and services produced by government departments. Several government activities and national assets have either been converted to State-owned enterprises and placed on a commercial footing, sold to the private sector, or discontinued altogether. Goods and services tax was introduced in 1986 and applies to all of the Department's prices within New Zealand. Initially set at 10 per cent this tax was increased to 12.5 per cent in 1989 and has had a significant impact on sales. Government has made clear its intention to reduce the size of the public sector, and to reduce and eliminate costs wherever possible. Many of the Department's traditional clients are other government departments that now operate on very limited budgets and most are unable to purchase the Department's outputs at previous levels.

Over the last four years the Department has moved from cost recovery levels of 7 per cent of total costs, up to 62 per cent. That is an increase in revenue from $NZ 3 million to $NZ 33.5 million. In 1990/91 the target is $NZ 38.5 million (70%).

In the last three years the new State Sector Act has placed chief executives and a range of senior staff on contract, and delegated financial and industrial relations responsibility. It has also made chief executives accountable through annual performance agreements and external reviews. Also, in the last two years a new Finance Act has changed the period of the financial year and required all government departments to move from cash to accrual accounting, to pay depreciation and return on assets, and to establish monthly, weekly and daily cash flow profiles. Also, chief executives have to specifically identify resources and performance measures against clearly defined outputs.

These requirements have forced the Department to review the range of products and services provided and to make substantial changes to management structures, pricing policies and market orientation with a view both to short-term survival and to positioning for the future. The long assumed benefits to the nation provided by mapping cannot be taken for granted. Activities need the continued support of Government and communities, but no longer will a standard product or service suit the Department's various clients. There is a need to relax any preoccupation with production as such, and take up a market orientation. It is essential to become familiar with the needs and problems facing those providing financial support, as the emphasis is now being placed on the results obtained from Government expenditure, their quality, quantity and costs. Government wants outputs which materially contribute to its policies and programmes.

#### *Outputs*

Government departments are now required to classify their activities within "output" groupings approved by Government. Map production is part of the Land Information group of outputs approved for the Department.

By identifying individual outputs, and the resources allocated to their production, Government can decide whether it wishes to purchase a particular output, and if so in what quantity. Costs are directly identified with each output so that the costs/benefits of each activity are transparent and can be assessed in terms of priority and contribution to Government's social and economic and environmental objectives.

*The original text of this paper appeared as document E/CONF.83/L.23.

### Organizational changes

To enable the Department to meet the challenge of achieving Government's cost recovery targets, while maintaining production at satisfactory levels, a number of organizational changes have been implemented.

The Department has been restructured to relate to a concept of a unified business of land information. Major subdivisions group surveyors, photogrammetrists amd remote sensing in "Information generation". Computer services, digital cadastral database and digital topographic databases form an "Information management" group. "Information applications" includes cartography, aeronautical charting, client services, land information and statutory activities. Corporate services form another group, including human resources, industrial relations, training and marketing. Divisions such as training, computer services, research and development and corporate servicing are used as a Department-wide resource and work functionally with the various groups as tasks and circumstances require.

The organization structure has also been "flattened", reducing the number of management levels from 5 to 3 in most areas, improving efficiencies in communication and control.

Corporate planning has been upgraded to provide essential direction of the Department towards its identified priorities and objectives. This provides a systematic planning approach for the whole survey and mapping organization. Strategic thinking, missions and goals cascade down through mid-term planning to budget-aligned business plans. The linking of resource use and programming is critical to the effective application of corporate planning. Goals, objectives, policies, and output measures of quality, quantity and unit costs all need to fit congruently into this corporate management approach

As well as methodically ensuring that the focus is on the right activities these need to be done exceptionally well. In this regard the concepts of total quality management (TQM) can be applied. Arising out of the thinking of Dr. Edward Deming and the impressive Japanese achievements, this management philosophy offers a very effective method of business improvement. While TQM in Japan has been successful largely in production-based organizations, its systematic approach to continuous business improvement through total staff participation promises major benefits in survey and mapping organizations also. Most of the Department's staff have been exposed to training on the concepts and practice of TQM, and beneficial results are already being achieved.

### Map production and revision

For descriptive purposes it is convenient to separate mapping production and revision into four categories:

Basic topographic mapping
Derived mapping
Client mapping and charting
Cadastral mapping

#### *Basic topographical mapping*

The Department is the only organization that produces large-scale topographical mapping coverage of New Zealand. Its chief executive is responsible for civil mapping under the title of Surveyor-General and for military mapping in his role as Director of Survey of the Army General Staff for which he carries the honorary rank of Colonel in the New Zealand Defence Force. As the 1:50,000 large-scale topographical map series is designed to suit both civil and military requirements there is no duplicated effort or wasted resources.

Although the topographical mapping function is centralized in the Department, actual map production is decentralized throughout the Department's district offices. Control of production is exercised by the Head Office in Wellington through the preparation of production and revision programmes, the setting of specifications and standards, and the supply of materials and other logistical support.

A reduction in staff numbers working on mapping has resulted from (*a*) improved production methods; (*b*) the need to divert staff to other high priority activities within the Department; and (*c*) the loss of approximately 15 per cent of staff through attrition over the past four years. This has meant that in some cases the cartographic units in district offices are now very small and the costs of servicing them from Head Office, and of providing adequate training in cartographic production, are disproportionately high in relation to their output. In the drive for increased efficiency avoidable costs have to be eliminated, and the trend is therefore towards increasing the proportion of cartographic production within Head Office, while continuing to rely upon district offices for the collection of field data as required.

The revision of topographical mapping is essential to maintain its usefulness. In addition to its direct use by purchasers, basic mapping also provides the information from which smaller-scale maps are derived. With the approaching completion of the 1:50,000 topographical map coverage of New Zealand, future emphasis will be on ensuring that the series is sufficiently up-to-date to meet the demands of users and the requirements for derived mapping.

Basic topographical mapping requires ongoing Government funding support. In New Zealand, this is achieved through a direct budget allocation and through a maintenance contribution from military users. The 1:50,000 metric topographical series of 324 sheets, and its predecessor the 1:63,360 series, cost approximately $NZ 4.2 million per annum to produce and maintain. This cost is funded as follows:

*Government*: 40 per cent
- National security
  - Military (general purpose)
  - Police
  - Civil defence
  - Search and rescue
  - Agricultural disease control
  - Pollution monitoring
- Planning
  - Statutory purposes
  - Land administration/management
  - Scientific studies
  - Land use/inventories
  - Resource studies
  - Environmental studies
- Social
  - Education
  - Recreation

*Defence (Army)*: 11 per cent
- Contribution to maintenance of military mapping

*Map sales*: 36 per cent

*Copyright licensing: 13 per cent*

Production to date has almost entirely been by conventional manual methods with minimal digital input. However, research is continuing into data capture/structure/management/output systems with a view to creating a structured topographical database. The best option at present is the scanning of existing 1:50,000-scale topographical map separations.

Investigations are also being made into the feasibility of producing 1:10,000-1:20,000 digital topographical mapping for areas where specific needs are identified.

### *Derived mapping*

Derived mapping is intended to become self-funding through the sale of either published maps or derivatives. National and Forest Park maps and recreation mapping are partially funded through an agreement with the Department of Conservation whereby that department purchases sufficient maps to ensure that the Department of Survey and Land Information recovers full production costs.

A 1:250,000 structured topographical database of New Zealand has already been created, including all information shown on the published 1:250,000 topographical map series of 18 sheets. This database will be used to produce a number of maps and charts at medium and small scales. In addition, significant sales of this data have been made to both public and private sector clients.

### *Client mapping and charting*

All aeronautical chart production for both civil and miltary purposes in New Zealand is centralized in the Department and is carried out in Head Office by a small team of cartographers who have a close working relationship with civil and military aviation clients. As the chart specifications for each client vary in many respects a certain amount of duplication occurs in production, with a separate version of some charts being published for each client. However, with the increasing need to reduce costs, charting specifications are currently being examined with a view to producing single charts for both civil and military users where this is feasible.

The advantages of centralized mapping are nowhere more apparent than in the production of aeronautical charts. As mentioned previously, the Department produces nationwide topographical data and, as New Zealand's aeronautical charting agency, it is ideally placed to merge the data from the topographical and aeronautical databases. As the originator of the information, the Department can ensure that appropriate and consistent standards are achieved for all products.

Aeronautical charting, and all other work carried out for specific clients, is charged at full cost. This includes all products and services provided for other government departments, local authorities, private organizations etc.

### *Cadastral mapping*

Large-scale cadastral plans are available for inspection in the Department's offices in each land district. However, published mapping has been discontinued owing to the high costs of production and low usage. The Infomap 261 cadastral map series at 1:50,000 scale, which was previously published, is now maintained in the form of transparencies by local offices and plan print copies are able to be purchased.

A digital cadastral database (DCDB) is being established, updated on a daily basis as changes are made on approved survey plans. Full national coverage is expected to be available in 1992, and data is already being licensed to users to recover costs.

## INTEGRATION

With the development of computer technology, the historical lines between specialized activities such as surveying, photogrammetry, cartography, and so on, have become blurred. The disciplines that contribute to mapping can no longer operate efficiently if they focus on their own perceived needs in ignorance of the wider requirements of information systems.

The Department's responsibility for geodetic, survey, cadastral and topographical systems has facilitated the change from manual to digital methods. The aggregation of data and the incremental increases in knowledge through making a variety of relationships, connections etc. yield new levels of information beyond that evident from the sum of individual data components. Clearly, independent and restricted databases and systems are no longer adequate even for their primary original purpose.

The emphasis on only a single end-product or service is no longer an efficient or economic manner in which to utilize the basic data resource. The problem is that insufficient attention has in the past been paid to data as the basis of a service or product. New digital technologies show up the foolishness of separate and duplicated land information activities. In addition, these emerging technologies provide the means for an immensely improved cost effectiveness and increased information support. The competition for public money and the taxpayers demand for value make the attention to the low cost provision of land information imperative.

The technique and technology challenges now being overcome are being replaced by management and economic challenges. A systematic and corporate approach is needed which links databases and activities, and provides the greatest cost effectiveness. An organization-wide information strategy is important so that various components can be interrelated and can form modules for further growth and development.

The various technological and management issues have been addressed by the Department, and have resulted in corporate policies that recognize the integration of land information as the key to future growth and progress. Databases are designed as part of a land information business, rather than with specific uses or products in mind.

## COPYRIGHT AND LICENSING

All information generated by the Department is protected by the New Zealand Copyright Act for a period of fifty years.

A range of standard licences has been created for the use of land information by other organizations. This is necessary both to provide a source of revenue, and to protect the Department's data from misuse, while allowing legitimate uses of information at appropriate cost.

## PRICING POLICIES

Prices and charges for most products and services have risen from free-of-charge or token payment to either full cost recovery rates or to a level that maximizes revenue. For example, the price of a 1:50,000 scale topographical map has risen from $NZ 2.00 in 1987 to $NZ 11.65 in 1990, and while sales volumes have fallen, net revenue has considerably increased.

### Geographical names

A vital function of any mapping organization is to ensure that maps depict correct geographical names. The New Zealand Geographic Board was established by an Act of Parliament in 1946 to provide a central authority for the approval of place-names in New Zealand. The Surveyor-General is permanent chairperson of the Board, and secretarial support is provided by the Department.

An emphasis is placed on identifying original indigenous names and adopting these where appropriate. Considerable research is required, as many Maori names exist only in oral history or in widely dispersed written records, and the Department is to become more active in establishing a network of information sources throughout New Zealand.

New Zealand also has a close association with other Pacific countries through the early migrations, and many names occur in a number of countries, sometimes in groups. In November 1990 the Department hosted a Pacific Place-Names Conference which was attended by delegates from several Pacific countries. Three further international geographical names conferences are scheduled to be held in New Zealand in 1992.

### Off-shore projects

Through its experiences during recent years, the Department has become a leaner, more efficient organization, and has developed strategies that should ensure continuing growth and progress in the land information business. It is appropriate that the benefits of this experience should be shared with other countries, and the Department has become more active in seeking off-shore opportunities in Asia and the South Pacific. The Pacific rim is seen as a significant growth area for the future, and the Department is well positioned to participate in international cooperation and resource management. Many countries are now developing their own land information systems and need effective environmental monitoring and land management and land tenure systems. New Zealand's position as a developed Pacific country with strong indigenous links provides countries seeking land information management skills and assistance with an ideal partner. In particular, New Zealand offers cost effective solutions to countries that have resource constraints.

Currently, the Department is involved with the provision of a land information strategy for Fiji, two staff have been posted to Nine to assist with the introduction of a land titling system. Assistance is also being provided to the Western Samoan Government for their survey and mapping operations. Representations will be made to the Asian Development Bank and the World Bank with a view to promoting New Zealand's capabilities in providing this type of assistance to other countries.

### Conclusion

Although Government mapping agencies in New Zealand have been subjected to a rapidly changing operating environment owing to a deterioration in the national economy, the Department of Survey and Land Information has been able to successfully adapt to the new conditions. By accepting that change is necessary, rather than resisting the inevitable, the Department has been able to make adjustments in a controlled way, meeting the Government's budgetary requirements while still maintaining essential mapping programmes.

A review of activities, organization restructuring, increases in prices and charges, the development of a market orientation, the introduction of a TQM philosophy and the pursuit of off-shore ventures are some of the management initiatives that have been implemented.

However, the important issue for future progress is the development of a fully integrated land information database from which a wide range of products and services can be extracted to enable clients and Government to achieve their commercial, social and economic objectives.

## (d) *Geographical names*

## PRINCIPALES INTERVENTIONS SUR LES NOMS GÉOGRAPHIQUES*

*Document présenté par la France*


### SUMMARY

The report describes three major projects in geographic names standardization carried out by the Institut géographique national: the publication of *Guide toponymique cartographique;* research for preparation of a phonetic standard covering the dialects of the Melanesian islands of New Caledonia; and the compilation of toponymic data bank containing the languages and dialects of the national territory of France. The outline of the data bank is given.


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### Guide de toponymie cartographique

L'Institut géographique national (IGN) vient d'éditer, dans le cadre de ses publications techniques et scientifiques, un *Guide de toponymie cartographique.*

Ce document s'inscrit dans un double objectif : tout d'abord initier les cartographes et les topographes aux particularités linguistiques que connaît la France, et les aider par là-même dans le recueil et le traitement des toponymes, pour la plupart dialectaux, devant figurer sur la carte de base à 1/25 000.

Les renseignements contenus dans le guide devraient d'une manière générale faciliter la lecture et la compréhension de la carte, quel que soit l'utilisateur.

*The original text of this paper appeared as document E/CONF.83/L.49

Le guide répond ensuite à une recommandation émise par le groupe d'experts des Nations Unies sur la normalisation des noms géographiques, visant à inciter chaque pays membre à établir des guides à l'intention des utilisateurs nationaux et étrangers. A cet effet il a été présenté lors de la quatorzième session du groupe d'experts, qui s'est tenue à Genève du 17 au 26 mai 1989.

Le guide comprend deux parties principales : la première traite des questions d'écritures cartographiques (emploi des majuscules, des accents, des traits d'union, des articles); la seconde aborde les aspects de la toponymie dialectale par la description des principales langues allogènes présentes sur le territoire national (alsacien, basque, breton, corse, flamand).

Il convient de remarquer qu'une diffusion à l'étranger nécessiterait une adaptation de la présente édition et en particulier un développement de la première partie.

Les quelques chapitres que contient ce guide devraient cependant pouvoir constituer la trame, ou l'amorce, d'un document à vocation européenne.

## Présentation de la convention phonétique établie pour la Nouvelle-Calédonie

A l'occasion de la révision de la carte au 1/50 000 de la Nouvelle-Calédonie, qui a débuté en 1983, le Service topographique a entrepris une vaste enquête auprès des habitants.

Cette investigation a permis de recueillir, et bien souvent faire resurgir, de nombreux toponymes tradionnels dont la plupart n'avaient jamais été répertoriés sur des documents cartographiques, et qui représentaient un patrimoine culturel considérable.

Le Service topographique de la Nouvelle-Calédonie s'est heurté dans cette entreprise à une double difficulté : d'une part, une grande diversité de langues et dialectes et, d'autre part, l'absence d'une véritable écriture codifiée.

C'est pourquoi une convention phonétique a été mise au point par le Service topographique de la Nouvelle-Calédonie et l'Institut géographique national (IGN), avec l'aide des linguistes de l'Institut national des langues et civilisations orientales (INALCO).

Cette convention, différente pour la Grande-Terre et les îles Loyauté, présente l'intérêt de respecter la richesse linguistique de ce territoire, tout en permettant de transcrire la toponymie à l'aide d'une orthographe homogène accessible au plus grand nombre d'utilisateurs.

Les langues mélanésiennes de la Nouvelle-Calédonie et des dépendances appartiennent à la famille linguistique austronésienne qui s'étend sur le Pacifique. Ces langues sont sœurs des langues polynésiennes telles que le tahitien.

Au nombre d'une vingtaine, elles diffèrent les unes des autres comme les langues d'Europe. Beaucoup de sons n'ont pas d'équivalents en français. On trouvera dans cette étude des indications nécessaires à la lecture des cartes. Dans certains cas, la prononciation indiquée est approximative.

Les investigations auprès des habitants ne sont pas encore complètement terminées. Une présentation plus complète est envisagée à la fin des opérations.

## Description de la banque de données toponymiques et avancement

Cette banque de données concernant les toponymes français a débuté en saisie en 1986.

*Contenu du fichier original*

*Nocarte* (6 caractères) : Pour le numéro de la feuille à 1/25 000 sur laquelle les attributs du toponyme ont été relevés.

*Numordre* (4 caractères) : Pour le numéro affecté à l'objet lié au toponyme. Une série de numéros par feuille. Chaque toponyme désignant le même objet a le même numéro.

*Codcom* (5 caractères) : Pour le code INSEE de la commune associée au toponyme (objet ponctuel); ou pour le code INSEE de la commune principale associée (objet zonal); ou pour le code INSEE de la commune associée à la première lettre du toponyme (objet linéaire, ex : route, rivière...)

*Suitcom* (1 caractère) : De valeur "1" pour signaler la présence d'autres communes associées.

*X, Y,* (4 + 4 caractères) : Pour les coordonnées *X* et *Y* exprimées en Lambert zone I, II, III, ou IV.

Objet ponctuel : Correspond à la position de l'objet sur la carte à 1/25 000;

Objet étendu (forêt, lieu-dit...) : Correspond au centre apparent de l'objet;

Objet linéaire (route, rivière...) : Correspond à la position de la 1re lettre du toponyme.

*Toponyme* (70 caractères) : Pour le nom associé à l'objet (le toponyme).

*Suitnym* (1 caractère) : S'il existe une autre orthographe dans le fichier secondaire (0 ou 1).

*Designat* (4 caractères) : Pour identifier la nature de l'objet :

LD : lieu-dit;

RIV : rivière;

ECAR : groupe d'habitation;

HABI : habitation isolée.

*Codécrit* (3 caractères) : Nous indiquant le code écriture IGN du toponyme (113, 234, 354...) sur le 1/25 000.

*Codechel* (1 caractère) : Pour savoir si le toponyme issu du 1/25 000 est présent au 1/50 000.

0 : Toponyme figurant uniquement sur le 1/25 000.

1 : Toponyme figurant uniquement sur le 1/50 000 et le 1/25 000.

*Rephotocom* (1 caractère) : Au cas où il y aurait une faute d'orthographe à corriger sur la prochaine édition :

0 : pas de faute

1 : faute à corriger sur le 1/25 000;

2 : faute à corriger sur le 1/50 000;

3 : faute à corriger sur le 1/50 000 et la 1/25 000.

*Specifi* (1 caractère) : Nous indiquent les spécificités éventuelles du toponyme :

en marge, à cheval, sur deux coupures, généralisées au 1/50 000 (0, 1, 2, 3).

*MODIF* (15 caractères) : Nous donnent les modifications éventuelles lors d'une prochaine édition de la carte (usage interne à l'IGN).

*Autre25* (6 caractères) : Si le toponyme figure en marge de la feuille 1/25 000 sur laquelle il a été relevé. Ces six caractères nous indiquent alors le numéro de la première feuille voisine comportant ce toponyme.

*Autre25-2* (6 caractères) : Idem avec l'éventuel numéro de la deuxième feuille adjacente comportant ce toponyme.

*Numéro50* (4 caractères) : Pour le numéro de la feuille à 1/50 000 associé au 1/25 000 de départ.

*Date* (*8 caractères*) : Pour la date d'archivage du toponyme sous la forme jj/mm/aa

*Mode de livraison*

1) *Organisation du fichier*

Sous DOS et dans sa forme standard, le fichier est en format texte en ASCII étendu (1 enregistrement par ligne, soit 144 caractères par ligne).

Toujours sous DOS, le fichier peut être livré dans les formats suivants : dBase, Visicalc, Multiplan, Lotus 1-2-3, PFS.

Sous VMS et sous UNIX, le fichier est en format texte (80 caractères par ligne); en ASCII, le fichier est alors entièrement retranscrit en majuscules.

2) *Système d'exploitation choisi à l'arrivée DOS*

Support : Disquettes 5 pouces 1/4 en 360 KO ou 1,2 MO

Disquettes 3 pouces 1/2 en 740 KO ou 1,44 MO

*UNIX*

Supports possibles : Disquettes 5 pouces 1/4
Bandes magnétiques
DC 600 ou DC 300
Exabyte

(Il est évidemment plus rapide, donc moins coûteux, d'utiliser un streamer pour le transfert.)

Format d'écriture sur support :
TAR
ANSI

VMS

Supports possibles :
Bandes magnétiques
TK 50
Exabyte
Format d'écriture sur support :
A convenir (Par ex : Back-up bandes)

3) *Listing*

*Etat d'avancement de la base de données toponymiques*

Au 1 janvier 1990 : 1 050 000 noms et attributs saisis, représentant environ 65 % des toponymes metropolitains (total estimé : 1 600 000)

Achèvement de la saisie initiale au plus tard en 1993

*Condition de cession*

Standard : Ensemble des toponymes relatifs à un département ainsi que les attributs décrits précédemment.

Pour les autres sorties (Support: cassette de streamer, bandes..., sous UNIX ou VMS), il conviendra de s'entendre préalablement sur les coûts et des délais (ceux-ci dépendant évidemment des personnels et des machines disponibles).

## REPORT ON THE SECOND TRAINING-CUM-WORKSHOP ON GEOGRAPHICAL NAMES*

*Paper submitted by Indonesia*

### RÉSUMÉ

En application de la résolution 20 de la onzième Conférence cartographique régionale des Nations Unies pour l'Asie et le Pacifique et à la suite du succès remporté par le premier stage expérimental de toponymie organisé en Indonésie en 1982 ainsi que de l'intérêt manifesté par les pays de la Division du Sud-Est de l'Asie et du Pacifique Sud-Ouest du Groupe d'experts des Nations Unies pour les noms géographiques, l'Indonésie a accueilli du 16 au 28 octobre 1989 le deuxième stage de formation en toponymie.

L'Agence nationale BAKOSURTANAL avait pris l'initiative de s'entretenir de cette question à la fin de 1988 à Enschede (Pays-Bas) avec M. F. Ormeling, président du Groupe de travail sur les stages de formation du Groupe d'experts des Nations Unies pour les noms géographiques. Après des consultations internes, le Groupe a déterminé une forme plus précise pour ce stage lors de sa 14e session, tenue à Genève en mai 1989, sous la présidence de M. Henry Dorion. Comme il s'agissait du deuxième stage organisé par la Division, on a jugé plus utile de lui donner la forme d'un atelier afin que les intéressés puissent y prendre une part plus active. Ceux qui assisteraient à ce stage pour la première fois pourraient y acquérir une formation et se familiariser avec le sujet.

La proposition a reçu sa forme finale à la suite d'un échange intensif de télécopies entre le Siège de l'ONU à New York, le bureau de M. Dorion à Québec (Canada), le bureau de M. Ormeling à l'ITC à Enschede et BAKOSURTANAL en Indonésie.

M. Jacub Rais, chargé d'organiser l'atelier, a demandé que M. Ormeling veuille bien convoquer les candidats étrangers et faire office de coorganisateur pour le compte du Groupe d'experts des Nations Unies pour les noms géographiques. Le secrétaire de ce groupe, M. Max de Henseler, et le chef du Groupe de la cartographie à l'ONU ont apporté une aide précieuse notamment pour l'élaboration d'un dossier contenant la documentation à remettre aux participants. M. Dorion a rédigé et envoyé une circulaire de présentation à tous les membres de la Division, et réuni, avec l'aide du Comité permanent canadien pour les noms géographiques et de la Commission de toponymie du Québec, un deuxième jeu de documents à distribuer.

*The original text of this paper appeared as document E/CONF 83/INF.32

L'Indonésie a financé l'organisation de l'atelier, y compris les frais de voyage et d'hébergement des experts et conférenciers étrangers.

Elle aura donc accueilli deux des six stages organisés jusqu'ici par le Groupe d'experts des Nations Unies pour les noms géographiques, ce qui est tout à fait remarquable. L'expérience acquise lors du premier stage expérimental a servi au deuxième stage, dans la mesure où les circonstances très différentes l'ont permis.

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Recalling resolution 20 of the Eleventh United Nations Regional Cartographic Conference for Asia and the Pacific, and taking into account the success of the Pilot Course on Toponymy, held in Indonesia in 1982, and the interest expressed by countries of the Division for Asia, South East, and Pacific, South West, of the United Nations Group of Experts on Geographical Names, Indonesia again hosted the Second Training Course in Toponymy from 16 to 28 October 1989.

In 1988, in Enschede, Netherlands, the National Coordination Agency for Surveys and Mapping (BAKOSURTANAL) took the initiative of discussing this matter with Dr. F. Ormeling, Sr., Chairman of the Working Group on Training Courses of the United Nations Group of Experts on Geographical Names. After a process of preliminary talks among the Group of experts, in May of 1989 the proposed training course assumed a more definite shape during the Group's fourteenth session, in Geneva, presided by Dr. Henry Dorion. Since this was to be the second training course held under the auspices of the Division, it was thought more appropriate to hold it as a workshop in which those who attended would be able to participate more actively, while those who were participating in this activity for the first time would consider it as training and an opportunity to gain knowledge about the subject.

The final elaboration of the proposal took place via intensive telefax-communication between United Nations Headquarters in New York and Dr. Dorion's home office in Quebec, Canada, Prof. Ormeling at the International Institute for Aerial Survey and Earth Sciences (ITC) in Enschede, and BAKOSURTANAL in Cibinong, Indonesia.

Prof. Jacub Rais as Convenor of the Workshop/Training course requested Dr. Ormeling to be the foreign Convenor and coorganizer on behalf of the Group of Experts. The Chief of the Cartographic Unit of the United Nations and Secretary of the Group of Experts, Dr. Max de Henseler, shortly before his retirement, provided substantial assistance, *inter alia,* with the compilation of a document kit containing selected papers to be handed out to the participants. Dr. Dorion prepared and sent out an introductory circular to all members of the Division and compiled with the assistance of the Canadian Permanent Committee on Geographical Names and the Commission de toponymie du Québec, a second set of documents to be distributed.

Indonesia provided the funding for organizing the Workshop/Training course, including the travel and lodging of foreign experts and lecturers.

In organizing this Workshop/Training in Toponymy, Indonesia built a unique record of hosting two of the six training courses sponsored by the Group of Experts that have so far taken place. The experiences contracted during the pilot course were, as far as the quite different circumstances allowed, made use of for this second course.

### Objectives and scope

The obvious motivation of the United Nations to promote geographical names standardization is nowadays supported by international demand felt by any nation or Government finding itself on the threshold of automation of its inventory and management functions. Geographical names are stored in digital toponymic databases which, in turn, are coupled with geographical information systems (GIS), that are envisaged to substitute in the near future for all or most of the manual planological systems, and ultimately even to become the primary sources for most kinds of spatial information called for by public bodies as well as private professional interests.

Many of the countries of the Division of Asia, South-East, and Pacific, South West, have recently embarked on GIS development. Most of the countries, hosting many linguistically diverse populations, are as yet far from nationwide standardization, and larger-scale base mapping is still in progress.

The timing of this second Indonesian initiative therefore undoubtedly enjoys the approval of other members of the Division.

### Workshop/training facilities

The Workshop/Training course was held from 16 to 28 October 1989, in Sindanglaya, a hilly resort some 20 km south of Bogor, the home town of the world-famous tropical botanical garden built by Sir Thomas Stanford Raffles, during his reign from 1811 to 1816. The Workshop/Training course itself was accommodated in Hotel Bukit Raya Permai, a valley hotel, where suitable accommodation and lecturing rooms were found. This place was selected because of its close range to the field exercise area, which is only a twenty-minute drive southward to the town of Cianjur and just a five-minute drive to the western limit of the area.

All participants and lecturers/instructors were accommodated in the hotel. Located on the main road from Bogor to Bandung, but isolated in a deep valley surrounded by steep slopes, it combined excellent accessibility with the isolation needed to facilitate full concentration on the lecture programmes and discussions throughout the course of the Workshop/Training course. In addition, the relaxation necessary to maintain concentration throughout the course was offered in the form of various sport facilities, a swimming pool, a fish pond and a discotheque staging karaoke entertainment.

### Opening of the course

The opening ceremony on 16 October 1989 consisted of addresses and welcoming speeches delivered successively by the Organizing Committee, the Division Chairman on behalf of the United Nations in general and the Group of Experts in particular, and lastly, the Chairman of BAKOSURTANAL as host of the Workshop/Training course.

Immediately following the ceremony, the audience was led through a display of maps and gazetteers with the help of a printed guide introducing those invited into the domain of toponymy

### Programmes and lecturers

In view of the increasing importance of automated processing techniques and the incorporation of processed geographical names into geographical information systems, these items were given particular attention. Further, although various experts advocated a standardized course programme focusing on the main issues of names standardization, a more flexible syllabus was chosen adapted to the needs of the Division for which the course was held. This called for finding a balance between applied toponymy, automated names processing and cultural and historic aspects of names.

The resulting lecture programme contained the following items:

1. United Nations achievements in standardization of geographical names;
2. Terms used in geographical names standardization;
3. Global distribution of languages and scripts;
4. The role of geographical names for cartographic and non-cartographic purposes;
5. Social and economic benefits of geographical names standardization;
6. Diversity of languages in Indonesia;
7. The etiology of place-naming in Indonesia;
8. Exonyms;
9. National names authority;
10. Indonesian implementation of United Nations resolutions on names standardization: the establishment of a national names authority and the production of gazetteers in Indonesia;
11. Old maps and census documents as toponymy sources;
12. Glossaries and national gazetteers;
13. Writing systems and romanization;
14. Overview of toponymy activities in Canada;
15. Standardization of regional languages;
16. Needs for geographical names standardization in Indonesia;
17. Field collection and office treatment of geographical names;
18. Automatic processing of geographical names;
19. Toponymic databases and geographical information systems;
20. Collection of geographical names in the Sundanese-speaking part of Java.

Lecturers contributing to the course, 13 in all, were from the following countries: Australia, Canada, Hungary, Indonesia, Netherlands and the United Kingdom.

### Participants

There were 50 participants, of which two were from the Survey Department of Brunei Darussalam, two from the Royal Thai Survey Department, and one from the Place-Name Committee of the Northern Territory, Australia, as well as the Secretary of the Committee for Australian Geographical Names, who acted also as a lecturer.

The rest of the participants were Indonesians, invited from various government and private mapping organizations, provincial planning agencies, the Bureau of Statistics, universities and, more important, also journalists of famous daily newspapers in Jakarta.

With newspapermen in the Workshop, the intention of the organizer was to inform the public of the importance of standardization and the role of geographical names in communication in a modern society. And this seemed successful, since a number of articles appeared in leading newspapers on geographical names written by participants in the Workshop.

### Field exercises

Following the lecture programme and the technical visits to BAKOSURTANAL and private mapping companies in Bandung, which carried out base mapping contracts, three days were spent in the field to become acquainted with the practical problems faced when collecting geographical names. The field-work area was located in and around the city of Cianjur, an area containing a great diversity of topographical features. Seven teams were formed for the exercises, each supplemented by a guide. The teams were supplied with: photo-types of blank 1:25,000 mapsheets (recently compiled and plotted by BAKOSURTANAL in the regular mapping programme, but not yet published); names forms (including a written instruction on how to complete them); compasses; transparent sheets; written materials; and glossaries of terms occurring in Sundanese toponyms (the local population was predominantly Sundanese-speaking).

Owing to tightness of schedule, instructions before entering the field were essentially limited to an explanation of how and why to complete the name forms. It was up to the members of each team themselves to choose a working strategy.

The report of the field collection exercises, including the complete results (name forms, recapitulation forms and plotting were kept at BAKOSURTANAL) led to the collection of the names of 580 features, 292 (50 per cent) of which were also names on the reference map. Comparison of the results of the field exercises with the names on reference maps shows, that on the latter, 39 per cent of the names were written in a way that would not be recommended after field collection; in addition, 15 per cent of the names were placed differently from those on the reference map.

The *Proceedings of the Workshop on Toponymy*, edited by T.R. Tichelaar, was printed and published by BAKOSURTANAL as document No. 07/1990 (ISSN No. 0126-4982). It contains all papers presented by the lecturers.

### Closing remarks

The Organizing Committee would like to extend its gratitude to all parties—the United Nations Group of Experts on Geographical Names, the Divisional Chairman, Professor Ormeling, Sr., and all lectureres and participants, and those who have made the Workshop a successful experience and a memorable event.

# DIVISIONAL REPORT OF THE UNITED NATIONS GROUP OF EXPERTS ON GEOGRAPHICAL NAMES FOR THE DIVISION OF ASIA, SOUTH-EAST, AND PACIFIC, SOUTH-WEST*

*Paper submitted by Malaysia*

## SCOPE OF THE REPORT

This report covers the activities up to December 1990, undertaken by the Division of Asia, South-East, and Pacific, South-West, of the United Nations Group of Experts on Geographical Names, in the period following the Eleventh United Nations Regional Cartographic Conference for Asia and the Pacific, held in January 1987.

## DIVISIONAL MEETINGS

During the period under review, two Divisional Meetings were held, as follows:

*Fourth Divisional Meeting, 12-14 September 1988, Bangkok*

Experts from Brunei Darussalam, Indonesia, Malaysia and Thailand attended the meeting, which was attended also by an observer from Australia.

*Fifth Divisional Meeting, 27-28 August 1990, Perth, Australia*

Experts from Australia, Brunei Darussalam, Indonesia, Malaysia and Thailand attended the meeting, which was attended also by an observer from New Zealand.

It is heartening to note that Australia was unanimously accepted as a full-fledged member of this Division. It hosted the fifth Divisional Meeting at Perth. At the same meeting, New Zealand's application to join the Division, was duly accepted, following the unanimous agreement of all member countries present and through correspondence with the member countries of the Lao People's Democratic Republic, Myanmar, Papua New Guinea and the Philippines, which were unable to send representatives to the meeting.

Considering the importance of the work of the United Nations Group of Experts on Geographical Names, it is hoped that member countries will make every effort to participate in the activities of the Division, which now has, besides the two new admissions of Australia and New Zealand, ten other members: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Papua New Guinea, Philippines, Singapore, Thailand and Viet Nam. As is always the case, the Divisional Chairman welcomes contributions by correspondence in the case of member countries that are not able to send representatives to participate in the meetings.

## PROJECTS UNDERTAKEN BY THE DIVISION

While noting that each member country has its own programme on the standardization of geographical names, there are several ongoing projects being undertaken by the region as a whole. The regional projects take the form of regional maps (political and physical), concise and regional gazetteers and training courses. A regional atlas has been proposed, but the type and identity of the member country to be responsible for the production of the atlas is yet to be agreed upon at future meetings. Obviously these regional projects allow not only for exchange of technical information in the realm of geographical names standardization, but also foster closer regional cooperation.

### *Map of Asia, South-East, and Pacific, South-West*

The Department of Survey and Mapping, Malaysia, was entrusted with the publication of (*a*) a political map and (*b*) a physical map of the Asia, South-East, and Pacific, South-West, region, based on the information supplied by member countries of the Division.

A full-colour fifth edition of the *Political Map* and also a third edition of the *Physical Map* at scale 1:7 million was published and distributed during the 4th and 5th Divisional meetings at Bangkok in 1988, and at Perth, Australia, in 1990 respectively. Both the maps depict the geographical names of features as supplied by Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore and Thailand. However, areas covering the map faces of Cambodia, the Lao People's Democratic Republic, Myanmar, Papua New Guinea and Viet Nam were left blank, since no information was received from these member countries.

As Australia and New Zealand have been unanimously accepted into the fold as member countries of this Division, it was proposed at the 5th Divisional Meeting, held at Perth, that both the countries concerned should be included and printed on the reverse side of the map of Asia, South-East, and Pacific, South-West. The Department of Survey and Mapping, Malaysia, will continue to carry on the production and publication of the maps at a scale to be decided, at either 1:7 million or 1:6 million.

### *Gazetteers*

Two gazetteers were produced: the *Concise Gazetteer* and the *Regional Gazetteer*. Copies of the gazetteers were distributed to members at the 5th Divisional Meeting.

The first edition of the *Regional Gazetteer* and the second edition of the *Concise Gazetteer* remain as the latest editions. Both gazetteers were devoid of information from the member countries Cambodia, the Lao People's Democratic Republic, Myanmar, Papua New Guinea and Viet Nam. Lists of geographical names from these countries are yet to be received for inclusion.

Australia and New Zealand will need to submit geographical names for concise gazetteers based on a map at 1:7 million scale.

Apart from the above, each member country maintains its own national gazetteer. However, Australia, Indonesia, Malaysia and New Zealand have reported the use of modern computer technology in the compilation and updating of their gazetteers.

### *Training courses*

As mentioned in the 4th Meeting of the Division at Bangkok in 1988, Indonesia offered to host the Second Training Course in Toponymy, following the success of the first Pilot Training Course in Indonesia in 1982. The Second Training Course was held in Cipanas, Bogor, Indonesia from 16-28 October 1989; it was highly praised and accepted as an unqualified success. A total number of 50 participants from member countries of Australia, Brunei Darussalam, Indonesia and Thailand attended the course.

*The original text of this paper, prepared by Abdul Majid Mohamed, Department of Survey and Mapping Malaysia, appeared as document E/CONF 83/INF 36

*Regional atlas*

At the 5th Divisional Meeting at Perth, it was agreed by member countries that the regional atlas project should be postponed to be revived later, if needed, on the agreement that a member country should take responsibility for production of the atlas.

*GEONAMES Newsletter*

Referring to the report of the 4th Meeting a consensus was reached after much deliberation by member countries that the *GEONAMES Newsletter* should be dropped in favour of a similar *Newsletter* now being produced by the United Nations. The Divisional Chairman requests that each member country should submit news of its activities for publication to the United Nations Secretariat, New York.

NEXT MEETING

The next meeting of the Division is proposed to be held, tentatively, in Wellington, New Zealand, on a date to be decided.

## STANDARDIZATION OF UNDERSEA FEATURE NAMES*

*Paper submitted by the International Hydrographic Bureau*

### RÉSUMÉ

Afin d'éviter une désignation anarchique des formes du relief sous-marin, le Sous-Comité des noms géographiques des formes du relief sous-marin du Comité de la carte bathymétrique générale des océans a été créé en 1974 sous les auspices de l'Organisation hydrographique internationale et de la Commission océanographique intergouvernementale de l'Unesco. En 1981, une publication donnant des directives et une liste de termes et de définitions intitulée "Normalisation des noms des formes du relief sous-marin" a été diffusée. Cette publication, portant la cote BP.0006, désormais disponible en anglais/espagnol, anglais/français et anglais/russe, est distribuée gratuitement. Les particuliers et les organisations qui souhaitent donner un nom à une forme du relief sous-marin non encore désignée sont invités à se conformer aux principes et aux modalités définis dans le document BP.0006.

En outre, un index des noms géographiques des formes du relief sous-marin qui figurent sur les feuilles de la carte bathymétrique générale des océans, établi conjointement par le Bureau hydrographique international, situé à Monaco, et par le Sous-Comité des noms géographiques des formes du relief sous-marin du Comité de la carte bathymétrique a été publié en 1988 sous la cote IHO BP.0008. On y trouve environ 1 400 noms de formes du relief sous-marin se trouvant dans des zones situées au-delà des eaux territoriales, avec, pour chacun, mention de la latitude et de la longitude; cette publication est en vente au Bureau hydrographique international.

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In recent years, considerable concern has been expressed about the indiscriminate and unregulated naming of undersea features, which are often printed in articles submitted to professional journals or on ocean maps and charts without any close scrutiny having been made concerning their suitability, or whether the feature has already been discovered and named.

In order to remedy this situation and to bring the geographical names of undersea features to better standardization, an IHO publication called *Standardization of Undersea Feature Names* (BP-0006), containing guidelines, a name proposal form and a list of terms and definitions, has been worked out through collaboration between the GEBCO Sub-Committee on Geographical Names and Nomenclature of Ocean Bottom Features (appointed in 1974 by the Joint IOC/IHO Guiding Committee for the General Bathymetric Chart of the Oceans (GEBCO)) and the Working Group on Maritime and Undersea Features of the United Nations Group of Experts on Geographical Names, in accordance with the provisions of appropriate resolutions of United Nations Conferences on Geographical Names.

The first edition of this publication, which was published jointly with the International Oceanographic Commission (IOC), was issued in 1981, and the second edition in 1989. Versions are available in English/French (edition 1989), English/Spanish (edition 1985) and English/Russian (edition 1983). New editions of the last two are planned in 1991. In addition, arrangements have been made for English/Chinese, English/German and English/Japanese versions, now in preparation.

At the request of the Joint IOC/IHO Guiding Committee for GEBCO, in order to obtain the largest distribution of these guidelines and to bring the geographical names of undersea features to better standardization, the first edition (BP-0006) is available gratis from the International Hydrographic Board (IHB) and from IOC.

The publication essentially contains a list of definitions or "generic terms" to reflect physiographic descriptions of undersea features, which are defined as parts of the ocean floor or seabed that have measurable relief or are delimited by relief. An example is:

*canyon:* A relatively narrow, deep depression with steep sides, the bottom of which generally has a continuous slope, developed characteristically on some continental slopes, e.g. Hudson Canyon

*The original text of this paper appeared as document E/CONF.83/L.8

*Ref.* F. P. Shepard, and R. F. Dill, *Submarine Canyons and other Sea Valleys* (Chicago, Rand McNally, 1966). 381 pp.

As for naming features, the principal concern is to provide effective, conveniently usable and appropriate reference. The sphere of activity is limited to those features entirely or more than 50 per cent outside waters under the jurisdiction of States. Accordingly, individuals and agencies wishing to apply names to unnamed features in international waters should adhere to internationally accepted principles and procedures, as described in the BP-0006. They are invited to submit their proposals to the IHB or to the IOC, for consideration by the IOC/IHO GEBCO Sub-Committee on Geographical Names and Nomenclature of Ocean Bottom Features (SCGN); this will advise on any potentially confusing duplication of names. The Undersea Feature Name Proposal form, included in the above publication, should be used. Proposal forms in English, French, Arabic, Greek, Italian, Portuguese and Spanish versions are available from the IHB. Versions in other languages are being prepared.

In other respects, as recommended by the 1987 International Hydrographic Conference, publishers of ocean maps and editors of scientific journals, are invited to require compilers and authors in their countries to provide written evidence of proposed new names, before accepting for publication any maps or scientific articles containing these names.

During a session of the "Joint IOC/IHO Guiding Committee for GEBCO" in 1983, the IHB was requested to prepare a gazetteer of the geographical names of undersea features shown on the GEBCO sheets and on the small-scale international chart series, so that they could be used on chart series and in order to standardize these names.

The IHB accepted the task, particularly since the small-scale INT Charts, produced by IHO member States, were increasingly showing more detailed ocean morphology with more geographical names. After several drafts of the *Gazetteer* had been prepared and then considered by the GEBCO SCGN, the first edition was eventually approved in 1988 by the GEBCO Officers, and was published by the IHB in the same year, with the publication number BP-0008.

In this *Gazetteer*,

(*a*) Geographical names are given in alphabetical order in English;

(*b*) Generic terms used to define the nature of each undersea feature are those which appear in the BP-0006 *Standardization of Undersea Feature Names;* Geographical positions—latitude and longitude—are given for each geographical name. They consist of 1 or 2 points, depending on the extent of the feature, are approximate and must be used only to identify the undersea feature on the referenced chart(s).

This *Gazetteer* has been published solely for standardization on nautical and bathymetric charts, and must not be construed as having any legal or political connotation whatsoever. The first edition of BP-0008 *Gazetteer of Geographical Names of Undersea Features* contains 1,400 names and is available for purchase from the IHB. A new edition will be published in 1991.

# AGENDA ITEM 9

## Technical assistance and transfer of technology

### TECHNICAL COOPERATION ACTIVITIES FOR SURVEYING, MAPPING, CHARTING AND REMOTE SENSING*

*Paper submitted by the Secretariat*


### RÉSUMÉ

Le Service de l'infrastructure, qui fait partie de la Division des ressources naturelles et de l'énergie du Département de la coopération technique pour le développement**, apporte une assistance technique aux pays en développement pour leur permettre de planifier, mettre en œuvre, entretenir et exploiter une grande variété d'ouvrages publics. Comme la cartographie (levés et établissement de cartes) et la télédétection jouent un rôle vital dans la planification et l'exploitation des infrastructures, elles font partie des fonctions du Service.

L'assistance à la création d'institutions ou l'appui direct sont dispensés dans le cadre de projets de coopération technique auxquels contribuent à la fois l'ONU et le gouvernement bénéficiaire. L'ONU dispense des services consultatifs techniques par l'entremise d'experts internationaux, aide à former le personnel local, tant sur place qu'à l'étranger, et fournit divers équipements nécessaires à la réalisation des projets. Le gouvernement contribue le plus souvent par des équipements sur place, du personnel d'appui et, parfois, des spécialistes nationaux.

Lorsque son assistance est requise, le Service de l'infrastructure fournit des services consultatifs par l'intermédiaire de ses administrateurs ou de consultants spécialisés et très qualifiés engagés pour des missions très précises. Il procède à des missions préparatoires de courte durée afin d'aider le gouvernement à définir ses besoins d'assistance technique, élabore les rapports et prévoit les documents nécessaires.

Le Service aide actuellement de nombreux gouvernements à répondre aux besoins d'entretien et de réparation des infrastructures matérielles et à améliorer les capacités institutionnelles de gestion des systèmes existants et de planification de nouveaux systèmes. Environ 80 % de ses activités sont financées par le PNUD, mais il reçoit aussi des demandes de services entièrement financés par des gouvernements ou des tiers.


#### OVERVIEW

The Infrastructure Branch is part of the Natural Resources and Energy Division of the Department of Technical Cooperation for Development (DTCD)** and provides technical assistance to developing countries in the planning, construction, maintenance and operation of a large variety of public works. As cartography (surveying and mapping) and remote sensing are vital tools in the planning and operation of infrastructure activities, they are included in the functions of the Branch.

Assistance in institution building, or direct support, is provided through technical cooperation projects to which both the United Nations and the Government requesting assistance contribute. For its part, the United Nations makes available technical advisory services rendered by international experts, assists in training of local personnel, both in-country and overseas, and provides various items of equipment needed to meet the objectives of projects. The Government in most cases contributes, *inter alia,* in-country facilities and support personnel, as well as—in some instances—national professionals.

Upon request for assistance, the Infrastructure Branch provides advisory services through its professional staff, or through highly qualified and specialized consultants engaged for very specific advisory assignments. They undertake short-term preparatory missions to assist Governments in defining their needs for technical assistance, and prepare the necessary reports and project request documents.

Currently the Infrastructure Branch is assisting many Governments to meet the need for the maintenance and repair of existing physical infrastructures, and to improve national institutional capability for management of systems and the planning of new ones. While at present approximately 80 percent of the work of the Infrastructure Branch is funded by the United Nations Development Programme (UNDP), requests for services funded entirely by Governments or by third parties are also being received.

#### SERVICE FUNCTIONS

The Infrastructure Branch assists Governments with planning, development and management of its human and tech-

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**Names of United Nations entities are referred to by the terminology in use at the time of the Conference.

nological resources and related needs, including public services and facilities associated with its physical infrastructure, for economic and social development. The expertise available through the Branch can be summarized as follows:

*Cartography*. Topographical surveying and mapping, cadastral and hydrographic surveys, urban and utility mapping, thematic cartography.

*Remote sensing*. Techniques, services, and installation of remote sensing facilities for the exploration of natural resources and infrastructure development.

*Public works*. Planning, survey, design, construction, operation, maintenance, repair and restoration of vital public works services and related communication modes, municipal engineering activities, as well as public utilities.

These services and expertise are normally made available for the following types of projects:

(*a*) Preparatory assistance projects;

(*b*) Direct support projects with primary functions to provide:

- (i) Development strategies, plans, programmes and projects,
- (ii) Substantial technical advice,
- (iii) Operational assistance,
- (iv) Investment-oriented projects,
- (v) Preparation of specific technical documents;

(*c*) Institution-building projects;

(*d*) Direct training projects with primary functions to provide:

- (i) An ad hoc or short-term group learning effort (study tours) and/or:
- (ii) Individual fellowships;

(*e*) Experimental projects,

(*f*) Pilot projects,

(*g*) On-the-job training or outside-the-country training.

### CARTOGRAPHY (MAPPING/SURVEYING AND REMOTE SENSING)

Technical cooperation projects in cartography include institution building, transfer of technical expertise to national cartographic and hydrographic institutions and provision of training and equipment. The technical cooperation activities in this field are for the most part aimed at institution-strengthening of national mapping and charting organizations. The strategy applied for all projects is in line with the general development strategy of the United Nations Development Programme, which means that emphasis is placed on increased self-reliance of the recipient Government organizations. To achieve this goal, formal and on-the-job training of national personnel at key as well as at operational levels is being recognized as the most important factor, to which all other project actions are generally subordinate.

Technical cooperation projects related to cartography are playing an increasingly important role in the economic, social and cultural development of the recipient countries and in the implementation of a vast variety of specialized development projects. If such projects are to be successful, it is necessary, first and foremost, to achieve an adequate balance between the major elements of which they are composed: expertise for the transfer of technology, on-the-job training and formal training abroad of national counterpart personnel, equipment for training for the transfer of technology and for carrying out production at a minimum and balanced level, and subcontracts covering elements which are either beyond the present technical capacity of the recipient organization or which are required on an urgent basis.

In this context, the high unit costs of certain types of equipment particularly computer-assisted systems, make it increasingly difficult for new projects to achieve a level of balance acceptable to some donors. It is expected that the problems created by the relative dominance of the equipment component will become even more pronounced. The introduction of new and more flexible forms of projects co-funding with investment-oriented donors has so far produced few tangible results, but is nevertheless pursued vigorously.

"New dimensional" aspects of technical cooperation are becoming increasingly more manifest in ongoing projects: sub-contractual arrangements with national cartographic institutions have proved to be a viable alternative, long-term assignment of groups of experts to the same project is the exception rather than the rule. On the other hand, short-term consultancies in very specialized fields and the use of highly qualified national professionals in the function of national project coordinators is much more visible. This changing aspect of project implementation, however, requires more direct involvement of the executing agency in the monitoring of projects.

The level of involvement of the United Nations in technical cooperation activities in the Asia and Pacific region, as far as surveying and mapping is concerned, has remained at about the same level. Ongoing projects dealing with cartography and remote sensing in the region are presently being executed in Bhutan, India, Islamic Republic of Iran, Jordan, Nepal and Viet Nam.

The ongoing cartographic projects are generally well on schedule. The lengthy and complex process of nominating national candidates for fellowships abroad—although still a serious problem—appears to be better understood by recipient Governments and has led to a marked improvement of the implementation rate of this project element. Some cases of extensive damage (in transit) to highly sensitive equipment have demonstrated that the elements of *force majeure* and flexibility must be given their due share in the design of projects.

Technical cooperation activities in remote sensing include the preparation of projects and establishment of remote sensing centres on national as well as regional levels. These projects focus on providing technical assistance, including fellowships and interpretation equipment, with the long-term objectives of enabling developing countries to use up-to-date technology in locating and developing natural and human resources. Assistance in the use of remote sensing for resources development has also been provided for several countries. As of 1990 about 30 countries have received technical assistance and advisory services which resulted in project designs for further implementation either on a multinational or bilateral assistance level. The range of technical assistance may cover simple processing of remote sensing data to establishing the infrastructure of a fully developed remote sensing centre.

The Cartography and Remote Sensing Unit of the Infrastructure Branch regularly publishes "World Cartography Bulletin" which serves as a communication tool for member countries on novelties in technology, and the *Newsletter* of the United Nations Group of Experts on Geographical Names, which is a means of finding out not only about the experiences and successes obtained in toponymy but about the needs and deficiencies where international cooperation could be of service.

The Cartography and Remote Sensing Unit also is the liaison focal point of DTCD to the Committee on the Peaceful Uses of Outer Space and is involved in planning and conducting of workshops and seminars.

In 1990, the Interregional Seminar on Land Information Management in the Development World was formulated by the United Nations Technical Cooperation for Development and subsequently developed in conjunction with the Australian Trade Commission. The aim of the Seminar was to highlight the achievements, issues and developments relating to land information management, with particular reference to the developing world, and to formulate recommendations on future directions and for further action to be taken.

The Seminar was co-sponsored by the Department and the Australian Government. The South Australian Government Technology Transfer Company, SAGRIC International, together with the South Australian Department of Lands, acted as facilitators for the Seminar. The Seminar was held in Adelaide, South Australia, from 4 to 11 February 1990, at St Mark's College, a residential college of the University of Adelaide.

The Department sponsored and arranged for participants from twenty developing countries, which are actively involved in land information systems and management, to attend and participate in the Seminar. A total of 100 people attended, including experts from industrialized countries, and lecturers from academia.

In implementing resolutions from the Eleventh United Nations Cartographic Conference for Asia and the Pacific, held in January 1987, a Workshop on Training and Transfer of Technology in Digital Cartographic Systems for Digital Mapping was convened at the United Nations Office at Vienna from 24 September to 2 October 1990, to study the situation and to make appropriate recommendations. The Group assembled at the Vienna International Centre in September 1990 and began with a review of its terms of reference and objectives under the guidance of the elected Chairman.

The target audience for the report to be prepared by the Group was discussed. It was recognized that for the purpose of the technical report, to distinguish between developed and developing countries in the context of GIS was not appropriate because the distinction is primarily related to the extent of the availability of resources, rather than to any inherent differences in the types of technical and institutional problems that are faced. It was of course recognized that these problems differ considerably in intensity. The Group concluded that the prime target of the report would be the public sector and government agencies that would be attending the twelfth United Nations Regional Cartographic Conference for Asia and the Pacific in Bangkok in February 1991.

In 1989, the Department convened the Fourth United Nations Regional Cartographic Conference for the Americas in New York, in accordance with Economic and Social Council decision 1985/124. The Conference was attended by 120 representatives or observers of 39 countries, 7 specialized agencies and 7 intergovernmental and international scientific organizations.

Within its mandate, the Department, through its Cartographic Unit is planning the following meetings and conferences:

(*a*) A seminar on receiving and processing of digital satellite data to be held in 1991 in Berlin, Germany;

(*b*) A training course in toponymy to be held in June/July 1991 in the United Kingdom;

(*c*) United Nations Group of Experts on Geographical Names to be held in September 1992 in connexion with the Sixth United Nations Conference on Standardization of Geographical Names;

(*d*) United Nations Seminar during the Congress of the International Society for Photogrammetry and Remote Sensing, September 1992, Washington, D.C.

It is to be hoped that the participation of surveying and mapping specialists of Asia and the Pacific region in conferences, seminars and symposia organized under the auspices of the United Nations will remain at the present high level. The United Nations Secretariat will assist interested organizations and individuals in this respect in every possible way.

## TECHNICAL COOPERATION

*Paper submitted by Japan*

### RÉSUMÉ


L'Institut géographique japonais, le Département d'hydrographie et le Service japonais des levés géologiques mènent un certain nombre d'activités conçues pour dispenser une assistance technique et assurer le transfert de technologie dans le domaine de la cartographie.


#### TECHNICAL COOPERATION IN SURVEYING AND MAPPING

Guided by the conviction that a national base map of an appropriate scale enhances the efficient utilization, development and conservation of land and its natural resources, as well as providing for essential infrastructure, the Geographical Survey Institute (GSI) of the Government of Japan began its technical assistance in 1963. Major features of such activities can be grouped into three categories: namely, training, dispatching of experts and mapping projects, which are conducted through the Japan International Cooperation Agency (JICA) commissioned by the Ministry of Foreign Affairs.

*Training*

*Group training*

During the Second United Nations Regional Cartographic Conference for Asia and the Far East, held in Tokyo in 1958, the need for organizing group training courses in surveying and mapping was translated into concrete terms. In view of this, in 1963 GSI initiated group training courses, the scope of which covered geodetic surveying, photogrammetry, and map compilation and reproduction. Each course, conducted at three-year intervals, ranged from six to seven months in length. However, both the social and technical situations have changed, and the demands of developing countries have diversified. Therefore, GSI has modified the courses which were geodetic surveying, mapping, and planning and management; the last is still at the planning stage. The time periods for the courses are approximately six, eight and two months. The programme is organized to provide both lectures and practical training in major subjects. Group training courses have been provided to 251 participants from 44 countries.

*Geodetic survey course.* This course is aimed at introducing participants to the design of horizontal and vertical geodetic networks, adjustment by least squares in geodetic survey, trilateration and traversing, using electronic distance measurement (EDM), satellite positioning and precise levelling, through lectures and practical training. The course includes such traditional methods as triangulation and astronomical observation for latitude, longitude and azimuth, while gravity and geomagnetic observations are included as applied subjects.

*Mapping course.* After a series of lectures required for understanding the theory of photogrammetry, geographical survey, map compilation and reproduction in the case of 1:25,000 scale topographic maps and some thematic map making, trainees try to practice them, using instruments and tools.

*Planning and Management Course.* The aim of this course is to assist an engineer in making a suitable plan for surveying and mapping that will harmonize with development and stability of the national economy. The engineer should be a superintendent who can formulate a plan for survey education and training conducted by an appropriate organization and enforcement structure. Hence the programme covers the present situation of surveying and mapping, survey planning, quality control, process control, latest technology, preservation of environment, measurement of safety etc.

*Follow-up team.* To follow up on the ex-participants of the Group Training Course in Surveying and Mapping, a team was dispatched to the countries of Panama and Peru in 1989.

*Individual training*

The individual training programme is prepared so as to meet the needs of each trainee and his home Government. The training period lasts one to five months. Up to 1990, 86 trainees from 24 countries were accepted.

### *Dispatching of experts*

In 1964, the GSI sent out four senior staff members to survey the national boundaries of Saudi Arabia. Since then, the GSI and the International Engineering Consultants Association (IECA), a public service corporation functioning under the supervision of the GSI, which consists of major aero-surveying companies in Japan, have sent 171 senior, experienced engineers as technical assistance experts. 121 of them were dispatched as short-term experts, who generally remain from several weeks to two months, to carry out particular projects based on the requests addressed to the Government of Japan by the recipient Governments, while others are long-term experts who cooperate with their host Government.

TABLE I DISPATCHING OF LONG-TERM EXPERTS. 1975-1990

| | | | | |
|---|---|---|---|---|
| Indonesia | Control point survey | GSI | 1975-1976 | |
| | Control point survey | GSI | 1975-1977 | |
| | Control point survey | GSI | 1977-1978 | |
| | Photogrammetry | GSI | 1978-1980 | |
| Malawi | Surveying and mapping | GSI | 1975-1977 | Volunteer *1 |
| Liberia | Geodetic surveying | GSI | 1978-1980 | |
| | Photogrammetry | IECA | 1978-1980 | |
| Venezuela | Geomorphology | GSI | 1978-1980 | |
| | Geomorphology | *2 | 1981-1985 | |
| Saudi Arabia | Photogrammetry | GSI | 1979-1982 | |
| | Printing | GSI | 1979-1981 | |
| | Photogrammetry | *3 | 1979-1982 | |
| | Mapping | IECA | 1979-1981 | |
| | Map compilation | IECA | 1979- | In progress |
| | Photo processing | IECA | 1979-1982 | |
| | Printing | GSI | 1981-1983 | |
| | Mapping | IECA | 1981-1984 | |
| | Photogrammetry | GSI | 1982-1984 | |
| | Photo processing | IECA | 1982-1984 | |
| | Printing | GSI | 1983-1985 | |
| | Mapping | GSI | 1984-1986 | |
| Nepal | Surveying and mapping | GSI | 1980-1981 | Volunteer *4 |
| Papua New Guinea | Photogrammetry | GSI | 1981-1983 | |
| | Photogrammetry | GSI | 1983-1985 | |
| | Photogrammetry | GSI | 1985-1987 | |
| | Geodetic surveying | GSI | 1987-1989 | |
| | Geodetic surveying | GSI | 1989- | In progress |
| Bolivia | Photogrammetry | IECA | 1981-1982 | |
| Kenya | Geodetic surveying | IECA | 1981-1983 | |
| | Geodetic surveying | IECA | "-" | |
| | Geodetic surveying | IECA | "-" | |
| | Geodetic surveying | GSI | 1983-1985 | |
| | Geodetic surveying | IECA | "-" | |
| | Geodetic surveying | IECA | 1985-1987 | |
| | Geodetic surveying | GSI | 1986-1989 | |
| | Geodetic surveying | IECA | 1987-1989 | |
| | Geodetic surveying | GSI | 1989- | In progress |
| | Geodetic surveying | IECA | 1989- | In progress |
| Guinea | Geodetic surveying | IECA | 1982-1984 | |
| | Geodetic surveying | IECA | 1982-1984 | |
| Panama | Atlas | GSI | 1983-1986 | |
| | Printing | GSI | 1985-1988 | |
| Philippines | Geodetic surveying | GSI | 1985-1986 | |
| Peru | Photogrammetry | GSI | 1986-1988 | |
| | Photogrammetry | GSI | 1988- | In progress |
| | Geodetic surveying | IECA | 1990- | In progress |
| Malaysia | Geodetic surveying | GSI | 1988-1990 | |
| Costa Rica | Mapping | GSI | 1990- | In progress |

*1, *4 Dispatched as Japan Overseas Cooperation Volunteers
*2 Dispatched from Niijima Senior High School on GSI's recommendation.
*3 Dispatched from Geological Survey of Japan.

### *Mapping projects*

In 1971, the GSI started its first overseas mapping project in Indonesia with the objective of preparing a national base map of that country. The role of the GSI in this field is to give advice to the authorities concerned both in Japan and in the host countries, on all aspects of surveying and mapping involved in the projects and to supervise the actual work.

The projects are conducted by the IECA acting as contractor for the JICA under the supervision of the GSI, which is well equipped and staffed to tackle overseas surveying and mapping. Such projects include all the related work, including aerial photography, and control point surveying and field reconnaissance, such as checking geographical names. Some of the work was conducted in collaboration with the recipient Governments. Most consisted of topographic mapping. Completed mapping projects and those in progress are as shown in Table 2.

TABLE 2 OVERSEAS MAPPING PROJECT

| | | | |
|---|---|---|---|
| *Indonesia* | Aerial photo | 1:50,000 | Fiscal |
| Barito River Basin | Area | 19,300 km$^2$ | 1971-1974 |
| | Mapping | 1:50,000 | |
| | Area | 19,300 km$^2$ 34 sheets | |
| Upperstream area of the Negara River basin | Aerial photo | 1:50,000 | Fiscal |
| | Area | 10,000 km$^2$ | 1983-1985 |
| | Mapping | 1:50,000 | |
| | Area | 6,500 km$^2$ 9 sheets | |
| Downstream area of the Negara River basin | Aerial photo | 1:20,000 | Fiscal |
| | Area | 6,300 km$^2$ | 1983-1985 |
| | Photomapping | 1:10,000 | |
| | Area | 1,200 km$^2$ 48 sheets | |
| *United Republic of Tanzania* | Aerial photo | 1:50,000 | Fiscal |
| Musoma area | Area | 12,730 km$^2$ | 1973-1976 |
| | Mapping | 1:50,000 | |
| | Area | 12,730 km$^2$ 23 sheets | |
| *Bolivia* | Aerial photo | 1:60,000 | Fiscal |
| Chapare area | Area | 30,000 km$^2$ | 1974-1977 |
| | Mapping | 1:50,000 | |
| | Area | 30,000 km$^2$ 44 sheets | |
| *Kenya* | Aerial photo | 1:60,000 | Fiscal |
| Eastern area | Area | 30,000 km$^2$ | 1975-1980 |
| | Mapping | 1:50,000 | |
| | Area | 27,000 km$^2$ 37 sheets | |
| Eastern Area (Thematic map) | Thematic mapping | | Fiscal |
| | Area | 14,700 km$^2$ | 1981-1983 |
| | 1:50,000 | 3 themes 12 sheets each | |
| | 1:100,000 | 2 themes 4 sheets each | |
| Southern area | Aerial photo | 1:60,000 | Fiscal |
| | Area | 29,800 km$^2$ | 1987-1990 |
| | Mapping | 1:50,000 | |
| | Area | 29,800 km$^2$ 43 sheets | |
| *Guinea* | Aerial photo | 1:100,000 | Fiscal |
| Whole country | Area | 245,000 km$^2$ | 1977-1981 |
| | Mapping | 1:50,000 | |
| | Area | 12,000 km$^2$ 16 sheets | |

TABLE 2 (*continued*)

| | | | |
|---|---|---|---|
| | Photomapping | 1:50,000 | |
| | Area | 233,000 km$^2$ 372 sheets | |
| *Panama* | Aerial photo | 1:60,000 | Fiscal |
| Caribbean coastal area | Area | 8,000 km$^2$ | 1978-1980 |
| | Mapping | 1:50,000 | |
| | Area | 6,000 km$^2$ 12 sheets | |
| *Philippines* | Aerial photo | 1:30,000 | Fiscal |
| Cagayan Valley | Area | 15,000 km$^2$ | 1978-1982 |
| | Mapping | 1:25,000 | |
| | Area | 11,000 km$^2$ 72 sheets | |
| | Photomapping | 1:10,000 | |
| | Area | 300 km$^2$ 12 sheets | |
| National capital region | Mapping | 1:10,000 | Fiscal |
| | Area | 1,500 km$^2$ 57 sheets | 1985-1988 |
| | Thematic Mapping | 1:10,000 | |
| | Area | | |
| | Land use map | 823 km$^2$ 33 sheets | |
| | Land condition map | 484 km$^2$ 16 sheets | |
| *Peru* | Aerial photo | 1:60,000 | Fiscal |
| Satipo area | Area | 30,000 km$^2$ | 1982-1986 |
| | Mapping | 1:25,000 | |
| | Area | 12,500 km$^2$ 64 sheets | |
| Lima Metropolitan area | Aerial photo | 1:30,000 | Fiscal |
| | Area | 1,570 km$^2$ | 1989- |
| | Mapping | 1:10,000 | |
| | Area | 1,250 km$^2$ 50 sheets | |
| | Land use map | 500 km$^2$ 21 sheets | |
| *Tunisia* | Aerial photo | 1:80,000 | Fiscal |
| Whole country | Area | 164,000 km$^2$ | 1985-1988 |
| | Mapping | 1:200,000 | |
| | Area | 83,000 km$^2$ 17 sheets | |
| Central region | Aerial photo | 1:60,000 | Fiscal |
| | Area | 35,500 km$^2$ | 1990- |
| | Mapping | 1:50,000 | |
| | Area | 27,000 km$^2$ 45 sheets | |
| *Thailand* | Aerial photo | 1:20,000 | Fiscal |
| Bangkok metropolitan area | Area | 4,000 km$^2$ | 1986-1988 |
| | Mapping | 1:10,000 | |
| | Area | 2,000 km$^2$ 61 sheets | |
| | Mapping | 1:4,000 | |
| | Area | 300 km$^2$ 40 sheets | |
| *Morocco* | Aerial photo | 1:40,000 | Fiscal |
| Topographic mapping | Area | 8,500 km$^2$ | 1988-1990 |
| | Mapping | 1:25,000 | |
| | Area | 8,500 km$^2$ 57 sheets | |

TABLE 2 (*continued*)

| | | | |
|---|---|---|---|
| *Senegal* | Aerial photo | 1:60.000 | Fiscal |
| Western area | Area | 25,500 km² | 1988- |
| | Mapping | 1:50,000 | |
| | Area | 25,000 km² 43 sheets | |
| *Costa Rica* | Aerial photo | 1:20.000 | Fiscal |
| San José metropolitan area | Area | 1.600 km² | 1988- |
| | Mapping | 1:10.000 | |
| | Area | 1.600 km² 79 sheets | |
| | Land use map | 800 km² 40 sheets | |
| Nepal | Aerial photo | 1:50,000 | Fiscal |
| Lumbini zone | Area | 9,000 km² | 1990- |
| | Mapping | 1:25,000 | |
| | Area | 9.000 km² 81 sheets | |

## TECHNICAL COOPERATION IN HYDROGRAPHY

### *Forms of technical cooperation in hydrography*

Technical cooperation programmes in hydrography carried out by the Government of Japan range from acceptance of trainees in Japan and dispatch of Japanese experts to developing countries along with provision of equipment and materials, as well as project-type technical cooperation combining organically the preceding programmes, development surveys etc. The governmental institution in charge of the implementation of technical cooperation programmes on a unified basis is the Japan International Cooperation Agency (JICA).

### *Training*

The Hydrographic Department of Japan is currently conducting three group training courses on the JICA basis, as follows:

*Group training*

*Hydrographic Survey Course* Since 1 June 1988, this Group Training Course has been recognized by the FIG/IHO International Advisory Board as a Category B course pertaining to specialization in nautical charting and port and near shore surveys.

The duration of the course is from April to November every year.

The curriculum of the course is constructed with lectures and practice, strictly complying with the requirements under the *International Standards of Competence for Hydrographic Surveyors* (5th edition, 1988).

Lectures: About 74 days

Practice: About 17 days

Field/shipboard training: About 33 days

Observation and study tour: About 19 days

Qualifications of applicants are as follows. Applicants should:

(*a*) Be nominated by their Government in accordance with the procedures stipulated in the General Information on the course;

(*b*) Be technical college graduates or equivalent with at least two years occupational experience in hydrographic services;

(*c*) Have obtained credits for a two-year course of mathematics and physics at least on the level of technical college or equivalent educational institution;

(*d*) Be presently employed at the national hydrographic office or other related organizations;

(*e*) Have a sufficient command of spoken and written English;

(*f*) Be not more than 40 years of age.

The number of participants accepted in the Group Training Course in Hydrographic Survey (1986-1989) is shown below.

| *Country* | *1986* | *1987* | *1988* | *1989* | *Total* |
|---|---|---|---|---|---|
| Bangladesh | | 1 | 1 | 1 | 3 |
| Costa Rica | 1 | 1 | | | 2 |
| Côte d'Ivoire | | | 1 | 1 | 2 |
| Egypt | 1 | 1 | 2 | 2 | 6 |
| Indonesia | 1 | 2 | 1 | 1 | 5 |
| Malaysia | 1 | 1 | | 1 | 3 |
| (Myanmar) | 1 | 1 | | | 2 |
| Pakistan | | 1 | 2 | 1 | 4 |
| Panama | 1 | | | | 1 |
| Philippines | 1 | 1 | 1 | 1 | 4 |
| Republic of Korea | 1 | 1 | | 1 | 3 |
| Sri Lanka | 1 | 1 | | | 2 |
| Thailand | 1 | | 1 | 1 | 3 |
| TOTAL | 10 | 11 | 9 | 10 | 40 |

*Physical Oceanographic Survey Course.* The duration of this course is from November to March, conducted alternately with the Group Training Course in Nautical Charting, every year.

The curriculum is constructed with lectures and practical training:

Lectures: About 39 days

Practice: About 12 days

Field/shipboard training: About 14 days

Observation and study tour: About 16 days

Qualifications of applicants are as follows. Applicants should:

(*a*) Be nominated by their Government in accordance with the procedures stipulated in the General Information on the course;

(*b*) Be presently employed at the national hydrographic office or other related organization, and currently engaged in physical oceanographic surveys and research such as offshore and coastal oceanographic observations, tide and tidal current observations, oceanographic data processing, analysis and management;

(*c*) Have basic qualification or some experience in hydrography, oceanography, or relevant discipline, and preferably be college graduates or equivalent with some occupational experience in oceanographic survey and research;

(*d*) Have a sufficient command of spoken and written English;

(*e*) Be not more than 40 years of age.

From 1992, the Group Training Course in Physical Oceanographic Survey will be revised in accordance with demands, suggestions, requests etc. made by developing countries that have been sending participants to the course.

*Nautical Charting Course.* The duration of the course is from November to March, conducted alternately with the Group Training Course in Physical Oceanographic Survey, every year.

The curriculum is as follows:

Lectures: About 34 days

Practice: About 22 days

Field/shipboard training: About 10 days

Observation and study tour: About 10 days

The qualifications of applicants are as follows. Applicants should:

(*a*) Be nominated by their Government in accordance with the procedures stipulated in the General Information on the course;

(*b*) Be presently employed at the national hydrographic office or other organizations engaged in carrying out hydrographics activities for safe navigation of ships, nautical charting and oceanographic survey for utilization of the ocean;

(*c*) Be not more than 35 years of age;

(*d*) Have a sufficient command of spoken and written English;

(*e*) Be a graduate of a junior college or special school graduate or equivalent.

The number of participants accepted to group training courses in Physical Oceanographic Survey (PO) conducted in 1986 and 1988, and in Nautical Charting (NC) conducted in 1987 and 1989 is shown below.

| Country | 1986 (PO) | 1987 (NC) | 1988 (PO) | 1989 (NC) | Total (PO) | Total (NC) |
|---|---|---|---|---|---|---|
| Argentina | 1 | | 1 | | 2 | 0 |
| Bangladesh | | 1 | 1 | 1 | 1 | 2 |
| Colombia | 1 | | | | 1 | 0 |
| Costa Rica | | | | 1 | 0 | 1 |
| Egypt | 1 | | 1 | 1 | 2 | 1 |
| Fiji | | | | 2 | 0 | 2 |
| Indonesia | 1 | 1 | | 1 | 1 | 2 |
| Malaysia | 1 | 1 | 1 | 1 | 2 | 2 |
| Nigeria | | | 1 | | 1 | 0 |
| Philippines | 2 | 1 | 1 | 1 | 3 | 2 |
| Republic of Korea | | 1 | 1 | 1 | 1 | 2 |
| Sri Lanka | | 1 | | | 0 | 1 |
| Thailand | | 1 | | 1 | 0 | 2 |
| Uruguay | 1 | | | | 1 | 0 |
| TOTAL | 8 | 7 | 7 | 10 | 15 | 17 |

*Individual training*

Individual training is divided into two categories: counterpart training and ad hoc individual training. In the counterpart training, the counterparts in the countries receiving JICA experts, project cooperation, development survey etc. are admitted to Japan for training, to increase the effectiveness of these technical cooperation programmes. Determination of the number of persons to be admitted to individual training is made by taking into consideration such factors as past performance. The countries concerned are informed of the quota in advance.

Individual training conducted in 1986-1989 is shown below.

| Country | 1986 | 1987 | 1988 | 1989 | Total |
|---|---|---|---|---|---|
| Malaysia | 1 | | | 1 | 2 |
| Philippines | | 1 | 1 | 1 | 3 |
| TOTAL | 1 | 1 | 1 | 2 | 5 |

*Application procedures*

To invite applicants to the group training courses, General Information (GI) pamphlets containing information on the conditions for admission to each course, the content of the courses etc. are sent through diplomatic channels to the Governments of the developing countries concerned.

Determination of the number of persons to be admitted to the individual training courses is made by taking into consideration such factors as past performance. The countries concerned are informed of the quota in advance. They then present requests on behalf of trainees they wish to send, within the quota.

*Dispatch of experts*

The dispatch of experts is accomplished in various ways. In all cases, its main purpose is to transfer the knowledge and technology of the experts to the people of developing countries, through orientation, survey and research, advice etc. The experts are dispatched by JICA, according to requests submitted by developing countries, from Japan to the government agencies of such countries.

The procedure for the dispatch of experts from Japan begins with a request for assistance presented to the Government of Japan through the Japanese embassy by the Government of the developing country concerned. The request is made using a Form A-1, which should contain information on the background of the request, the duties of the expert, the institution to which the expert will be assigned, the post to be occupied by the expert, the required number of years of experience, period of stay in the recipient country etc.

| Expert in | Dispatched to | Duration |
|---|---|---|
| Tidal observation | Department of Survey and Mapping, Malaysia | Oct 1985–Oct 1987 |
| Hydrographic survey | Bureau of Coast and Geodetic Survey, Philippines | Oct. 1985–Oct. 1987 |
| Tidal current prediction | Suez Canal Authority, Egypt | Nov. 1986–Jan 1987 |
| Tidal observation | Department of Survey and Mapping, Sarawak, Malaysia | Oct. 1987–Oct. 1989 |
| Oceanographic date banking | Coast and Geodetic Survey Department, Philippines | Jan 1988–July 1988 |
| Hydrographic survey | Bureau of Coast and Geodetic Survey, Philippines | Jan 1988–Oct 1988 |
| Tidal current prediction | Suez Canal Authority, Egypt | Apr. 1988–Jun. 1988 |
| Electronic chart | Arab Maritime Transport Academy, Egypt | Dec 1988 |
| Notices to Mariners and Radio Navigational Warnings | Coast and Geodetic Survey Department, Philippines | Dec 1988–Sept. 1989 |
| Hydrographic survey | Coast and Geodetic Survey Department, Philippines | Apr. 1989–Oct 1989 |
| Hydrographic survey (Seminar) | Coast and Geodetic Survey Department, Philippines | July 1989 |

| Expert in | Dispatched to | Duration |
|---|---|---|
| Oceanographic data banking | Coast and Geodetic Survey Department, Philippines | Oct 1989– Aug 1990 |
| Tidal observation | Department of Survey and Mapping, Malaysia | Oct 1989– Oct 1991 |
| Hydrographic survey | Coast and Geodetic Survey Department, Philippines | Oct 1989– Oct 1991 |
| Notices to Mariners and Radio Navigational Warnings | Coast and Geodetic Survey Department, Philippines | May 1990– Dec 1990 |

*Provision of equipment and materials*

The objective of the programme for provision of equipment and materials is to contribute to the economic and social development of developing countries by facilitating technical training, technology transfer etc. with the provision of needed equipment and materials. When this programme is combined with the dispatch of experts, and technical training in Japan, it can enhance the effectiveness of cooperation.

The procedure is as follows:

1. The demands of the Government of a developing country are first studied by the Japanese embassy, and based upon the results of this study, the implementation plan for the aid is prepared by the Ministry of Foreign Affairs, Japan.

2. When the official request is presented, JICA starts the procedures to acquire the equipment requested on the basis of consultations with the Ministry of Foreign Affairs.

*Project-type technical cooperation*

Three types of technical cooperation programmes of training, dispatch of experts and provision of equipment can be implemented independently, but in the interests of better coordination and effectiveness, they sometimes are combined to a new form of technical cooperation, called "project-type technical cooperation."

Recently, a smaller-scale project-type technical cooperation programme has become implemented. This programme is called "Mini-project-type technical cooperation", with a maximum period of three years for its implementation schedule.

As for the normal procedure of implementation, a Record of Discussions (R/D) is prepared for each project and is signed by the Japanese executing agency (JICA) and the authority concerned in the recipient country. This recommends the project to the respective Governments for their acceptance, the details of the implementation plan as well as the obligations to be observed by the two parties concerned.

TECHNICAL COOPERATION IN GEOLOGICAL SURVEYS

The Geological Survey of Japan (GSJ) has long been involved in geological programmes of international importance. The scope of these activities is steadily expanding into all phases of geosciences, and the programmes are gaining increasing importance within the Survey.

*Training of technical personnel from developing countries*

GSJ has conducted two training courses in offshore prospecting methods and groundwater development.

*Cooperative research*

GSJ has conducted six cooperative research projects with developing countries, including Pakistan and the Philippines, for the study of mineral deposits etc.

*Cooperation with international organizations*

GSJ has participated in various projects of international organizations. It is especially involved in the compilation of maps for the projects of the Commission for the Geological Maps of the World. It is responsible for the compilation of various thematic maps for the north-west quadrant of the Circum-Pacific Map Project.

*Bilateral technical cooperation*

GSJ has sent technical experts in the fields of geological survey, mineral resources and geochemistry, to developing countries in south-east Asia, Central America, etc.

Examples of technical cooperation rendered by the Government of Japan with two developing countries, the Philippines and Thailand, are seen in the following articles, E/CONF.83/L.15 and L.16.

## LARGE-SCALE URBAN BASE MAPPING IN THE METRO MANILA REGION*

*Paper submitted by Japan and the Philippines*

### RÉSUMÉ

En 1984, le Gouvernement philippin a demandé la coopération technique du Gouvernement japonais pour des travaux de cartographie urbaine (cartes en courbes de niveau, cartes planimétriques, cartes de l'utilisation et de l'état des sols) pour la région métropolitaine de Manille. Pour les deux gouvernements, il s'agissait de la première opération de coopération internationale pour l'établissement de cartes à grande échelle de la topographie et de l'utilisation et de l'état des sols d'une grande agglomération. Pour résoudre les problèmes urbains, il faut en effet disposer de cartes à grande échelle des régions urbaines, qui permettent de connaître la situation réelle dans la ville et dans ses environs, par exemple pour les opérations d'urbanisme ou la lutte contre les inondations.

Après avoir examiné l'étendue des travaux à entreprendre et les caractéristiques des cartes à établir, on est parvenu à la conclusion que la coopération technique porterait sur

*The original text of this paper appeared as document E/CONF.83/L.15

l'établissement, sur une période de quatre ans, de "l'information graphique de base sur la région métropolitaine".

Les travaux ont commencé en 1985 et ont été achevés en 1989. Les cartes de base suivantes ont été établies :

| | | | |
|---|---|---|---|
| Carte en courbes de niveau : | 1/10 000 | 1 500 km² | 57 feuilles |
| Carte planimétrique : | 1/10 000 | 1 500 km² | 57 feuilles |
| Carte de l'utilisation des sols : | 1/10 000 | 823 km² | 33 feuilles |
| Carte de l'état des sols : | 1/10 000 | 476 km² | 16 feuilles |

Les travaux entrepris sur place, tels que les relevés ponctuels de vérification au sol, la reconnaissance sur le terrain, le recensement des modes d'utilisation des sols et l'étude de l'état des sols, ont été effectués par l'Agence japonaise de coopération internationale et par le Service philippin des levés côtiers et géodésiques. Le premier de ces organismes s'est chargé de la restitution du relief ainsi que de la compilation et de l'impression des cartes.

L'Institut géographique japonais a, pour l'ensemble du projet, fourni les services consultatifs nécessaires.

Le rapport décrit les opérations, les problèmes techniques rencontrés, l'intérêt de ces cartes et leurs divers usages.

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The 1:10,000 urban base mapping project for the Metro Manila region was implemented by JICA under a four-year programme, starting 1985, in response to the request by the Government of the Philippines, and completed in March 1989.

The project area (1,500 km$^2$), extending around Manila, borders in the east on the southern end of the Sierra Madre Mountain Range, which runs from the north-east of Luzon Island, and on Manila Bay in the west. It is adjacent to the central plain of Luzon in the north-east and to the river delta area. The Laguna de Bay lies in the south-east.

The area includes four cities and 13 municipalities which are all confronted with many urban problems caused by drastic urbanization. The Metro Manila region has become overcrowded owing to a drastic influx of population into the present inadequate urban infrastructures, such as the road system and housing facilities. The situation has become rapidly worse, as observed in the increase of temporarily inhabited areas and the chronic inundations caused by the heavy rainfalls.

In order to bring about proper and reasonable solutions to such urban problems, it is necessary that urban base maps be produced to ascertain the existing conditions in the region and its environs. The Philippine Government therefore requested the Japanese Government in March 1984 for technical cooperation in urban base mapping (contoured, planimetric, land use and land condition maps) of the Metro Manila Region. In response to this request in 1985, the Japanese Government sent a contact mission and a preliminary survey team to the Philippines for discussions with the Bureau of Coast and Geodetic Survey.

After discussions on the scope of work and the map specifications by the two Governments, it was concluded that the technical cooperation will be carried out under a four-year programme for the establishment of a "Graphic Information Base of the National Capital Region".

It is therefore expected that the maps would be used as the basic materials for development and preservation planning for the region but also that the general report would be a reference for the use of these maps.

This paper describes all aspects of the 1:10,000 urban base mapping project, incorporating its background, mapping method, information and use of maps.

## WORK FLOW OF THE PROJECT

The work flow of the Metro Manila urban base mapping project is shown in Figure I and the areas covered by the four kinds of maps produced are shown in Figure II.

*First year*

For the preparation of contoured and planimetric maps, ground control point survey, pricking and field identification were carried out. Concurrently, field identification for the land-use map was conducted, with emphasis on functional classification in the Metro Manila region. Aerial triangulation and stereo plotting were conducted in Japan based on the survey data.

*Second year*

Compilation was prepared from the plotting manuscripts. Uncertain items found in the compilation were verified in the field, and re-survey was conducted on the changes, aided by aerial photography. After the field-work, original manuscripts were prepared for drafting and printing of the contoured map in five colours, and the planimetric map in two colours.

For the land condition mapping, the preliminary photo interpretation for landform classification and the minor order levelling were also conducted.

*Third year*

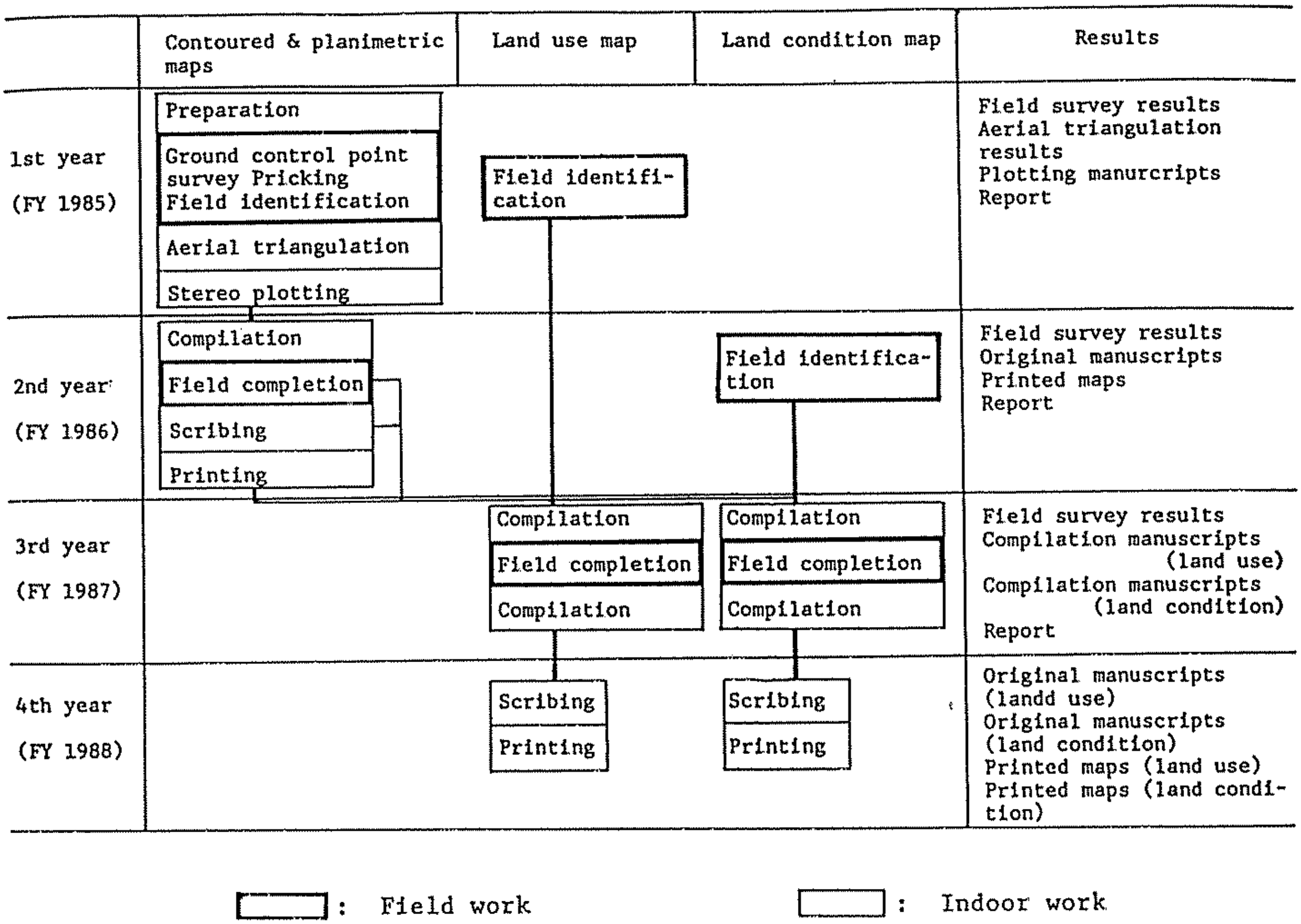
Compilation of land-use and land condition maps were conducted using the 1:10,000 contoured map as the base. Uncertain items found in the compilation were verified by field completion for correction.

The aerial photo-maps prepared in 1986 were used for the land-use map, and the land forms before artificial deformation were surveyed, using old aerial photos taken at around 1968. As for the land-use and land condition maps, the symbol specifications were finally agreed on the basis of the results of a series of field survey and technical discussion.

*Fourth year*

After drafting and printing, the land-use map (7 colours) and land condition map (12 colours) were completed. On the back of each sheet of the land-use and land condition maps, a text on "Information and usage" was printed for the benefit of map users.

Figure I. Work flow of Metro Manila Urban base mapping.




Upon completion of the project, the general report describing all aspects of the project was prepared.

### CHARACTERISTICS OF FOUR KINDS OF MAP

The urban base maps are composed of four kinds: 1:10,000 scale contoured, planimetric, land-use and land condition maps.

The contoured and planimetric maps were finished early in 1987, and they have already been utilized widely in the Philippines. The land-use and land-condition maps were completed in 1989.

Characteristics of each map and the reason why these four different kinds of map are required as urban base maps are as follows:

The contoured (topographic) map is utilized not only for study and planning but also as a base map for preparation all other kinds of map. The contoured map at scale 1:10,000, prepared in this project, was developed precisely as a 5-colour printed map based upon geodetic control point survey and aerial photogrammetry in which the topography is expressed by 2-m interval contour lines. The drainage system, urbanized areas, communities in the suburbs, roads, railroads, vegetation etc. are also shown in detail.

The "planimetric map" was developed as a 2-colour printed map from the contoured map by removing the contour lines and colours for water-surface etc. It is expected that this map is to be used as the base map for purposes of measuring and designing.

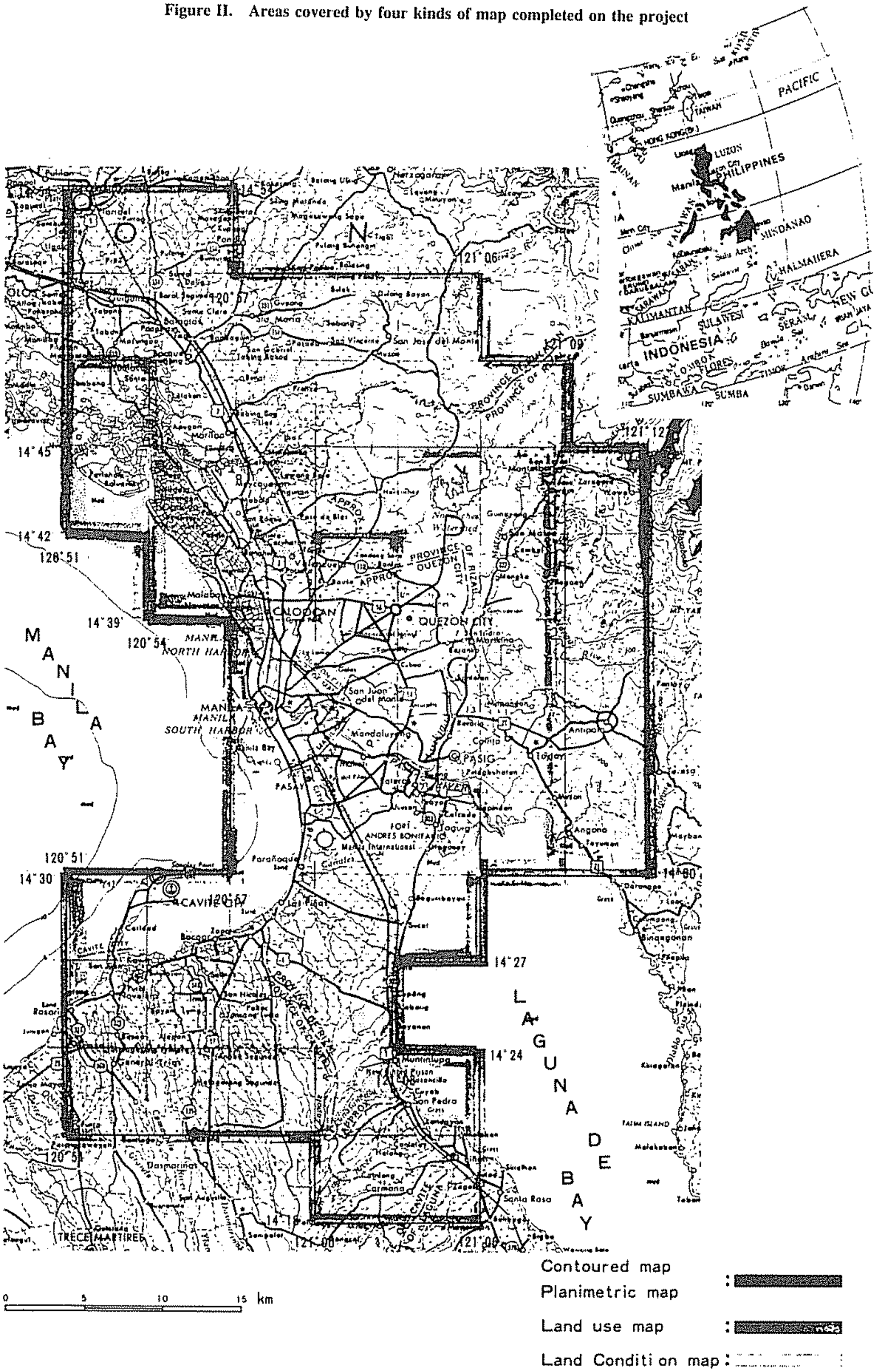
The land-use map is a 7-colour printed map based upon the 1:10,000 contoured map expressing actual use of lands and buildings.

The circumstances of land use in the rural area are fairly recognizable even in the contoured map; however, in the urban area, it is difficult to obtain from the contoured map usage and function in the congested building and housing area.

In the land-use map, usage and functions of the built-up and congested urban area are classified by different colours. Land use, even in the mapped suburbs, is much more recognizable than in the contoured map or planimetric map.

The land condition map is a novelty in the Philippines. It is a 12-colour printed map, developed by employing the 1:10,000 contoured map as base map, showing detailed classified landform units and micro-relief in the lowland, as well as the locations of facilities related to disaster prevention and land development.

**Figure II. Areas covered by four kinds of map completed on the project**



The landform classification was made in order to identify the areas susceptible or not susceptible to disasters such as flooding, earthquake etc. Generally, areas coloured pale blue and green on the map are susceptible to disaster, while the areas in yellow and orange are mostly safe from disasters. Ground heights are shown in detail, obtained by additional direct-levelling, in the lowland in blue or green situated along the coastal area or around the lower part of rivers.

Furthermore, the public facilities related to disaster prevention or land development and useful facilities for evacuation and rescue during calamities, such as hospitals, churches, schools etc. are expressed on this map.

### USE OF THE FOUR KINDS OF MAP

The contoured and planimetric maps are the most basic, showing precisely the patterns of land configuration, drainage systems etc., as well as the locations of buildings and routes of roads etc. These maps are widely available for various studies and planning as basic data.

These maps are also important as basic maps or background maps on which the result of surveys or new plans can be drawn. In the course of this mapping project, the land-use and land condition maps were prepared by using the contoured map as the base map. In addition, the contoured and planimetric maps may be utilized as base maps for various purposes depending upon the users, such as urban planning, road plannings, disaster prevention planning etc. These maps, prepared at this time, are able to satisfy the requirements of numerous studies and plans, as they were developed according to precise geodetic control survey, areal photogrammetry and field identification.

The land use and land condition maps have been, in recent days, indispensable thematic maps for urban planning and disaster prevention planning. It is possible to determine proper use or misuse in a certain area by means of reading these two maps together. For example, in the land condition map, it is possible to judge the susceptibility of the area to disaster, recognize ground-height, and infer the stability of earth, as well as ascertain the existence of facilities for disaster prevention and/or evacuation. In the land-use map, it is possible to find out how lands are utilized and the use and function of buildings on those lands.

By comparing both maps, the suitability of present land use can be checked and a selection can be made of areas where future improvement is necessary, areas suitable for development and those where appropriate disaster prevention facilities are required.

As earlier stated these four kinds of maps, prepared as the urban base maps in the Metro Manila Area, will contribute greatly, being connected with each other, to synthesized urban planning and disaster prevention planning in the area.

# TOPOGRAPHIC MAPPING PROJECT OF THE BANGKOK METROPOLITAN AREA*

*Paper submitted by Japan and Thailand*


## RÉSUMÉ

En 1985, le Gouvernement thaïlandais a demandé au Gouvernement japonais une assistance technique pour l'établissement de cartes topographiques de la zone métropolitaine de Bangkok.

Afin de résoudre les problèmes d'urbanisme, des fonds de carte topographique à grande échelle seront nécessaires. Ils permettront de déterminer les conditions dans la zone métropolitaine et dans ses environs et seront utilisés pour planifier le développement urbain, les mesures de lutte contre les inondations, etc.

Après avoir délimité la portée du projet et décidé les spécifications à retenir, les deux gouvernements sont convenus que le programme de coopération technique serait étalé sur trois ans.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In response to a request from the Government of the Kingdom of Thailand, the Government of Japan conducted a topographic mapping project of the Bangkok metropolitan area from September 1986 to March 1989. Through the project, 61 sheets of topographic map at scale 1:10,000, of the Bangkok metropolitan area and 40 sheets of 1:4,000 topographic map at scale 1:4,000 of the central area of Bangkok were prepared.

Japan dispatched 64 surveyors to Thailand and 81 Thai surveyors were involved in the project. Technical cooperation and technical transfer between the two countries were well achieved throughout the project. It is expected that the maps will be fully utilized as a basic material for urban development of the Bangkok metropolitan area and will contribute to the future development of Thailand.

### OUTLINE OF THE PROJECT

#### *Background*

The Bangkok metropolitan area has been suffering from the widely prevailing urban problems of traffic congestion, inadequate housing development, and insufficient sewerage due to drastic expansion of urbanization.

Furthermore, other than the above general urban problems, there are problems related to chronic inundation caused by frequent flooding of the Chaophraya River, which runs through the centre of the area, as well as by ground subsidence.

The Government of Thailand has prepared and implemented drastic and comprehensive urban planning efforts in order to improve such unfavourable conditions in the area and to establish a sound environment. To prepare correct, rational and comprehensive urban development plans, it was necessary to grasp the actual state of the present Bangkok

*The original text of this paper appeared as document E/CONF 83/L 16

metropolitan area accurately, in detail. Therefore, it was most urgent and important for the Government to prepare urban base maps.

### *The request*

The Government of the Kingdom of Thailand sent a letter to the Government of Japan in May 1985, requesting technical cooperation on topographic mapping of the Bangkok metropolitan area.

The outline of the request was as follows:

(*a*) 1:20,000 aerial photography covering 4,000 $km^2$ of Bangkok and its surrounding area for various surveys and planning;

(*b*) 1:10,000 topographic mapping covering 2,000 $km^2$ of the Bangkok metropolitan area for multi-purpose usage;

(*c*) 1:4,000 topographic mapping covering 300 $km^2$ of the central area of Bangkok for multi-purpose usage.

### *Preliminary survey*

In order to discuss the project, the Government of Japan assigned the Japan International Cooperation Agency (JICA) to organize and dispatch a preliminary survey team. The team was sent twice to Thailand between January and March 1986.

After a series of discussions between the Japanese team and the Thai team, the main members of which were personnel of the Bangkok Metropolitan Administration (BMA), the requesting agency in Thailand, and the Royal Thai Survey Department (RTSD), the scope of work of the project was agreed upon. The outline was as follows:

1. Outline of the Survey
   - Aerial photography (1:20,000): Bangkok and its surrounding area (4,000 $km^2$)
   - Topographic mapping (1:10,000): Bangkok metropolitan area (2,000 $km^2$), 61 sheets
   - Topographic mapping (1:4,000): Central area of Bangkok (300 $km^2$), 40 sheets
2. Reference ellipsoid: Everest
3. Projection: Universal Transverse Mercator
4. Datum: Indian datum 1975
5. Vertical datum: Mean sea level at Koh Lak
6. Map sheet format:
   - 1:10,000 topographic map, 5 km × 7.5 km (50 cm × 75 cm)
   - 1:4,000 topographic map, 2.5 km × 3.75 km (62.5 cm × 93.75 cm)
7. Contour line interval: 2 metres
8. Accuracy of ground control survey:
   - Horizontal
     - 3rd order SQR(DX*DX + DY*DY)/S = less 1/15,000 (closure ratio of coordinates)
   - Vertical
     - 3rd order DH = less 12 mm * SQR(S) (circuit closure)
     - Minor order DH = less 60 mm * SQR (S) (circuit closure)
     - (S = distance in kilometres)
9. Accuracy of map:
   - Planimetry: SQR (DX*DX + DY*DY) = less 0.5 mm on the map
   - Elevation: Photogrammetric spot height: DH = less 0.7 mm
   - Contour: DH = less 1 metre
10. Map symbols and specifications: Determined on the basis of existing systems of map symbols and specifications in Thailand and Japan.

### *Implementation of the project*

The work was started in September 1986 and completed in March 1989.

The field-work, such as the ground control survey, field identification and so on, was carried out by the survey team dispatched to Thailand by JICA with help of the Royal Thai Survey Department and personnel of the Bangkok metropolitan area. The team comprised members from the International Engineering Consultants Association (IECA) and private surveying and mapping companies of Japan which were contracted for implementation of the project by JICA. The stereoplotting and map compilation works were carried out by IECA and the companies in Japan. Finally, 1:10,000 topographic maps were printed by RTSD in Thailand.

For the arrangement and implementation of the project the Geographical Survey Institute (GSI) of Japan supplied necessary advisory services.

The works done for the implementation of the project is outlined as follows:

| | |
|---|---|
| Aerial photography, 1:20,000 | 17 courses $km^2$ |
| 3rd order ground control survey: | 67 points |
| Levelling: | 50 km (3rd order)<br>250 km (minor order) |
| Pricking: | 470 points |
| Aerial triangulation: | 17 courses, 425 models |
| Field identification/stereoplotting/ field completion | |
| 1:10,000 | 57 sheets, 1,700 $km^2$ |
| 1:4,000 | 40 sheets, 300 $km^2$ |
| Map compilation/drafting | |
| 1:10,000 | 61 sheets, 2,000 $km^2$ |
| 1:4,000 | 40 sheets, 300 $km^2$ |
| (Thai and English versions of maps at each scale) | |
| Plate making/printing 1:10,000 | 61 sheets |
| (Thai and English versions) | |

### *Delivery of project products*

The final products of the project were delivered to the representative of the Thai Government by the representative of the Japanese Government at the beginning of the Seminar on the Topographic Mapping of the Bangkok Metropolitan Area, held at Bangkok in March 1989. About 250 participants from related agencies and companies of both Thailand and Japan attended the Seminar, and they discussed possibilities of utilization of the maps prepared in the project.

## TECHNICAL REMARKS

To cope with the natural and social conditions in Thailand, which are different from those in Japan, necessary improvements and modifications were added to the standard mapping procedure for the implementation of the project.

### *Aerial photography*

Aerial photography was conducted using an aircraft and a camera transported from Japan because they were not available for civil use in Thailand.

Aircraft: CESSNA TU-206
Camera: WILD RC-10 15/23
Film: KODAK PLUSX

Don Muang Airport, located north of the photography area, was used for the base of aerial photography. Aerial photography was successfully completed during the period of 6-31 March 1987 owing to the exceptionally fine weather. For the flight operation a security officer from RTSD was on board.

In order to improve mapping accuracy for subsequent stages, the flight direction E-W was selected, and much effort was made to take photographs of each flight course with no break. Consequently there were only four (4) courses containing breaks of photography. To avoid strong halation because of the high solar altitude, the flight operation was made from 15:00 to 16:30 hrs considered to be the optimum time.

### *Ground Control Point Survey*

Using 7 RTSD triangulation points, 67 ground control points were newly established and monumented with theodolities. Wild T2 and electro-optical distance meters, YHP3808.

As for the point selection, in order to improve the strength of the control point network, efforts were made to achieve a standard of about 6 km distance between points, and fewer than 6 sides of a polygon in the network.

The survey area was flat, at less than 2 m above sea level on the average. In the suburbs where there are few tall buildings and many trees of about 15 m high, intervisibility was very poor and observation towers were constructed, the highest about 22 m. Iron pipes made for general building construction were used for constructing the tower instead of wood, which is scarce and expensive in Thailand.

### *Field identification*

Field identification was carried out by pairs of Japanese surveyors and Thai counterparts. The purpose of field identification was to identify the objects that did not appear clearly in the aerial photographs, as well as to collect geographical names, facility names and so on.

To show the characteristics of the urban area of Bangkok, new symbols for a gasoline station, a propane gas station, a fountain and so on, were added to the specifications.

As for the geographical names and building names, much attention was paid to consistency between the notations in Thai and English.

The situation in the field was recorded on notes, with cameras and tape recorders. The records were put together in the office and compared to each other as well as to other data obtained from related agencies; then final annotations were determined. Fishponds, salt beds and ordinary ponds, which are seen frequently in the mapping area of the 1:10,000 topographic maps, are likely to appear the same. Distinction between them was made with help of the land owners.

### *Stereoplotting*

Although the Bangkok city area is congested, with many buildings, the buildings were plotted one by one without generalization for the maps at both scales. For the urban area of Bangkok, generalization was made at the compilation stage.

### *Printing*

Printing was conducted for the 1:10,000 topographic maps in Thailand by RTSD. This was six-colour printing, using blue, orange, red, brown, green and black. These six colours were selected to represent as well as possible the appearance of the topography and features in Bangkok. Consequently, for the urban area the orange and red colours prevail while blue and green are for the suburbs.

The RTSD also conducted the printing of 1:4,000 topographic maps in black and white.

## Conclusion

The 1:4,000 topographic map for the central part of Bangkok and the 1:10,000 topographic map for the suburbs showed up well the present conditions of the city. Following are the examples:

(*a*) One of the causes of the severe traffic congestion is that main roads pass through the centre of the city;

(*b*) The number of bridges for many large and small rivers, including the Chaophraya River are not enough, and many roads end at rivers;

(*c*) The urban area is well distinct from surroundings.

There is no doubt that these topographic maps are indispensable basic materials for development planning of the Bangkok metropolitan area in a wide variety of fields, such as the urban planning, and planning for harbour transportation, irrigation, flood control and so on.

# TECHNICAL CO-OPERATION IN MAPPING FOR AGRICULTURE*

*Paper submitted by the Union of Soviet Socialist Republics*

## RÉSUMÉ

L'Institut de recherche géodésique par photographie aérienne pour l'agriculture a été créé en 1932 afin de mettre en place des méthodes de télédétection et de les utiliser pour cadastrer les terres agricoles. Les cartes cadastrales ainsi produites sont à l'échelle de 1/10 000 et 1/250 000. Chaque année, environ un million de kilomètres carrés sont ajoutés au cadastre

L'Institut étudie chaque région de manière intégrée, c'est-à-dire que les mêmes données de télédétection sont utilisées par les topographes, les cartographes, les géobotanistes, les agronomes et les spécialistes du sol et de l'aménagement du territoire afin de

*The original text of this paper, prepared by V. Tarasik, All-Union Institute of Aerogeodetic Research for Agriculture, appeared as document E/CONF 83/INF 45 réaliser des cartes thématiques dans le cadre d'un seul projet général. Les levés aérophotogrammétriques sont effectués durant la saison qui convient et selon certain paramètres qui améliorent la qualité des données. Leurs résultats sont traités par ordinateur.

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The All Union Institute of Agricultural Aerophotogeodetic research was created in 1932 in order to introduce methods of remote sensing and use them in the production of cadastre maps of farming lands. These maps are produced at scales 1:10,000 and 1:250,000, and each year about 1 million kilometres are added to the coverage.

The Institute applies an integrated approach to the study of each region, which means that the same remote sensing data is used by topographers, cartographers, geobotanists, agronomers, land management and soil specialists to make thematic maps in the framework of a single general project. Aerophotographic survey is carried out in the appropriate season, and according to certain parameters of survey which makes for better quality of data. The results of aerophotographic surveys are computer processed.

In the table below a wide assortment of maps are listed at scales from 1:1,000 to 1:1,000,000.

Among other things the Institute carries out projects in land management based on the above-mentioned thematic maps and other information.

AGRICULTURE AND LAND UTILIZATION

| *Map themes* | *Final production* | *Special features* | *Technology* |
|---|---|---|---|
| | *Thematic agricultural cartographic work using remote sensing data* | | |
| Land areas, scales, 1:1,000,000/1:500,000/ 1:200,000 | Maps showing lands, quality characteristics (in accordance with accepted classification and legends based on the typological method)<br>Used for analysis of land use possibilities | Objective information due to optimal agreement between map and space-image patterns;<br>Warranty of interpretation of the image and accuracy of cartographic drawing;<br>Rapid assessment of intensity of land use in larger territories;<br>Delineation of areas to be mapped in more detail;<br>Outlining and control of major man-made changes in landscape | Interpretation of materials of satellite imaging in conjunction with available large-scale maps: interpretation of contours, field investigation; map production |
| Soils, scales 1:200,000/1:500,000/1:100,000 | Maps with optimal information on character of soil cover revealing landscape-related genesis of soil;<br>Scientifically verified soil structure | Enhanced accuracy and objectivity of soil core structure represented;<br>Serves as scientific base for land inventory, agricultural planning, plans for soil use and improvement of fertility | Interpretation of satellite-imaging material and soil ground; field work using traverse-and-reference method; map production |
| Fitness categories, land classifications | Maps of agro-production; groups of soils with explanatory notes, with emphasis on the relative possibilities of various soils within the limits of individual arable land | Objective warranty of boundaries;<br>Agronomical thrust of maps, with each soil ground having agro-production characteristics necessary for practical land farming | To be compiled based on a soil map with due regard for additional data from spacial processing of satellite imaging |
| Geobotanic, scales 1:1,000,000/1:500,000/ 1:200,000 | Typological map of vegetation, reflecting general regularities of vegetation distribution;<br>Used for regional inventory and planning of vegetation resources | Special technology of mapping associated groups and their complexes as basic targets to be depicted;<br>Combined portrait of dynamic and static status of vegetatal cover | Interpretation of space images, explanation of outlined contours; field-work using the traverse-and-reference method; map production |
| Productivity of natural grazing, scales 1:1,000,000/1:500,000/ 1:200,000 | Fodder-botanic maps singling out types of pasture and haymaking lands and compiled using a special legend;<br>Used in inventory and assessment of grazing lands | Vegetatal cover interpreted according to economic value regarding productivity of grazing lands | Compilation based on a geobotanic map complimented by data from specialized investigations |

(*continued*)

| Map themes | Final production | Special features | Technology |
|---|---|---|---|
| *Complex agricultural and land conservation mapping using aerophoto survey data* | | | |
| Soils, scales 1:50.000/1:25.000 | Complex maps based on results of morphological, chemical and water-physical field observations. depicting soil grounds (according to classification worked out with due regard for local natural conditions) | Synthesis of aerophotographs and satellite images in conjunction with climatic. geological. hydrogeological. geobotanic, agronomical and geomorphological data | Interpretation of materials of satellite imaging and aerophoto-survey; analysis of geological. climatic and hydrogeological, geomorphological. agronomical and topographic data |
| Soil erosion, scales 1:50.000/1:25.000 | Maps depicting degree of soil erosion;<br>Used for development and application of corresponding counter-erosion measures | Assessment of erosion-prone territories based on analysis of remote sensing data and the entire complex of natural features of the territory and their economic use;<br>Outlining of erosion-prone areas under water, wind or both<br>Washed and depleted soils. scours, ravines | Specialized processing of satellite imaging and aerophotographs and their interpretation on the basis of soil maps and materials collected for compilation;<br>Boundaries of erosion. linear forms of water erosion |
| Land use, scales 1:50.000/1:25,000 | Maps showing, by a special legend, the use of lands involved in agriculture and expressing quality characterisitics (at the moment of observation) | Rapid assessment based on remote-sensing data of agricultural land use, showing arable land (bogara, irrigated. drained) hay-making lands, pastures, multi-aged forest stands, forests, bushes, disturbed lands etc | Interpretation of satellite images. and aerophotos in conjunction with other materials, and field follow-up on interpreted contours;<br>Calculation of surface areas and compilation of legends |
| Botanic, scales 1:50,000/1:25.000 | Maps showing natural vegetation associations, as well as vegetation productivity by season | Remote-sensing data based disclosure of composition and structure of vegetation cover and its relation to habitat conditions, seasonal usage, fitness for grazing, crop capacity. quality of fodders. crops, technical condition, peculiarities in use of fodder lands etc | Processing of materials of special satellite imaging and aerophotosurvey, use of literature materials and data on vegetation, climate, topography, soils hydrology etc.;<br>Landscape zoning of the fodder lands. identification of the geobotanic grounds within landscapes, selection of reference points, field observations, data extrapolation, traverses, chemical analysis; Map production |
| Ecological, scales 1:50,000/1:25,000 | Maps interpreting remote sensing data, results of soil and geobotanic observations, with regard for climatic. biological and other natural conditions affecting the productivity of natural vegetation | Assessment of the territorial status based on material from satellite imaging. aerophoto surveys, and soil and geobotanic observations. taking note of hazardous changes in the environment;<br>Working out of recommendations for prevention of harmful and undesirable outcome | Interpretation of remote sensing, soil, geobotanic, geological climatic data;<br>Identification of factors affecting productivity of natural vegetation, working out of recommendations |
| Cadastre, scales 1:5,000/1:2.000/1:1.000 | Maps showing up-to-date utilization of land at farms. regions etc.<br>Used for regulation of landowners' relations, taxes and payment of duties | Legend based on aerophoto materials; photoplan is equal to drawings<br>Helps to estimate remote sensing data for each landowner | Interpretation of aerophoto materials, levelling of shots, photogrammetry. Map production |

## AN INTRODUCTION TO THE GUIDE TO TRAINING FACILITIES IN SURVEY AND MAPPING FOR OVERSEAS STUDENTS IN GREAT BRITAIN*

*Paper submitted by United Kingdom of Great Britain and Northern Ireland*


### RÉSUMÉ

De nombreux établissements britanniques dispensent une formation en cartographie et dans des domaines apparentés, tels que les levés hydrographiques, le cadastre, l'utilisation du sol, la télédétection, les techniques de reproduction et l'impression. Cette formation va des cours d'introduction ne débouchant pas sur un titre universitaire aux possibilités de recherche, en passant par la délivrance de diplômes nationaux, grades et diplômes d'études supérieures.

En 1989/90, l'Overseas Surveys Directorate a rédigé un guide de ces formations, qui sont présentées succinctement ici.


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The Ordnance Survey's Overseas Surveys Directorate (OSD) acts as advisor to the British Council on all applications for United Kingdom training awards in the fields of cartography, photogrammetry, and land survey. As such it has an unparalelled overall perspective of such training.

To assist in fulfilling this role OSD has, over a number of years, acquired information about the range of training opportunities that exist in Britain and has sought to make this information as widely available as possible. As part of this task, in 1989, OSD produced a Guide in the form of a booklet entitled "Full-time training facilities in Great Britain in survey and mapping and related fields". This compendium, of over 100 pages, gives details of the majority of the training courses available at that time. This paper summarizes the information contained in the Guide.**

The Guide is intended to be a factual statement of the full-time training that is available. Apart from the "market leader" indications given within each subject heading in the summary list (see below), no specific recommendations or comments have been made as to the relative merits of particular courses.

The Guide was compiled from information collected during the first part of 1989. No responsibility is accepted by the editor for any inaccuracy, or for misleading or incorrect information contained therein. Applicants are advised to check with individual departments that details are still current at the time of making an application and to request more background information before making a firm decision on the training to be selected.

As there is a frequent review of the teaching of these subjects, and changes each year in the range of courses being offered, it is our intention to prepare a revised and updated edition of the Guide in time for the start of the 1990/91 academic year. Overseas departments and mapping organizations that are interested in securing a copy should contact OSD.

### SUBJECTS COVERED IN THE GUIDE

The training described in the booklet centres around full-time courses in cartography, photogrammetry and land survey, such as will be followed by people wishing to make a career or profession in any of these subjects. Nevertheless, related subjects are covered where they impinge on the principal three; these include hydrographic surveying, land registration and land use, remote sensing, reproduction techniques and printing. Aspects of these which are not directly related to cartography etc. are omitted.

The Guide is not a comprehensive account of all teaching given in those subjects in the United Kingdom, and in particular, it make little mention of the many other university geography and civil engineering departments that offer limited instruction in those subjects during a first degree course, or of postgraduate facilities for research, although most of the university departments listed do accept students for such studies. It also makes no reference to the many opportunities for part-time or block release study.

Surveying courses are only included when they are sufficiently broad in concept as to encompass the different conditions and laws encountered overseas. Courses in estate management and land economy, which concentrate solely on United Kingdom land law and practice are avoided. The Guide also describes only land survey and closely related fields; it does not cover quantity, building, mines, geological or soil surveying, nor rating and valuation of property. Hence, only a few of the national certificate and diploma courses in surveying are included. Likewise "computing" is only included where it is covered in a survey context.

There are few full-time courses in the United Kingdom for basic technician training in land survey, cadastre or land registration apart from courses arranged by firms and organizations for their own staff. Full-time first degree or technical college courses in a single field of photogrammetry, remote sensing, cartography or map reproduction are available only as part of broader courses such as geography, topographical science, or general printing. The photo lithography courses listed do not relate specifically to map printing.

Shorter, ad hoc courses and technical study visits to meet individual training requests are not discussed in any detail in the Guide, but OSD have been able to arrange a number of such training attachments, and candidates have received sponsorship through the British Council or from United Nations agencies. The Overseas Training Liaison Officer at the Ordnance Survey is able to give advice and assistance in arranging short-term specialist training.

The Guide does not contain details of training facilities individually designed to meet special needs that may be available from Air Survey and Mapping companies in the United Kingdom.

### COURSES FOR OVERSEAS STUDENTS

In general, all university and polytechnic courses are open to students from any country provided that the student has

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*The original text of this paper, prepared by G.B. Bishop, Ordnance Surveys Directorate, appeared as document E/CONF.83/INF.28

**A limited number of copies of the guide were distributed among the delegates to the Conference. They may also be obtained from the Overseas Training Liaison Officer of the Directorate.

the necessary entry qualifications. Pressure on university places is, however, great and a student may need more than the basic qualifications in order to stand a chance of being accepted.

Formal courses usually lead to professional, technician or academic qualifications: they are the standard courses offered to British students and they are not arranged specially for people from overseas. Several of the courses listed are particularly designed to meet British needs; applicants should make enquiries direct to the establishments concerned to satisfy themselves that the courses offered cover their particular requirements.

Ad hoc courses normally aim at practical proficiency and do not award recognized qualifications; they can however, by implication, be particularly designed to meet the needs of overseas students.

### LANGUAGE OF TUITION

All instruction is in English. Students must be able to read and write English fluently and have a good comprehension of the language in order to be accepted. Most institutions require a candidate to pass an English test arranged by the British Council, which is taken in his own country. Some awards are conditional upon the student following an English course in the United Kingdom before commencing his technical training.

### FUNDING FOR OVERSEAS STUDENTS

Students at universities, polytechnics and colleges may be either private or government-sponsored; those at the other organizations listed must be government-sponsored, or be in receipt of a United Nations fellowship or European Development Fund or some other similar award. Private students must apply in the first place through their own embassy in the United Kingdom. Applications for sponsored students seeking United Kingdom government awards must usually be made by their Government to the local British Council representative, or where there is no representative to the British Embassy or High Commission. Details of awards are given in the publication of the United Nations Educational, Scientific and Cultural Organization (UNESCO) entitled *Study Abroad*, No. XXV (1987/88) and in later editions.

United Kingdom Government awards will not normally be made for training in Britain if suitable facilities are available locally or regionally.

Inclusion of a course in the Guide does not imply that it is necessarily eligible for a United Kingdom Government Award.

No indication is given in the Guide of the fees charged by each Department.

### LAYOUT OF THE GUIDE

In preparing the Guide, all colleges and establishments were asked to revise their entries to reflect courses commencing September/October 1989 for the academic year 1989/90. New courses have also been added, where known. However, because it has proved impossible to verify some information, a data of currency has been included with each entry.

The Guide comprises three sections:

*Introduction* (7 pages). This includes a list of establishments and a locational map.

*List A.* A table of subject headings and qualification levels. The list gives information, catalogued by subject, on the full-time courses/training available at various levels in Great Britain. An indication is given of the colleges that have, in the opinion of OSD, provided the best training for students from developing countries.

*List B.* Detailed entries on each training establishment. The list shows, in alphabetical order, all colleges and organizations offering courses and provides details on length of course, month of starting, latest month of application, number of years for which a course has been offered, average annual intake, entry requirements, course content, number and qualifications of teaching staff and equipment available.

To help in compiling the Guide, colleges were asked to give an indication of the proportion of all students who come from overseas, sources of funding in sponsoring overseas students and whether students attending that particular course tend to come from certain geographical areas, or if the college has special links with a particular country.

### FURTHER INFORMATION ON TRAINING

Specific enquiries concerning particular courses are best addressed directly to the college or establishment concerned, but the Overseas Training Liaison Officer in OSD is happy to give more general training advice and can provide assistance in arranging for technical and professional study attachments to the Ordnance Survey and to other survey and mapping organizations in the United Kingdom.

Users of the Guide are invited to send their comments to the editor, so that cognizance can be taken of these in the preparation of the next edition.

## HYDROGRAPHIC TECHNICAL ASSISTANCE*

*Paper submitted by the International Hydrographic Bureau*


## RÉSUMÉ

Le présent rapport expose les principes de l'assistance technique en hydrographie fondés sur la conception de l'OHI dans ce domaine et donne la liste des missions d'assistance technique récemment effectuées par le personnel de l'OHI ainsi que la description des services rendus par le Comité de coordination de l'assistance technique. Il indique également les centres de formation et les centres d'entretien régionaux. La dernière partie est consacrée à la coopération avec les organismes des Nations Unies.


*The original text of this paper appeared as document E/CONF.83/L.9.

The International Hydrographic Organization (IHO) attaches great importance to the provision of technical assistance and advice to developing countries in order to facilitate the setting up or expanding of their hydrographic services. These have become increasingly important for the socio-economic development of all the coastal States, particularly after the adoption in 1982 of the United Nations Convention on the Law of the Sea. An IHO paper entitled "Status of hydrographic surveying and nautical charting in the Asia and Pacific region (E/CONF.83/L.4), being presented at the present Conference, highlights the need and importance of hydrography and summarizes the present status of hydrography and nautical charting within 52 coastal States in Asia and the Pacific. The report points out serious deficiencies in many of the States, which must adopt immediate measures to improve their hydrographic and nautical charting status by allocating national resources and obtaining external assistance as a matter of priority. In order to avoid repetition of what is stated in that paper, it should suffice to emphasize that nautical charts for maritime development in Asia and the Pacific must be considered in the same way that maps provide an essential basis for planning roads, railways and general urban and rural development in the hinterland.

It is hard to quantify the potential economic benefits of hydrographic and nautical charting projects and the problem is compounded in many developing countries, which lack the requisite local expertise. It is therefore incumbent on IHO and the concerned United Nations agencies to advise the concerned Governmental agencies of the developing countries that hydrographic projects should be given at least equal priority as those with more obvious benefits; a lack of modern hydrographic data and updated nautical charts will inevitably seriously impair their nation's economies, should they rely, as most countries do, on the efficient export and import of goods, and if they are to benefit fully from the potential available within their large Exclusive Economic Zones; in the case of many of the island States in the Pacific, these far exceed their land areas.

### Technical assistance programme of the International Hydrographic Organization

The member States of IHO fully appreciated the problems and formidable challenges faced by all the developing countries around the world to develop viable national hydrographic services and accordingly, in 1982, approved the expansion of the technical assistance and advisory role of the Organization by allocating funds to enable visits of IHB experts to any country—whether an IHO member State or not—requesting such visits, at no expense to the developing country. On receipt of such a request at IHB, the Directing Committee of IHB arranges for one of its senior professional staff to visit the country with a view to:

(*a*) Visiting all the various national organizations with marine responsibilities to discuss the present status of nautical charting and hydrographic services and the need for improvements;

(*b*) Explaining to all those senior officials with responsibility for marine activities the need for national cooperation, usually by the formation of a national hydrographic committee;

(*c*) Making a preliminary report including:

(i) A short description of the country, noting areas where marine activities have a potential for improving the national economy and outlining areas of marine activities that require hydrographic data, charts and other services;

(ii) An assessment of the present situation concerning charts and hydrographic services, including the facilities already available such as manpower, equipment, vessels etc.;

(iii) A description of the negative effects on the national economy resulting from the present situation and the benefits to be derived from improving the hydrographic facilities;

(iv) A preliminary programme for collection of hydrographic data and production of charts, with suggested priority of the areas to be surveyed;

(v) A preliminary recommendation of the most suitable hydrographic organization, including minimum level of personnel, equipment and vessels, maintenance facilities and training programme required;

(vi) Recommendations for national cooperation, including the early formation of a national hydrographic committee, if appropriate;

(*d*) Visiting the national financial authority and the resident representative of the United Nations Development Programme (UNDP) to discuss financial or technical aid from UNDP or donor countries and other aid-giving agencies;

(*e*) Investigating which donor countries have been, or are still, giving aid to the country and whether there are any current or proposed bilateral agreements on similar projects.

On return to the IHB, the expert produces a report of his visit, which is reviewed by the Directing Committee of the IHB and forwarded to the concerned Government authority of the country visited. The Government is advised to initiate the following actions, should it decide to follow up the recommendations of the report, particularly in respect of obtaining UNDP assistance:

(*a*) Enact legislation concerning the creation of a national hydrographic service, emphasizing that UNDP, donor countries and other aid-giving agencies cannot consider hydrographic projects until the formation of a national hydrographic service has, at least, been approved by the Government;

(*b*) Take necessary steps, in consultation with the UNDP resident representative, to include the project in the Country Programme Cycle;

(*c*) Prepare a Project Formulation Framework (PFF), with the assistance and guidance of the UNDP resident representative and the IHB;

(*d*) Subject to agreement with the UNDP on the PFF, prepare a draft UNDP project document, in consultation with the IHB.

### Technical assistance visits undertaken by the Bureau staff

Following the above policy guidelines for technical assistance, the IHB has responded to requests from several developing countries and has arranged visits during the past few years to Papua New Guinea (1983), the Kingdom of Tonga (1990) and Fiji (1990) in the Pacific, and Pakistan (1990) in Asia.

(*a*) The Kingdom of Tonga had accepted the need to establish a hydrographic service in order to replace the old and obsolete charts of its vast EEZ and coastal areas with charts based on modern hydrographic data, as required by its several national agencies such as port authority, fisheries, natural resources, defence etc. It is understood that, following the visit by an IHB expert and receipt of the visit report, a National Hydrographic Service and National Hydrographic Committee have now been established and that a survey vessel is expected to be delivered by Australia in May 1991 under the Australian assistance programme. However, the Kingdom still urgently needs external financial assistance to continue to maintain the services of a hydrographic technical advisor (at present funded by New Zealand on an ad hoc basis) and to procure some essential survey equipment.

(*b*) The Government of Fiji was provided with a survey vessel by the Australian Government in 1987 and a survey launch by the British Government in June 1990, but the Fijian National Hydrographic Service still needs some additional external financial assistance to replace old survey equipment, such as an electronic position fixing system and echosounders to take full advantage of these expensive and excellent existing facilities. Following a short visit by an IHB expert in March 1990, the Fijian Government is actively considering the establishment of a National Hydrographic Committee, which will have representatives from all the national agencies interested in the hydrographic data;

(*c*) Pakistan needs some essential survey equipment to enhance and strengthen its School of Hydrography and a dedicated survey vessel to progress hydrographic surveys of its coastal waters and newly acquired large EEZ;

(*d*) Papua New Guinea has been progressing the hydrographic surveys of its waters with the assistance of the Australian Government under a bilateral agreement. The Government has however been advised to initiate efforts aimed at achieving greater self-reliance, in accordance with the recommendations of the earlier report of the visit by an IHB expert in 1983.

In addition to the above visits, which were specifically directed towards technical assistance missions, several Asian and Pacific region countries and areas were visited by the President of the IHB between 1988 and 1990 to discuss the status of nautical charting and hydrography with the Hydrographers and other concerned government officials. These included Australia, Bahrain, China, Democratic Peoples' Republic of Korea, Hong Kong, Indonesia, Japan, Republic of Korea, Malaysia, Myanmar, New Zealand, Papua New Guinea, Thailand and Singapore.

### Technical Assistance Coordination Committee (TACC)

The IHO is concerned that in many developing countries, particularly those without a National Hydrographic Service, uncoordinated and independent approaches are often being made by different national departments interested in the development of hydrographic capabilities, to different United Nations or other organizations—IMO, IOC, FAO etc. In some cases, approaches are also being made to non-government or private sector companies for advice. In 1989 IHO therefore formed the Technical Assistance Coordinating Committee (TACC), with the International Federation of Surveyors (FIG) representing the private sector. The Terms of Reference of this Committee are:

(*a*) To establish and maintain a full, complete and up-to-date inventory of all hydrographic surveying and nautical charting projects involving technical assistance to developing countries; this includes assistance in the way of academic and on-the-job training of surveyors, nautical cartographers and maintenance staff, provision of expert advice, provision or loan of equipment and includes projects under consideration, in hand or recently completed. To distribute such data in a timely fashion to all known interested parties—including international and national organizations and funding agencies, as well as to those in the private sector;

(*b*) To establish procedures for the coordination of information about all expert advice and other technical assistance projects involving hydrography and nautical charting to any developing coastal State and for the monitoring of all such projects, so as to ensure the maximum benefit from them and to avoid wasted expense and effort by donor countries and/or funding agencies;

(*c*) To review the status of hydrographic surveying and nautical charting in developing coastal States, on an annual basis. To review the standards of accuracy, validity of data available and to consider the interaction of such standards and validity between coastal, offshore and harbour areas and between differing requirements of safety of navigation, dredging, port and coastal development, offshore exploration and exploitation and environmental protection. To make this information available to donor organizations to help them to decide where their assistance could be of most benefit and best utilized;

(*d*) To promote the perception of the importance of hydrography and of modern, updated charts to all coastal States at every opportunity and to encourage the provision of financial assistance to hydrographic projects by establishing close relationships with international organizations, such as IMO, IOC, FAO, UN and with international and national funding agencies.

It is felt that this Committee could make a significant contribution towards the coordination of national hydrographic activities and help to prevent independent and parallel approaches by different national departments of developing coastal States which could compete for technical assistance. It could facilitate efficient and effective utilization of the limited financial resources through the most appropriate national organization, provided the membership of TACC includes representatives of all the concerned international agencies involved with technical assistance and advice. At present, TACC consists of five members appointed by FIG and five appointed by the IHO, but it is proposed to expand this Committee by including United Nations and other agencies. The Committee works by correspondence and takes advantage of international conferences etc., at which formal meetings are also organized from time to time. The IHB provides the secretarial and administrative support needed to gather, hold and disseminate data on behalf of the Joint Committee. The IHB has started to issue periodical reports on all projects and advisory visits of which it has been informed.

### Regional training and maintenance centres

The IHO is well aware of the problems of maintenance of survey equipment and training of hydrographic personnel being faced by many developing countries that are remote from the manufacturers of modern hydrographic equipment and well-established training institutions. It is very expensive for these countries to organize such maintenance and training facilities on a national level, particularly for relatively modest requirements. The IHO feels strongly that there are good grounds for establishing regional centres for training and maintenance. The IHO is presently coordinating with the Economic Commission for Africa (ECA) to plan and establish up to three such centres in Africa. A proposal has already been drafted and presented by the IHO to ECA regarding the expansion of the existing Regional Centre for Services in Surveying, Mapping and Remote Sensing

(RCSSMRS) at Nairobi to include the maintenance and training facilities for hydrographic surveying and nautical charting and the appointment of a regional hydrographic adviser. As far as Asia and the Pacific are concerned, some training facilities are already available; these will be discussed under agenda item 8(a). There may be a need for more such training facilities and it may also be very useful for Asia and the Pacific to consider the establishment of at least one regional centre in each region, each with the capability to service and maintain equipment, such as echosounders, sidescan sonars, tide gauges and electronic position fixing systems etc.

### Cooperation with the United Nations agencies

The IHO has maintained close cooperation with various concerned United Nations agencies and is planning to further strengthen and broaden this very fruitful relationship through additions to the existing Memorandums of Understanding with IOC and IMO so as to include technical assistance and cooperation in respect of hydrographic projects of all the developing countries, including Asia and the Pacific. IHO also continues its active cooperation with the United Nations Secretariat as evidenced by the presentation of an updated report entitled "Status of hydrographic surveying and nautical charting worldwide", at the Fourth United Nations Regional Cartographic Conference for the Americas, 23 to 27 January 1989.

Technical staff members of IHB visiting various countries for technical assistance missions always arrange to visit resident representatives of the United Nations Development Programme (UNDP) to discuss the status of hydrography and nautical charting of the country visited, its future requirements and the financial implications of the development of urgently needed hydrographic infrastructure and equipment. These meetings with the UNDP representatives have been mutually rewarding and beneficial in appreciating the importance of hydrography and nautical charting for the socio-economic development of the coastal States and in understanding the complexity of the procedures to be followed by the countries to obtain UNDP assistance for hydrographic projects. Based on the experience gained during such discussions and the positive contributions made by the UNDP resident representatives and the UNDP headquarters in New York, IHO has recently updated its Guidelines relating to technical assistance by including details of the procedures to be followed when applying for UNDP assistance as promulgated in IHO's Information Paper No. 6 entitled "Hydrographic technical assistance to developing countries".