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Report on Mission

**FINAL REPORT TO THE
KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH
STATE OF KUWAIT**

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Note: The views expressed in this report are those of the author and do not necessarily reflect those of the United Nations Economic and Social Commission for Western Asia.

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SUMMARY

Interest in sustainable development and the growing public concern about environmental threats in Kuwait have triggered the Environmental and Earth Sciences division (EES), and the National Scientific Information Center (NSTIC) at the Kuwait Institute for Scientific Research (KISR) to cooperate with the Regional Information Technology and Software Engineering Center (RITSEC) in Egypt to develop a national Environmental Information System (EIS) archive that is catered for Kuwait's needs. The objective of this project is to transform the environmental database, made available, into useful information tool that will guide the local decision-makers in the national and local planning processes. The main objective of the current mission is to evaluate the first phase of the project and suggest measures to optimize and possibly maximize the utilization of the developed EIS.

Phase one of the project culminated in the development of an integrated and interactive environmental information system that is limited to the marine environment of Kuwait. Following the revision of this phase, and after discussions with KISR senior researchers, a number of observations could be made.

First, phase one of the project did not involve the incorporation of environmental indicators and/or indices for simplifying and/or reducing massive amounts of environmental data for the purpose of reporting to decision-makers. Such indicators would assist decision-makers at the local level in monitoring progress toward sustainable development, in developing policies, in evaluating the effectiveness of these policies and in allocating available resources.

Second, the developed information system, exclusively dedicated for environmental information, will not be adequate enough to provide the needed support for decision-makers to plan for sustainable development in the country. The value of EIS for the sustainable development of Kuwait could be greatly increased by cross-linking the data through interdisciplinary analysis.

Third, no active steps were taken yet by KISR to establish the Quality Assurance and Quality Control program (QA/QC) mentioned in the final report of Phase 1. Such a program would preserve the reputation of the newly developed system as a repository of high quality, useful and reliable information. The measures of environmental data quality including data precision, data accuracy, measurement completeness, and the detection limits of the analytical methods, provide very useful documented indicators of data quality to be entered into the developed EIS.

Fourth, the first phase of EIS did not provide yet any projection/prediction facilities, analytical capabilities, and/or modeling capacity for the environmental parameters of priority in management and planning. Projections and scenarios that can be developed exclusively through modeling will assist decision-makers in selecting policy options and forecast their potential implications.

Finally, it might be advisable for KISR to establish and incorporate an expert system for decision-making in the newly developed EIS. This system is an interactive

computer program that encodes different forms of information and expertise to give knowledgeable advice on a specific environmental problem.

I- INTRODUCTION

Interest in sustainable development and the growing public concern in Kuwait about environmental threats (particularly following the environmental damage inflicted by the Iraqi invasion) revealed the need for a system to document, store, retrieve, report and disseminate environmental information. Furthermore, decision-makers in Kuwait often require environmental information in order to base their judgments on solid grounds and to ensure the sustainability of development in their country. According to Agenda-21, the utmost priority for environmental management should include establishment and integration of existing data on physical, biological, demographic and user conditions into a database; maintenance of this database as part of the assessment and management process; promotion of exchange of data and information with a view to the development (or adaptation) of standard inter-calibrated procedures, measuring techniques, data storage, and management capabilities. Fortunately, Kuwaitis have recognized that effective management relies essentially on reliable and adequate information on how their environment behaves under natural and anthropogenic conditions. They also recognized that the current systems of information generation and management do not fulfill the requirements of integrated environmental management and decision-making system they strive for. Their main objective is to make environmental data available <u>where</u> it is needed, <u>when</u> it is needed and supplemented <u>with all supporting information</u> that is necessary for the user to understand and utilize the data to its maximum potential.

It is highly unfortunate to find that the wealth of environmental information generated and accumulated over the years in Kuwait is generally fragmented, misplaced, dispersed or sometimes totally lost. This long lasting malpractice has triggered the Environmental and Earth Sciences division (EES) and the National Scientific Information Center (NSTIC) at the Kuwait Institute for Scientific Research (KISR) to cooperate with the Regional Information Technology and Software Engineering Center (RITSEC) in Egypt - to develop a national Environmental Information System (EIS) archive that is catered for Kuwait's needs. Furthermore, Kuwaiti desideratum to create additional capacity enabling it to identify, select, collect, store, retrieve and update local environmental database became evident. Once "Phase II" of the project is finalized and the environmental database is made available, Kuwait can transform it into useful information tool that will guide the local decision-makers in the national and local planning processes.

The current mission is in response to KISR's request for technical advice to discuss the quality and usefulness of the outputs expected from the system and suggest recommendations for the second phase of the project. However, the main objective of the present mission, as agreed upon with senior officials at KISR, is to evaluate the first phase of the project and suggest measures to optimize and possibly maximize the utilization of the developed EIS.

II- EVALUATION OF PHASE ONE OF THE PROJECT

Phase one of the project culminated in the development of an integrated and interactive environmental information system that is limited to the marine environment of Kuwait. This system is currently available at KISR and in use on a testing basis. Due to some logistic problems (compilation of the information from Arc-Info to Arc-View software) to enable the use of window environment on regular PC, the system was not fully operational at the time of the visit. Experts from RITSEC provided an illustration of the basic framework. However the active involvement of Kuwaiti Nationals in developing and operating the system appeared to be very substantial.

The development of the EIS was based on a demand driven approach and involved the following successive activities:

1. Exploration and identification of information availability, assessment of users needs in addition to available and required resources.
2. Configuration and conceptual design of the system based on the identified needs in addition to the size and characteristics of the available information.
3. Development of Geographic Information System (GIS) for geo-referencing and other applications.
4. Installation and activation of the developed EIS and its associated GIS and then test the system applications.
5. Preparation of project's final report.
6. Capacity building and provision of "on-the-job-training" through the organization of practice sessions and workshop for potential EIS beneficiaries.

The collected data on Kuwait marine environment were grouped into several data subject areas which included geographical information, coastal and near-shore characteristics, industrial discharges, sewage and storm waters effluents, environmental quality, oceanography, etc. Three main GIS applications were identified for development. These included environmental sensitivity index mapping catered for oil spills, a data dictionary for non-recurring data, and selected regularly monitored environmental parameters.

The size and structure of the available data dictated the configuration of the EIS. For each data subject area relevant to the marine environment, entities were identified. The total number of entities mounted to some 75 among which logical relationships were also established. Then the most popular (Arc/Info) software was used to develop the integrated data model.

The system is driven by "user friendly" menu that includes modules for system maintenance & updating features, geographical (discrete) data sets, continuous data sets, and other sub-modules for editing, selecting, displaying, helping, etc. As demonstrated by RITSEC staff, most data entry, verification, correction, and retrieval is achieved using a series of menu-driven options beginning with the main menu.

According to the main users at KISR, testing the developed system has been proved to be successful in providing the information that can support decision-makers in the proper management and assessment of the marine environmental quality in Kuwait.

II-1- <u>OBSERVATIONS ON PHASE ONE OF THE PROJECT</u>:

Recent advances in information and communication technologies, coupled with the development of new tools such as remote sensing, satellite technology, GIS and expert systems, have dramatically changed the foundation of the decision making process for sustainable development. Unfortunately, planners in Kuwait are not yet taking full advantage of models and data as a routine practice. A better and more typical approach would be the establishment of a management model, usually in the form of an optimization model and incorporate into it some technological models such as water quality models, urban infrastructure models, air quality models, etc. as part of the objective function or the constraints. The solution to such an optimization problem would indicate the best decision to be made. KISR should acknowledge that the increased complexity of the environmental management problem on one hand, and the availability of advanced tools for management on the other hand, have changed the way the decision making process is accomplished. The modern approach involves two fundamental steps as follows:

1. Development of the integrated information system to support the decision making process as currently being materialized by KISR and RITSEC.
2. Developing and testing alternative environmental management scenarios by running each through the developed information system.

These two steps simply indicate that the environmental decision making process is becoming more interactive. This certainly indicates that the planner in Kuwait should be in a position to communicate with the information system and test the consequences and effects of his decision rather than arriving at a single fixed decision of unknown impact.

Undoubtedly, the development of a marine EIS in Kuwait is a significant effort towards the establishment of a more integrated system that encompasses all environmental compartments (water, soil and atmosphere) to be produced in phase II of the project. Following the revision of "phase I" of the project's report and after discussions with KISR senior researchers, the following observations could be made:

1. The first phase of the project did not include the incorporation of environmental indicators and/or indices for simplifying and/or reducing massive amounts of environmental data for the purpose of reporting to decision-makers.
2. The second phase of the project, currently in progress, is addressing the other environmental issues associated with terrestrial and atmospheric compartments. By the completion of the second phase Kuwait will possess an integrating EIS of extreme importance for the sustainable management of its environment.

However, the developed information system, exclusively dedicated for environmental information, will not be adequate enough to provide the needed support for decision-makers to plan for sustainable development in the country. It is clear in the mind of KISR officials that modern integrated information systems should not be exclusively designed for the sole purposes of environmental reporting, management and decision making. The ultimate goal of KISR officials is to develop an integrated interactive system that is capable of providing all needed information to ensure sustainability of development in Kuwait. This will entail the development of socio-economic and institutional information systems to be integrated with the presently developed EIS in order to ensure a reliable supply of comprehensive information for decision-makers to plan for sustainable development in Kuwait.

3. Quality Control (QC) and Quality Assurance (QA) for maintaining the EIS were mentioned in the final report of "Phase I". Nevertheless, no active steps were taken yet by KISR to materialize the objectives of the mentioned programs. This will entail the establishment of a QA/QC program to be considered as an inherent (by-default) component of the system. Following discussions with project's leader and senior project staff it became evident that quality control issues concerning the validity and integrity of the generated environmental information are seriously considered and would be addressed immediately. It is important to emphasize that the implementation of QA/QC will preserve the reputation of the newly developed system as a repository of high quality, useful and reliable information. The implementation of a QA/QC will necessitate the development of a procedural guideline and a filtering (auditing) system designed to ensure the quality of the data and/or information at the point of generation, reporting, and particularly during the information updating process. Data entry is provided by a series of menu driven options in order to simplify the process and ensure accurate entry of a wide variety of data. However, because the data system menus are available to all users with access to the EIS, limiting most information users to read only privileges will eventually provide quality control and data protection. Only those personnel with the responsibility of entering and maintaining databases should be provided with privileges to write and edit data in the system. KISR & RITSEC should conduct a national survey to identify the entities and/or personnel with registered rights for updating and editing. Furthermore, KISR & RITSEC should also develop an electronic tight control system to restrict access to write and edit without jeopardizing or hindering the inflow of new information into the system.
4. The first phase of the EIS did not provide yet any projection/prediction facilities, analytical capabilities and/or modeling capacity for the environmental parameters of priority in management and planning. It is important to note that there is always a need to up-date the information on the current situation in Kuwait, geo-referencing, and some way and means of anticipating and

projecting what the future may hold if the current trends either persist or change in the country. These projections and scenarios that can be developed exclusively through modeling will assist decision-makers in selecting policy options and forecast their potential implications.

In the following section of the present report, the aforementioned observations are elaborated and a number of action oriented recommendations are provided to be considered by KISR & RITSEC in the next phase of the project.

III- NECESSITY OF INCORPORATING ENVIRONMENTAL INDICATORS AND INDICES IN EIS:

Basically, the expected output from any EIS is to assemble the various elements in a coherent process that moves information quickly from initial data collection (generally by environmental monitoring agencies), through compilation and assessment to delivery in forms decision-makers can comprehend and make use of.

Indicators are developed from statistical parameters, but have additional characteristics. They provide simpler and more readily understood form of information compared to complex data and statistics. Generally, environmental indicators can be based on physical chemical and/or biological measures associated with environmental quality or natural resources. They summarize some aspects of the state of the environment, natural resources assets, and related human activities. To be useful in an overall sustainable development context for Kuwait, environmental indicators ought to relate environmental aspects to socio-economic factors as it will be illustrated below. One additional key characteristic of environmental indicators is that they can track changes over time. It is important to recognize that decision-makers in Kuwait (like the rest of the world) need concise information, put forward in a clear and unambiguous fashion and divested of all minor details. The purpose is to illuminate or highlight certain phenomenon or trends, through simplification, quantification and communication. As such they may not only be useful in improving information for decision making, but they may also simplify reporting requirements by replacing extensive data or descriptive text by commonly agreed measures. In general, decision-makers need information that allows some manipulation for alternative scenarios and customizing for national or local conditions. Indicators and indices should assist in this process.

Decision-makers in Kuwait may not have the technical background or training to allow them to use information from scientific, technical or statistical sources in the most productive manner. They are likely to rely on an adviser who interprets the information for them. This requires a careful consideration of the information supplying process, to produce the critical factors from the assessment process in forms that can be understood and utilized. Indicators and indices are one approach to this problem. Another is the use of information brokers to help interpret, manage, filter and add value to the flood of available information. The information broker is a facilitator who can raise awareness about what is available, at what costs and for what purpose. It is then easy to presume that the availability of unprejudiced brokers, who assist in the analysis and interpretation of massive technical data and re-packaging of information in an appropriate format, also influences the access of information by decision-makers.

Additionally, environmental indicators/indices should - in principle - serve to inform the ongoing process of policy dialogue between Kuwait, and the international community and to lay the basis for international, regional and sub-regional co-operation and agreements. For instance, environmental indicators/indices may be seen to parallel the role of socio-economic indicators already developed and used in social and economic policy coordination by the GCC countries and Human Development Indices (HDI) developed by the United Nations. Because indicators and indices need to be viewed in a dynamic context, they are subject to revision in order to reflect the changing nature of policy prospective and public perceptions regarding the seriousness of different environmental problems.

It is important to recognize that, indicators and indices of environmental performance should be developed with reference to environmental quality, national goals, regional understandings and international agreements. Their design should also be compatible with environmental reviews. The development of environmental indicators will require a second generation of environmental statistics and analyzed information.

It is important for both KISR & RITSEC to recognize that there are many international organizations working on developing environmental indicators and that it would be useful for KISR & RITSEC to coordinate their efforts towards the development of a uniform yet flexible core set of indicators for use in monitoring and managing the Kuwaiti environment. These efforts should also be aimed at developing a limited set of highly aggregated indicators (indices) for policy making at the national and international levels.

In a study commissioned by the United Nations Environmental Program (UNEP) it was stressed on the need to focus on the quality of environmental subsystems such as soil, water and air. In the atmospheric subsystem, Air Pollution Indicators (API), Air Quality Indices (AQI), Greenhouse Effect Indicators (GHEI), and Ozone Depleting Substance Indicators (ODSI) might have the merit to be used independently as excellent tools for the management of atmospheric environment in Kuwait. They can be extremely useful in compiling and reducing large amounts of data to a simple and single indicator or index value, which conveys information from technicians to others. In addition, they can be used to detect trends, compare between different atmospheric qualities and determine the degrees of success or failure of national ongoing air pollution abatement and atmospheric protection programs. Politically, these indicators and indices can also be used to justify major expenditures, allocate budgets, communicate technical information to decision-makers and the general public at large.

Several basic uses of environmental indicators from which Kuwait can profit are listed as follows:

1. Assist decision-makers at the local level in monitoring progress toward sustainable development, in developing policies, in evaluating the effectiveness of these policies and in allocating available resources.
2. Provide government officials in Kuwait, particularly in the Ministry of Planning with a tool to further their understanding of the impact of developmental activities on environment, natural phenomena and trend analysis.

3. Support Kuwait authorities, either through governmental or non-governmental organizations, with means to focus their data collection, to define their remedial action, and to plan for their lobbying campaign.
4. Supply Kuwaiti authorities with method for regional assessment by zoning, ranking and comparing uniform environmental indicators and indices. This will help developing early warning systems for sustainable development and in designing policies that are truly responsive to the needs of the country.
5. Provide Kuwait with specifically designed indicators and indices catered to interpret and communicate changes in environmental conditions. This will help decision-makers in formulating their policies.
6. Provide the authorities with an instrument to develop policies, designed to monitor performance and raise sustainable development public awareness in Kuwait.

III-1- CHARACTERISTICS OF ENVIRONMENTAL INDICATORS:

Two requirements are strongly tied to the purpose of the indicators as follows:

1. The indicator must have a wider significance than its immediate meaning as a measured value: it must represent a larger phenomenon.
2. An indicator is principally normative, that is: comparable with an aim or reference value. It is really the difference between the desired and the actual value that steers the feedback process.

III-2- PROPOSED AIR QUALITY INDICATORS FOR KUWAIT:

Pressure (Driving Force) Indicators: Emissions

Often simple pollutants such as tons/year of SO_2 are used as indicators for air pollution in general. According to the definition of indicators, emission data can act as indicators for policy support if they can be compared with a target or reference value, such as pre-industrial emissions or emission reduction targets as compared with a base year.

Air Quality (State) Indicators: Concentrations and Deposition

Concentrations and deposition levels can be used as indicators of air quality in Kuwait. They can often be compared with air quality standards. In Kuwait, air quality is measured. The monitoring programs should be focusing on sulfur dioxide (SO_2), nitrogen oxides (NO_x), Total Suspended Particulate (TSP), Ozone (O_3), volatile organic carbon (VOC_s) and lead (Pb). These indicators can be transformed into an Air Quality Index (AQI) by mathematically aggregating these indicators using the most proper function into an index number or color.

Air Quality Response Indicators:
Air quality response indicators should indicate Kuwait government efforts through legislation's, policy options, efforts, expenditures, enforcement and other responses to the changes in the state of the air quality in Kuwait. The most relevant air quality response indicators are as follows:

1. Expenditure on air pollution abatement in US$ (per capita) or (/GDP)
2. Reductions in the emissions of SO_2, NO_x (% per year)

III-3- WATER QUALITY INDICATORS FOR KUWAIT:

In general terms, Water Quality Indicators (WQI) similar to AQI can be developed by reducing measurements of two or more water quality variables to a single number or a set of numbers, words or symbols that retain the meaning through a sequence of mathematical manipulations. However, in case of WQI the water use is a fundamental factor in the design and application of the index. For instance water that has been rated by the index as good for agricultural purposes can be rated as very unhealthful for drinking intent.
The water uses of prominent importance that can be indexed in Kuwait can be listed according to their apparent priority as follows:

FIRST: Indicators for feed water, from the marine environment, used in the **desalination industry**. This suggestion is based on the fact that the quality of sea water at the intake of the desalination plants will ultimately affect both the efficiency of the power desalination processes and the quality of the distillate i.e. product drinking water.

1. Pressure Indicators: This group will include indicators such as tons per year of petroleum inputs in the near-shore marine environment of Kuwait (in its various forms), Nutrients particularly Phosphorous and Total Nitrogen, Heavy metals, Persistent Organic Micro-pollutants such as PCBs, Chlorinated Pesticides, etc., Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). It is important also to note that emissions into the sea can occur either directly or indirectly through air deposition, precipitation of atmospheric pollutants with rainfall, ground water seepage, etc.
2. State Indicators: This group of suggested indicators can be integrated into a WQI and might encompass the following parameters by giving them different weight: (1) Total Petroleum Hydrocarbon (TPH), (2) Volatile Liquid Hydrocarbons (VLH), (3) Total Algeal Content or Chlorophyll a, (4) Total Organic Halogen (TOX), (5) Salinity, (6) Turbidity and (7) Temperature.
3. Response Indicators: Response indicators will include the efforts made on the national level either to avoid or eliminate any deterioration as reflected in the state indicators.

SECOND: Indicators for **Ground Water Quality**: Ground water quality will be mostly affected by the rate of withdrawal and/or by pollution.

1. Pressure Indicators: (1) Rate of withdrawal as a percentage of recharge of ground water, (2) Quality, volume and toxicity of land-filled industrial and domestic waste in Kuwait, (3) Number of hazardous wastes contaminated sites etc.
2. State Indicators: (1) Total Dissolved Solids (TDS) in ground water, (2) Aggregated value for the level of pollutants such as nutrients (Nitrate, Nitrite, Phosphorous), (3) Heavy Metals (Ni, Pb, Cu, Cr, etc.), (4) Micro-organics (DDT, PCBs, etc.) in parts per billion (ppb).
3. Response Indicators: (1) National investment to eliminate over-drafting of ground water resources, (2) Waste minimization via recycling in tons/year using a reference year for background, (3) Public expenditure for waste minimization programs and waste management costs.

It is important to note that the suggested lists of proposed indicators and indices are very preliminary in nature and need extensive work for completion, verification and assessment of their suitability for application in Kuwait.

IV- INFORMATION FOR SUSTAINABLE DEVELOPMENT IN KUWAIT:

It is Kuwait's declared policy to preserve environmental quality for future generations as well as for the present. It was this consideration that led to the official adoption of sustainable development as the basic national policy in environmental management. Consequently, this has put significant demands on decision making process for management. Kuwait now needs more efficient, more effective, more integrated and more reliable decisions with which it can control and develop its own environment.

In Kuwait, all sectors, ministries and agencies have collectively accumulated over the years a wealth of information. Unfortunately, this vast volume of information is currently distributed on a sectoral basis to a specialized constituency. Environmental information system under development will most probably face similar destiny, thus reducing the expected benefits to a great extent. The value of EIS for the sustainable development of Kuwait could be greatly increased by cross linking the data through interdisciplinary analysis, such as relating epidemiological data on health conditions with environmental data on pollution problems or air quality problems in a specified area such as in Shuaiba Industrial Area (SIA). Another example might be relating the amount of emissions to the air with economic information such as the gross national or domestic product and/or institutional information such as issuance of legislation and building capacities for their enforcement. This approach will require development and integration of economic, social and institutional information systems associated with agreements on standard methods and definitions so that comparisons can be made effectively.

It is important to note that chapter 40 of Agenda 21 entitled "information for decision making" calls for the development of Indicators for Sustainable Development (ISD). In particular, it requests countries at the national level, and international governmental and non-governmental organizations at the international level to develop the concept of indicators for sustainable development. In its 1995 work program the Commission on Sustainable Development (CSD) grouped the desired indicators into four categories, namely, economic, social, institutional and environmental. Steps involving the inter-linking of economic, social, institutional and environmental indicators are considered as the most critical and difficult aspects of developing indicators. Understanding the linkages among the indicators and insuring that the sum of these linkages describes a whole process of sustainable development is a multi-disciplinary joint effort task that has to be developed in a later stage.

In a country like Kuwait, it is virtually impossible to collect all of the data generated resulting from the implementation of Agenda 21. Further, even if available, these data might be meaningful for specific activities or sectors, but it is unlikely that they would tell us much about sustainable development without a higher order level of interpretation. Such interpretation requires an understanding of the following:

1. What is important (parameters)
2. What is representative (indicators)

3. How and what can be aggregated (indices)
4. How and what can be inter-linked to describe sustainable development

In Kuwait, data limitations, both in terms of balance and quality, severely hinder the quantitative assessment and reporting on the state of the environment and sustainability of development. In the 21st century, data in EIS should support the development of more holistic information, understanding and knowledge. In this connection it is important to note that although high-quality data are vital for the credibility of the developed EIS in Kuwait, a systematic approach to information generation is largely lacking. At the current stage, the wealth of environmental information generated in Kuwait tend to be scattered and still difficult to be readily obtain, while proprietary and security factors inhibit dissemination and open access. There is also a common deficiency of infrastructure and standards to facilitate the easy exchange and correlation of data from different jurisdictions and disciplines in the country.

In this connection, it is important to recognize that reaching sustainability of development can be materialized only through inter-linking information systems covering environmental, social, economical and institutional aspects in Kuwait.

V- QUALITY CONTROL & ASSURANCE OF INFORMATION:

Data on environment in Kuwait are usually derived from monitoring programs and the interpretation of remotely sensed images. In case of the atmospheric environment in Kuwait, there are four main purposes for sampling and measurement. These are:

1. Environmental surveys and investigations such as the non-recurrent studies conducted by KISR
2. Monitoring networks such as the regular monitoring conducted by the Environmental Public Authority (EPA),
3. Compliance monitoring such as the inspection monitoring conducted by EPA and the Environmental Protection Center (EPC) at the Shuaiba Industrial Area (SIA) and finally,
4. Model validation mostly conducted on ad-hoc research bases by Kuwait University (KU) and KISR.

The main constraints limiting the atmospheric measurement program are budgetary in nature particularly, following the recent slump in oil prices. However, non-monetary constraints do also exist. They include inaccessibility of preferred sampling locations particularly for monitoring stack emissions, lack of security resulting in high risk of theft or vandalism and inadequate number of well-trained nationals in the field air quality monitoring and analysis.

In water quality monitoring, the data are strongly subject to non-homogeneities created by operators while similar effects also occur naturally. Errors in laboratory experimental analysis plus changes either in monitoring or laboratory practices also lead to inconsistencies better known as systematic errors. Furthermore, censored data usually reported as Not-Detected (ND) or Zero are below detection limits and are not described numerically by laboratory practices in Kuwait. All these limiting factors eventually make the utilization of water quality data difficult and impair the reliability of output information. The data available in the developed EIS were observed to have the following limitations:

1. Missing values that are usually random or systematic. No environmental information is made available during the Iraqi occupation of Kuwait for the period nearly extending from 2nd of August 1990 to end of 1991.
2. Sampling frequencies are often changing over the periods of records.
3. Multiple observations for one sampling period. A common reason for this to occur in the water quality data record is the storage of QA/QC data in the same computer records as the original water quality observation.
4. Uncertainty in the measurement procedures due to associated random analytical errors and variations in the calibration of measuring equipment.
5. The existence of outliers due to erroneous measurements or extreme events. It is usually very difficult to distinguish between the two.

Since the inception of the EIS, KISR & RITSEC have recognized the importance of the integrity and quality of information to be fed into the system. This conception will necessitate the establishment of firm policies and requirements to ensure that minimum binding Quality Assurance/Quality Control (QA/QC) programs and/or guidelines should be a basic and an integral part of data generation, reporting, collection, compilation, storage, retrieval and dissemination. Mechanisms for quality control and standard setting should be within the purview of the EIS core to achieve the required data quality, consistency, and comparability. Guidelines and protocols for data management should be developed as an integral part of the EIS.

In support of this effort, KISR in cooperation with RITSEC should prepare and issue various guidance and informational documents to assist data generators and suppliers in incorporating appropriate QA/QC measures into their monitoring and reporting programs. Among the various suggested aspects of QA/QC that must be addressed by KISR might include the following:

1. Identification and establishment of specific information quality goals to be achieved during the environmental monitoring processes.
2. Preparation of guidelines and description of procedures that should be used to measure or assess the quality of environmental measurements obtained for updating the EIS.
3. Preparation and description of the nature of the report or reports that will be used to document the quality of the measurements.
4. Only those personnel with the responsibility of entering and maintaining databases should be provided with privileges to write and edit data in the system.

For the newly developed EIS in Kuwait, a focus on the existing monitoring and survey system might be appropriate in the short term to evaluate the data available and its suitability for reporting purposes. In this connection, it is recommended to complement the developed EIS with a database reference system or inventory providing information on database characteristics such as:

1. purpose and content,
2. data acquisition methods,
3. QA/QC,
4. methods detection limits,
5. standards,
6. maximum allowable concentrations,
7. warning levels,
8. alarm levels,
9. advisories,
10. units of measurements,
11. geographic and temporal coverage,
12. update frequency,
13. output format,

14. conditions of use, limitations, and constraints,
15. contact persons, etc.

The objectives and conceptual framework of the developed EIS would determine the organization and scope of such a reference database. Information on data collection methods, bias and error estimates, consistency controls, and definitions will help provide a reading on reliability. Furthermore, the careful comparison between data sets showing different results will be necessary to obtain and rank the most credible sources of data.

It is also imperative that all environmental data used by Kuwaiti officials for decision-making purposes be of known (documented) QA/QC. The purpose of the suggested policy is the supervision of the quality of all environmental information used as criteria in making environmental decisions, thus ensuring that such decisions are made on sound basis. Without the suggested QA/QC, policy the efforts made in developing the EIS might be jeopardized and the system will lose its credibility among the targeted users.

The establishment of information quality goals is difficult at best. The primary origin of the goals is the objective of the whole EIS. In principle, the higher the quality of data the better it will satisfy the objectives of the developed EIS. Tending to limit the quality of the generated information are the inevitable constraints associated with virtually all EIS. The expected constraints in Kuwait include limitations on resources, time, equipment, methodology and technical expertise. This trade-off must be carefully considered and evaluated by KISR and RITSEC. It is important to note that QA/QC goals must adequately satisfy the EIS objectives, otherwise the system will be unsuccessful. However, the QA/QC goals must also be reasonably achievable within the available time, resources and methodology available.

Frequently, a predominant limitation on QA/QC is the measurement methodology itself. It is the responsibility of KISR to compile and document, in a standardized format, reference information on the quality of measurements obtained or achievable with currently applicable and available monitoring methods throughout Kuwait. The compiled information will assist in determining whether the currently used methodologies are adequate for their intended purpose.

The quality of environmental data to be entered into the EIS can be reported by its generator in several different ways. The four main suggested measures of environmental data quality include data precision, data accuracy, measurement completeness and the detection limits of the analytical methods. These data quality measures are widely used around the world and provide very useful documented indicators of data quality to be entered into the developed EIS.

<u>Precision</u>: Precision is a measure of agreement among individual measurements of the same property, under prescribed similar conditions. Precision is determined by measuring the agreement among a number of individual measurements (replicates) of the same sample. The agreement is calculated as either the range (R for duplicate measurements) or as the standard deviation (s). For the applied analytical procedure,

precision may be specified as either "intra-laboratory" i.e. within the same laboratory, or "inter-laboratory" i.e. among different laboratories. Intra-laboratory precision estimates represent the agreement expected when a single laboratory in Kuwait uses a specific method to make repeated measurements of the same sample. Inter-laboratory precision refers to the agreement expected when two or more laboratories in Kuwait analyze for the same or identical samples with the same method. Precision should ideally represent the entire measurement process, including sampling, analysis, calibration, and any other components of the method.

Accuracy: Accuracy is the measure of the closeness of an individual measurement or the average of a number of measurements to the true value. It is determined by analyzing a reference material of known pollutant concentration or by reanalyzing a sample to which a material of known concentration (spike) or amount of pollutant has been added. Accuracy is usually expressed as a percent recovery (*P*).

Completeness: Completeness is a measure of the extent of valid data obtained from an earlier approved monitoring program, expressed as a percentage of the number of valid data that should have been (i.e. planned to be) collected. Completeness is not intended to be a measure of representativeness, that is, how closely the measured results reflect the actual concentration or distribution of the pollutant in the media sampled. An approved monitoring program could virtually produce 100% data completeness (all samples planned were actually collected and found to be valid), but the results may not be representative of the pollutant concentration actually present. For instance, the analysis method might be biased, or the sampling time or locations might not provide a representative indication of the actual distribution of the pollutant in the matrix sampled.

Detection Limit: The Method Detection Limit (MDL) is the minimum concentration that can be measured reliably. It is determined by measuring the variability of replicate measurements at zero or near zero concentration. The MDL is reported in concentration units as the standard deviation of the replicate near zero measurements multiplied by the appropriate Student's t-value (for a one-tailed test at 99% confidence) for the number of replicates taken.

A default value of Not Detected (ND) < than the MDL should be provided as most sample analysis results in non-detection. ND for each element or compound should be recorded into the database according to the standard analytical method used. These values can be adjusted if necessary by changes and development in the analysis techniques. If a level < than the DL is being reported, a warning statement should be displayed by the system. As with any system in active use, changes in procedure and advances in knowledge necessitate modification of the system to meet new demands. For example when laboratory techniques improve, detection levels will be lowered. This necessitates the need to change the default MDL values.

Should sampling stations be added to or dropped from the monitoring networks, menus should be made available to easily make these changes. Stations which are added should have information provided on station number, projects associated with the station, exact location, reason for addition of the station, and time frame during which the station will be used. If larger modifications to the EIS are needed, such as ability for users to personally modify or delete incorrect data, new sub-programs must be created by RITSEC.

The use of the developed EIS to verify conditions of compliance or violation entails a risk factor in the form of an environmental parameter exceeding (or non-exceeding) a critical value recognized in Kuwait as the allowed standard. In this case it is advisable to develop a sub-routine that flashes and signals any exceeding value to bring the fact to the attention of the users.

VI- INCORPORATION OF DECISION MODELS IN THE EIS:

Modeling is the stage when data are transferred into information required for environmental management. Thus, it constitutes an essential component of the decision making process. The behavior of a complex environmental system such as that of Kuwait entails a multitude of uncertainties. Thus management decisions under these circumstances need to be realized under uncertain conditions. Furthermore, decision making for purposes of solving environmental problems becomes much more complicated when the objectives and priorities of the society are considered. Therefore, several diverse but interconnected factors of technological, social political and economical nature need to be carefully evaluated for planning and management of the environment. This is the spirit of integrated environmental management the United Nations is calling for.

It is only after the accumulation of monitoring data in the EIS that variables describing the environmental processes can be investigated as time series. Recently, the problems associated with aggregated environmental processes have grown in extent and complexity. Evidently, the selection of the best alternative solution to a particular environmental problem was deemed necessary in respect of the pre-identified sustainable development objectives. Thus, optimization techniques are presently considered as significant tools to assist in the decision making process for sustainable development in general and for environmental management in particular. Concurrent with the optimization methods, simulation techniques should also be considered by KISR to exploit the EIS data to arrive at, not "the best", but better environmental decisions.

There are two kinds of models that KISR & RITSEC can develop to cover environmental processes in their broadest sense. These are decision-making models (management) and technological models. Technological models are intended to delineate the behavior of natural environmental systems based on physical, chemical and biological concepts such as fluid dynamics and biochemistry. These are mostly developed and/or adopted by the hydraulics group and dispersion models applied by the Atmospheric Group at KISR. These are basically, scientific models, which serve to pinpoint representative variables, and diverse processes that take place mostly in the local marine and atmospheric systems. As such the developed models are considered as micro-level environmental models since they are concerned primarily with the identification of real phenomena. On the other hand, KISR has to recognize that there is also a fundamental need for the development of decision or management models at the macro-level. These models will evidently serve the purposes of decision-making, long-term planning, testing and projecting the future effects of management and control strategies currently adopted by the state. These are basically optimization and simulation models, which support decisions to be made, or engineering practice to be realized specifically for the Kuwaiti environment, for which, the true nature has been identified earlier by technological models. It is important to note that in comparison with technological models developed by the

Hydraulics and Atmospheric Groups at KISR, the decision models have larger dimensions as they account for economic, political, social and legal dimensions. It is therefore safe to assume that the technological models are no more than a single component of the decision models, incorporated into either the objective function or the constraints. A technological model, i.e. an ecological model in its broadest scale, can define the physical behavior of the environmental system in Kuwait. Ecosystem models can be evaluated in two ways for the sole purpose of environmental management. First, such models can be utilized to project the behavior of a particular environmental system for a set of given inputs. This step represents a simulation approach where the model plays a purely descriptive role. Second, when standards, criteria or specific environmental management requirements are incorporated, then ecosystem models can be evaluated jointly with a decision model where the optimal levels of inputs to the ecosystem model are determined by the decision model.

As long as the problem to be investigated has to be described first as a system, then, the "decision models" suggested to be incorporated in the EIS should be developed in a latter stage when information relevant to sustainable development is compiled and integrated into the EIS. KISR should recognize that the described system can be an ecological system in its broadest sense, constituting of economic, bio-geo-physical, social, political and legal subsystems. Each subsystem constitutes a component of a larger system, so that there are continuous interchange between these systems. Once the system is specified, identifying the objective function and the associated constraints will determine the form of the decision model.

Experience from around the world indicates that most decision models were formulated as optimization models where an optimum or the best solution could be obtained for the investigated problem. Often, the results of an optimization model were confirmed by simulation techniques, especially in case of complicated systems where the relationship between various system components could not be defined analytically.

In this connection KISR should be prepared in a latter phase to establish a relationship between environment, modeling and the decision-making processes. The environment-decision making relationship can be established as the Kuwaiti society manages its natural environment by means of a selected group of decision-makers. Within the decision making process, modeling acts as a tool so that environment-modeling-decision making relationship is developed. It is also important to note that additional factors can influence this tripartite (environment-modeling-decision making) relationship. Often the socio-economic, legal and political circumstances under which decision-makers function are very different from those of the modeler so that a direct relationship between the two cannot be developed. In such a particular case, investigations in the form of policy analysis should be conducted to provide the transition between modeling and decision making. This cooperation will undoubtedly require the expertise of both modelers and decision-makers. The notable point in the process is the communication and cooperative dialog between the two groups; that is modelers must ultimately develop mathematical models that can be readily utilized by the decision-makers in Kuwait.

VII- DEVELOPMENT AND INCORPORATION OF AN EXPERT SYSTEM FOR DECISION-MAKING IN THE EIS:

It might also be advisable for KISR to establish and incorporate an expert system for decision-making in the newly developed EIS. In principle, the expert system for decision-making is an interactive computer program that encodes judgment, experience, precedents, rules of thumb, intuition, empirical knowledge, and other form of information or expertise to give knowledgeable advice on a specific environmental problem. Such a program is knowledge based and is also domain-independent reasoning system. In other words, it can be applied to other numerical reasoning tasks in domains other than environment. The accumulated expertise about the problem area can be specified in the form of a model of the decision-making process. A model in the form of judgment or experience is constituted by a set of statements in a language of a special style. The program of reasoning reads a model or models from a disk file and creates an internal data structure that drives the consultation. Thus, changing the expertise in a knowledge-based system simply involves replacing one model by another.

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خلاصة

لقد شجع الاهتمام بالتنمية المستدامة، و القلق العام المتزايد حول التهديدات البيئية في الكويت، كلاً من دائرة العلوم البيئية و الأرضية، و المركز الوطني للمعلومات العلمية في معهد الكويت للأبحاث العلمية، على التعاون مع المركز الإقليمي لتكنولوجيا المعلومات و هندسة البرمجيات في مصر، و ذلك من أجل تطوير نظام أرشيف وطني للمعلومات البيئية، يكون مخصّصاً لحاجات الكويت. يكمن هدف هذا المشروع في تحويل البيانات البيئية، التي تم توفيرها، إلى وسيلة معلومات مفيدة يمكن أن توجه صانعي القرار في دولة الكويت نحو آليات التخطيط المحلية و الوطنية. أما الهدف الأساسي من هذه المهمة، فهو إجراء تقييم للمرحلة الأولى من المشروع و اقتراح إجراءات لتعظيم استخدام نظام المعلومات البيئية إلى الحد الأعلى.

انتهت المرحلة الأولى من المشروع بإعداد نظام متكامل و متفاعل للمعلومات البيئية، و هو مقتصر مبدئياً على البيئة البحرية للكويت. و بعد إتمام مراجعة هذه المرحلة، و إجراء المناقشات مع الباحثين في معهد الكويت للأبحاث العلمية، تم تدوين عدد من الملاحظات يمكن حصرها في الآتي:

أولاً، لم تتضمن المرحلة الأولى من المشروع دمجاً للمؤشرات و الدلائل البيئية التي تساهم في تبسيط و تقليص الكم الهائل من المعلومات البيئية بهدف تبليغها إلى صانعي القرار. تقوم هذه المؤشرات بمعاونة صانعي القرار المحليين في رصد التقدم نحو تحقيق التنمية المستدامة، و إعداد السياسات، و تقييم فعاليتها، كما تساعد في توزيع الموارد المتاحة.

ثانياً، إن نظام المعلومات المطور مخصصٌ حصراً للمعلومات البيئية، لذلك لن يكون هذا النظام مناسباً لتوفير الدعم اللازم لصانعي القرار للتخطيط للتنمية المستدامة في البلد. و يمكن تعظيم قيمة هذا النظام بالنسبة للتنمية المستدامة في الكويت، و ذلك من خلال ربط نُظُم المعلومات البيئية و الاقتصادية و الاجتماعية و المؤسساتية في منظومة متكاملة.

ثالثاً، يجدر بمعهد الكويت للأبحاث العلمية اتخاذ الخطوات الفاعلة لتأسيس برنامج ضمان و ضبط الجودة المشار إليه في التقرير النهائي للمرحلة الأولى. و يمكن لمثل هذا البرنامج أن يحافظ على سمعة النظام المُطوَّر حديثاً كأرشيفٍ لمعلومات موثوقة، مفيدة،

و ذات جودة عالية. هذا و تُعتبر مقاييس جودة البيانات البيئية بمثابة مؤشرات مفيدة و موثقة يتوجب إدراجها في نظام المعلومات البيئية المعدة. و يمكن أن تتضمن هذه المقاييس دقة البيانات، و درجة انضباطها، و اكتمال القياسات، إضافة إلى حدود الاكتشاف للوسائل التحليلية المستخدمة.

رابعاً، لم توفر المرحلة الأولى من مشروع تأسيس نظام المعلومات البيئية حتى الآن أية وسائل تمثيل رياضي للتنبؤ، أو قدرات تحليلية أو محاكاة للمعايير البيئية ذات الأولوية في التخطيط و الإدارة. هذا و يمكن لهذه التصورات المعدة حصراً من خلال المحاكاة أن تعاون صانعي القرار في اختيار السياسات و التكهن بآثارها المحتملة.

أخيراً، يجدر بمعهد الكويت للأبحاث العلمية أن يقوم بتأسيس نظام خبرات لصنع القرار و دمجه في نظام المعلومات البيئية. و يكون هذا النظام مكوناً من برنامج متفاعل للكمبيوتر يحوّل أشكال المعلومات و الخبرات المختلفة إلى رموز، و يقدم النصائح حول المشاكل البيئية المحددة، بناء على دراسات حالات سابقة.