



**ECONOMIC AND SOCIAL
COUNCIL**

Distr.
LIMITED
E/ESCWA/ENR/1997/WG.1/WP.5
27 March 1997
ORIGINAL: ENGLISH

Economic and Social Commission for Western Asia

**Expert Group Meeting on
Regional Water Studies
Amman, 31 March 1997**

Item (5) of the Provisional Agenda

**REGIONAL STUDY OF PALEOGENE CARBONATE
AQUIFERS IN ESCWA COUNTRIES**

PART ONE

WORK PLAN

General background

Mesozoic to Tertiary carbonate rocks extend over wide parts of the geological province of the Arabian Shelf. The carbonate sequence, comprising predominantly limestones, dolomites, chalks, marly limestones and marls, was deposited during a long period of submersion of the Arabian Shelf under the sea, which lasted from the Middle Cretaceous until the Eocene. The carbonate sequence includes two important aquifer complexes:

- Cretaceous limestones and dolomites with major outcrops in the sub-humid northwestern part of the ESCWA region;
- Paleogene deposits comprising prevailingly limestones and chalky limestones, which extend over
 - wide parts of the steppe (Badiyah) and the Hamad areas in Syria, Jordan, Iraq and northwestern Saudi Arabia,
 - parts of western Saudi Arabia, the Gulf region, southwestern Oman and southeastern Yemen,
 - parts of the sub-humid region in Syria and Lebanon.

-
- Issues without formal editing.

A study of groundwater resources in Paleogene aquifers of the ESCWA region is included in the work program of the ESCWA - BGR cooperation project 1996-97 within the general scope of ESCWA's activities to promote cooperation between member countries in the field of management of water resources and to provide governments with the required information and capabilities for the management of shared water resources.

The main objectives of studies of regional aquifer systems, conducted by ESCWA, are:

- to promote cooperation between ESCWA countries in the field of groundwater management;
- to improve the knowledge on hydrogeologic, hydraulic and hydrochemical characteristics of the aquifer systems;
- to introduce appropriate methods for investigation, development and management of the aquifer system;
- to formulate recommendations for technical measures for rational aquifer management in selected areas.

The activities of the ESCWA - BGR cooperation project in 1996-97 include a first phase of the study of Paleogene aquifers in the ESCWA countries, which comprises:

- An evaluation of available information and presentation of an outline of hydrogeological features in thematic maps and a report;
- The formulation of proposals for more detailed studies in selected parts of Paleogene aquifers on national or sub-regional level.

Work plan for the first phase of the study (3rd Quarter 1996 - 2nd Quarter 1997)

Main activities:

- Preparation of thematic maps;
- Evaluation of literature information on geological and hydrogeological features;
- Evaluation of available hydrochemical and isotope hydrologic data;
- Drafting of report;
- Presentation of maps and report to ESCWA countries, establishment of organizational framework for and planning of more detailed studies in selected areas.

1. Preparation of thematic maps

Tentative list of maps:

Maps at approximately 1:4,000,000 scale, covering the area of extent of Paleogene deposits:

- Outcrops of Paleogene carbonate formations, prevailing lithology;
- Topography and drainage;
- Mean annual rainfall;
- Extent of major Paleogene aquifer systems;
- Groundwater contours, main groundwater discharge areas;
- Depth to groundwater;
- Structural contours of top and base of Paleogene aquifers;
- Thickness of Paleogene carbonate rocks;
- Groundwater salinity.

Maps at 1:1,000,000 or 1:2,000,000 scale for selected areas, e.g. Syria and Jordan:

- Outcrops and prevailing lithology of Paleogene carbonate rocks;
- Hydrogeological basins;
- Groundwater salinity.

Available information:

- Geological map of the Arabian Peninsula 1:2,000,000;
- Geological maps of Syria, Jordan, Lebanon 1:200,000 to 1:500,000;
- Hydrogeological maps Syria, Jordan and Lebanon;
- Hydrological Atlas of Saudi Arabia;
- Publications and reports (see attached list of references).

Information on Paleogene aquifers in Iraq presently available at ESCWA appears insufficient.

Timing: September - December 1996.

2. Evaluation of literature information on geological and hydrogeological features

Available information see list of references.

Timing: 3rd to 4th Quarter 1996.

3. Evaluation of hydrochemical data

Data available mainly from ACSAD 1983, Al-Sayari & Zötl 1978, Al-Ruwaih 1995, Boeckh et al. 1970, GITEC & HSI 1995, Hobler et al. 1991, Otkun 1975, Sen & Al-Dakheel 1986.

Timing: 3rd to 4th Quarter 1996.

4. Evaluation of isotope hydrologic data

Data available from ACSAD 1983, Al-Sayari & Zötl 1978, Clark et al. 1987, Macumber 1995.

Timing: 4th Quarter 1996.

5. Drafting of report

Tentative contents of the report:

- Geological background: Extent of Paleogene deposits, lithological distribution, paleogeographic conditions, tectonic and structural features;
- Morphologic and climatic conditions;
- Hydrogeologic conditions: Extent of aquifers, regional and local groundwater flow systems, aquifer properties in different hydrogeological areas;
- Groundwater salinity and hydrochemistry;
- Information from isotope hydrologic evaluations: groundwater recharge, paleohydrologic conditions, groundwater retention periods and long-term flow systems;
- Preliminary conclusions: Regional aquifer systems shared by different countries, known and anticipated problems of groundwater exploitation, possibilities of groundwater development and needs for groundwater management;
- Recommended study program (Phase 2).

The recommendations to be presented to ESCWA countries for joint studies on national or subregional level during phase 2. It may relate to the following:

- Review and updating of the information presented preliminarily in the report and the maps;
- Study of possibilities of groundwater development and management in the Paleogene chalk - limestone aquifers in Syria and Jordan:
 - Hama and Aleppo areas, northwestern Syria: Study for groundwater management in areas with intensive groundwater abstraction for irrigation: review of data and monitoring programs, hydrochemical and isotope hydrologic study, application of hydraulic groundwater simulation models;
 - Eastern steppe areas (Badiyah, Hamad) in Syria and Jordan: Review of data, assessment of recent recharge (natural recharge and artificial improvement of recharge), groundwater development possibilities for rural activities.
- Study of groundwater development possibilities in marginal areas of Nefud and Rub al Khali deserts:
 - Regional groundwater conditions of the Dammam aquifer in the northeastern part of the Arabian Shelf (southeastern Iraq, northeastern Saudi Arabia and Kuwait), possibilities of development of brackish groundwater, possibilities of artificial

- recharge;
- Evaluation of information on the Dammam aquifer in the central Gulf area (Dhahran in Saudi Arabia, Bahrain, Qatar): Fresh water lenses, recent recharge, flow of fossil groundwater, salt water intrusion,
- Regional groundwater conditions in Paleogene aquifers on the southern to southeastern margin of Rub al Khali: northern Hadramawt plateau (Yemen), northern Sofar and Um as Samim areas (Oman), southeastern Saudi Arabia: study of possibilities of development of fossil groundwater, assessment of recent recharge in sand dune areas,
- Hydrogeologic conditions on the northern margin of Rub al Khali (Abu Dhabi, eastern Saudi Arabia) pursuing present investigations of the Dammam aquifer in Abu Dhabi, including evaluation of information from oil exploration wells, with a view to assess quantities of stored fossil groundwater and of relationships between the Dammam aquifer and overlying shallow aquifers.

Objectives and scope of the recommended studies will be presented in detail in the report as well as the available information on hydrogeologic conditions. Possible contributions of the studies to the solution of problems of groundwater development and management will be discussed and appropriate investigation techniques will be recommended. The studies recommended for phase 2 will consider field investigations only to a very limited extent, but may provide a basis for subsequent more extensive groundwater exploration on national levels.

Timing: First draft of report until end of 1st Quarter 1997.

6. Planning of activities of phase 2 of the study

- Distribution of the report and maps to ESCWA countries;
- Setting-up of work plan and arrangements with participating countries.

Timing: 2nd Quarter 1997, preliminary contacts in 1996.

PART TWO

PROGRESS ACHIEVED

Collection and Evaluation of Information, Status March 1997

1. Activities carried out:

Activities for implementing the study "Groundwater Resources in Paleogene Carbonate Aquifers in the ESCWA Region" started in late 1996 with the preparation of base maps and collection of information and data. First drafts of digitized base maps are available presenting mainly the topography and outcrops and extent of Paleogene formations. These base maps have still to be reviewed and modified, they can serve, however, already now as background for the compilation of various thematic maps at scales 1:500,000 to 1:5 million. Various hand drafts extracting hydrogeologic features from existing maps have been prepared, which will be used for the compilation of digital thematic maps.

Around 100 publications, reports and maps with information relevant to the study have been collected. The information base to be created covers the geological province of the Arabian Shelf which includes parts of 12 ESCWA countries. Egypt, the area east of Euphrates and the Oman Mountains are not considered, for the time being. The list of references comprises further 100 relevant reports which are, however, not available presently at ESCWA HQ for the evaluations.

A preliminary correlation of Paleogene formations occurring in different parts of the region has been made from the available literature (App. 1). For the mapping of Paleogene outcrops, a schematic sub-division of Paleogene formations into three main litho-stratigraphic units has been applied:

- Lower Unit: Paleocene to Lower Eocene, Umm er Radhuma Formation and corresponding formations;
- Middle Unit: Lower to Middle Eocene, subdivided into Rus and Dammam Formations and into Lower Eocene and Middle Eocene in some areas;
- Upper Unit: Upper Eocene, occurring prevailingly in Syria.

These main units comprise the following litho-stratigraphic series in different parts of the region:

Lower Unit: Paleocene to Lower Eocene:

- Umm er Radhuma Formation on the Arabian Peninsula and southern Iraq;
- the Limestone - Chert Series (Umm Rijam Formation, Belqa 4) in southeastern Jordan;

- an outcrop strip of silicified limestones and dolomites extending in the eastern Hamad along the boundary to outcrops of Upper Cretaceous rocks on the western flank of the Rutbah - Hail Arch.

Middle Unit: Lower to Middle Eocene:

- Rus and Dammam Formations on the Arabian Peninsula and southern Iraq;
- Lower Eocene Chert Limestone Series in the Hamad and Syria, including Paleocene to Lower Eocene marls and chalks in limited areas of Syria;
- Middle Eocene chalky and nummulitic limestones in Syria and the Hamad;
- undifferentiated Lower Eocene - Middle Eocene formations:
 - limestones and nummulitic limestones with cherts in the surroundings of Wadi Sirhan in Jordan and northwestern Saudi Arabia.

Upper Unit: Upper Eocene.

The preliminary legend for the map of Paleogene outcrops is shown in App.2.

The results of a first regional review of information on hydrogeologic conditions are summarized in Para.2.

2. Preliminary outline of regional hydrogeologic conditions:

According to the regional geologic and hydrogeologic conditions, the Paleogene aquifer system of the Arabian Shelf can be divided into four hydrogeologic sub-provinces:

- the North Arabian Platform covering parts of Syria, Jordan southwestern Iraq and northwestern Saudi Arabia;
- isolated Paleogene aquifers west of the rift zone in Palestine, Lebanon and Syria;
- the northern Gulf Basin extending over parts of Saudi Arabia, southern Iraq and including Kuwait, Bahrain and Qatar;
- the Rub al Khali Basin covering the Rub al Khali desert and its surroundings in Yemen, Oman and the UAE.

General characteristics of these sub-provinces are:

North Arabian Platform

The Paleogene deposits of the North Arabian Platform constitute deposits of a marine transgression of the Mediterranean Sea and are separated from the Paleogene of the Gulf Basin by the Hail - Rutbah uplift structure. The Paleogene rocks of the North Arabian Platform are prevailingly chalks, marly limestones and cherts, providing a fissure type aquifer with generally moderate productivity. Upper Cretaceous to Paleocene marls act as a regional aquitard, separating the Paleogene aquifer from the underlying Upper Cretaceous carbonate aquifer. On structural and

paleogeographic highs, the Paleogene becomes unsaturated, except for local perched aquifers.

The Palmyrean mountain chains separate the Paleogene aquifer system of the North Arabian Platform into a northern and southern block:

- the Aleppo - Hama area in northern Syria;
- the Hamad - Wadi Sirhan area (southern Syria, eastern Jordan, southwestern Iraq, northwestern Saudi Arabia).

The Paleogene of the North Arabian Platform comprises, in general, a single aquifer which may be locally subdivided by low permeability layers. Present-day recharge is significant in the northwestern parts of the sub-province with average annual rainfall of 300 - 400 mm. In the dry southern and eastern parts, recharge is restricted mainly to infiltration of sporadic wadi runoff.

Groundwater flow is directed towards areas of discharge in springs and sabkhas:

- closed basins: Jaboul, Matah, Azraq;
- the Euphrates river in the northeast;
- mainly indirectly through leakage into underlying aquifers to the Orontes in the west.

Areas west of the rift zone

Paleogene aquifers of limited extent occur in synclinal structures of the Judean highlands and the Lebanon and Ansariyeh mountain belts.

Northern Gulf Basin

Paleogene aquifers of the northern Gulf Basin constitute part of a complex regional aquifer system, including:

- a deep sandstone aquifer (Wasyah Formation);
- a middle aquifer: Aruma and Umm er Radhuma Formations (Upper Cretaceous, Paleocene);
- an upper aquifer: Paleogene Dammam (Khobar and Alat) Formation and Neogene to Quaternary formations.

The middle and upper aquifers appear, o a regional scale, hydraulically connected.

Karstified sections of the Umm er Radhuma and Dammam Formations provide, in some areas, aquifers with high productivity.

Groundwater movement is generally directed from outcrop areas of the Paleogene in the west to the Gulf coast and the Euphrates in the east and northeast, respectively.

Present-day recharge is limited in the very arid sub-province, but fresh water lenses related to recent recharge are known to occur.

Rub al Khali Basin

The Rub al Khali Basin adjoins the northern Gulf Basin to the south without strict separation and comprises a complex aquifer system similar to the northern Gulf Basin. The Umm ar Radhuma aquifer appears, however, to be situated at considerable depth in wide parts of the basin. The Paleogene is, to a large extent, covered by the Rub al Khali sand sea.

Some present-day recharge apparently occurs in the mountain areas of Hadramawt, Dhofar and central Oman. Groundwater movement is directed from the western, southern and southeastern margins of the Rub al Khali towards large sabkha areas within the desert and on the Gulf coast.

Overlying and deeper aquifers

In parts of all four sub-provinces, the Paleogene formations are covered by thick Neogene - Quaternary sedimentary or volcanic rocks, e.g. in the Ad Daw and Wadi Sirhan basins, the Euphrates depression, the Dibdiba Basin and the Jebel Arab basalt field. Hydraulic and hydrochemical relations with these overlying formations, as well as with underlying Mesozoic carbonate or sandstone aquifers, will have to be considered in the study.

Groundwater salinity

The groundwater salinity is generally low to moderate in the northwestern part of the North Arabian Platform and in the isolated Paleogene aquifers west of the rift zone. Brackish groundwater prevails over most of the Hamad - Wadi Sirhan area, the northern Gulf Basin and the Rub al Khali Basin. Fresh water or slightly brackish water occurs, however, in lenses or relatively extensive tongues in various parts of these areas. Groundwater with high salinity extends over the centers of closed basins, sabkha areas and along the Gulf coast.

Groundwater potential

The groundwater potential of the Paleogene aquifers may, in a very general and tentative view, be defined as follows:

- Moderate quantities of fresh renewable groundwater resources occur in the sub-humid to semi-arid northwestern parts of the region;
- The northern Gulf and Rub al Khali Basins contain huge quantities of brackish groundwater which is, to a large extent, non-renewable;
- Limited quantities of fresh groundwater occur in lenses or tongues in various parts of the arid areas, originating from recent or fossil recharge.

The main challenges of utilization of the water resources appear to be:

- Safe management of limited renewable fresh water resources;
- rational extraction of extensive non-renewable resources of fresh to slightly brackish groundwater;
- Conservation of the quality of exploitable water resources.

The study aims at contributing to these objectives through a regional comparative evaluation and presentation of available information.

3. **Envisaged programme of evaluations:**

The evaluations will result in a descriptive presentation of relevant information on hydrogeologic and hydraulic features, groundwater quality pattern and hydrochemistry. Information derived from isotope data will be included.

The following parameters will be presented on thematic maps:

- Outcrops of Paleocene - Eocene Formations on the Arabian Shelf;
- Main structural and tectonic features (Arabian Shelf and Arabian Shield);
- General orography and mean annual rainfall (Arabian Shelf and Arabian Shield)
- Main geomorphological features;
- Extent of major Paleogene aquifer systems;
- Structural contours and thickness of Paleogene aquifers;
- Groundwater flow systems;
- Groundwater salinity distribution;
- Aquifer productivity (well yields, hydraulic properties);
- Age of groundwater.

The maps will be compiled mainly through transfer of relevant features from existing maps and documents into computer files. This method facilitates

- the incorporation of information from existing maps at highly different scales;
- repeated plotting of draft maps or working documents during various stages of the evaluation;
- correction and modification of drafts;
- incorporation of supplementary information which becomes available at any stage of the evaluations.

For data processing and map preparation, the following hardware is used:

- a personal computer with relatively high capacity;
- a digitizing unit with A1 size tablet;
- an A1 size plotter using ink-jet technology.

The computer programme used for map preparation is AutoCAD, supported by a number of commercial software programmes:

- Spread sheets: QuattroPro, Excel
- Graphics programs: Surfer, Designer
- Word processor: WordPerfect
- Statistic data processing: Statgraphics
- Hydrogeologic and hydrochemical data application: GWW - Groundwater Software for Windows

The preliminary report and maps are expected to be ready for distribution to the countries by the end of 1977. A considerable part of the information presently available for evaluation originates from studies carried out many years or even decades ago. The required updating of the information may be achieved through review and comments of national institutions after receiving the report. It would, however, appear, preferable if up-to-date information could be made available already during 1977. Missions of concerned ESCWA staff to national institutions may be arranged for that purpose, if required.

	Saudi Arabia	Southern Iraq	Hamad	Syria	Jordan
Oligocene			sandstone and sandy limestone	terrigeneous sediments, clay, carbonate rocks	Tayyiba F.
Upper Eocene			limestone	carbonate, clayey and sandy sediments	Wadi Shallala chalk
Middle Eocene	Dammam F.: limestone and marl, up to 260 m	Dammam F.: dolomitic and marly limestone, 100 m	chalky limestone	prevailing chalky and nummulitic limestone	Umm Rijam chert F.
Lower Eocene	Rus F.: chalky limestone, marl, anhydrite, shale, 20-100 m	Jil or Rus F.: marl, dolomitic limestone, anhydrite, 50 m	chert, limestone, marly limestone	limestone with chert	
	Umm er Radhuma F.: chalky and dolomitic limestone, dolomite, chert, 320 m	Umm er Radhuma F.: chalky and marly limestone, dolomite, anhydrite, 300 m	northern and western Hamad: chalky limestone and marl; eastern and southern Hamad: limestone and dolomite	marl, clay, argillaceous limestone	
Paleocene					Muwaqqar chalk marl F.

Appendix 1: Correlation of Paleogene formations

a) Arabian Shelf

			Dhahran	Qatar	Bahrain
Middle - Lower Eocene	Dammam Formation	Alat limestone and marl	chalky dolomitic limestone, dolomitic marl, 0-145 m	Abarug: dolomitic limestone, marl, 10 m	limestone, partly dolomitic, 80 m, shale and marl
		Khobar limestone and marl	dolomitic limestone, marly limestone and marl, 0-75 m	Simsima: dolomite, limestone, 30 m	limestone, 40-55 m
		Alveolina limestone	limestone with shale and marl, 0-20 m	Alveolina limestone, 1 m	shark tooth zone
		Saila and Midra shales	shale with gypsum lenses, 0-20 m	Midra shale and Fhailil limestone, 6 m	
Lower Eocene	Rus Formation		chalky limestone, marl, anhydrite, shale, 20-100 m	dolomite, limestone, thick bands of gypsum, 28-44 m	chalky zone
Lower Eocene - Paleocene	Umm er Radhuma Formation		chalky and dolomitic limestone, dolomite, chert, 320 m	dolomite, chert bands, marl 300 m	dolomitic limestone, lenses of gypsum and anhydrite, 350-400 m

Appendix 1: Correlation of Paleogene formations

b) Northern Gulf area

			Saudi Arabia	Eastern Yemen	Southern Oman
Middle - Lower Eocene	Dammam Formation	Alat limestone and marl	chalky dolomitic limestone, dolomitic marl, 0-145 m	Habshiye F.: limestone, carbonate sandstone, interlayers of shale, marl and minor gypsum, 220 m	limestone
		Khobar limestone and marl	dolomitic limestone, marly limestone and marl, 0-75 m		
		Alveolina limestone	limestone with shale and marl, 0-20 m		
		Saila and Midra shales	shale with gypsum lenses, 0-20 m		
Lower Eocene	Rus Formation		chalky limestone, marl, anhydrite, shale, 20-100 m	Rus F.: gypsum, anhydrite, clay, marl, 300 m	chalky limestone, marl, evaporite beds
				Jeza F.: limestone, clay, gypsum, 100-150 m	
Lower Eocene - Paleocene	Umm er Radhuma Formation		chalky and dolomitic limestone, dolomite, chert, 320 m	limestone, dolomite, 300-400 m	limestone, 80-300 m
					dolomitic limestone, 250-300 m

Appendix 1: Correlation of Paleogene formations
c) Arabian Peninsula

		Arabian Peninsula and southern Iraq	Northwestern ESCWA region
	6		Paleocene to Eocene undivided
Upper Unit	5		Upper Eocene limestone series
Middle Unit	4a	Isolated outcrops of Rus and Dammam Formations in the Rub al Khali sand sea	
	4	Rus and Dammam Formations undivided	Lower - Middle Eocene chalk limestone with marl and chert
	3	Lower to Middle Eocene Dammam Formation	Middle Eocene chalky and nummulitic limestone series
	2	Lower Eocene Rus formation	Lower Eocene chert limestone series
Lower Unit	1a	Outcrops of Umm er Radhuma Formation in wadis	
	1	Paleocene to Lower Eocene Umm er Radhuma Formation	Paleocene to Lower Eocene limestone chert series

Appendix 2:

Preliminary legend for map: Outcrops of Paleocene - Eocene formations on the Arabian Shelf



