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**THEMATIC MAPPING FOR DEVELOPMENT AND MANAGEMENT OF
SHARED WATER RESOURCES IN THE ESCWA REGION**

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**Thematic Mapping for Development and Management of Shared Water
Resources in the ESCWA Region**

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Thematic mapping for development and management of shared water resources in the ESCWA region

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Abstract

ESCWA is carrying out studies and mapping of regional aquifer systems within the general scope 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.

Preparation of thematic maps of water resources is included in the following recent activities of ESCWA:

- A project entitled "Assessment of water resources in the ESCWA region using remote sensing and GIS techniques";
- An investigation of the regional basalt aquifer system in Jordan and Syria;
- A regional study of carbonate aquifers of the Lower Tertiary in the ESCWA region.

The methods applied for data compilation and processing and for map preparation are discussed on the example of the investigation of groundwater resources in the basalt field extending over 25,000 km² in southwestern Syria and northern Jordan, which has been carried out by ESCWA in cooperation with national institutions of both countries. The study comprised an evaluation of existing data and information through an iterative process of data processing, digitizing of relevant features from maps, plotting of maps as working sheets and drafts and discussion with specialists of national institutions in Jordan and Syria. The main results of the study are the presentation of 15 thematic maps to be used for the purposes of water resources planning and the provision of regional information to the national institutions. The presented information is, to some part, directly applicable to the planning and execution of measures of groundwater development and management, e.g. in connection with the quantitative assessment of groundwater resources, the adequate design of irrigation schemes or the delineation of prospective groundwater exploration areas.

ESCWA's water resources mapping program

ESCWA is the regional Economic and Social Commission of the United Nations for 13 Arab states in Western Asia. The ESCWA region is situated prevailing in zones with semi-arid to

¹ 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.

arid climate, only some mountain areas on the northwestern, southwestern and southeastern fringes of the region have Mediterranean or monsoonal sub-humid climate conditions with relatively reliable rainy seasons of limited duration (Fig. 1). Accordingly, water resources are, in general, limited and increasing exploitation of groundwater and surface water is creating serious and wide-spread problems of depletion of water resources and deterioration of water quality. Water shortages are already a reality in several ESCWA countries.

To achieve a balance between water availability and the growing water requirements for the socio-economic development, a rational management and conservation of the water resources are needed.

ESCWA's activities related to water resources management in the member countries aim at improving the information base and the technical know-how through information exchange, execution of joint studies of shared water resources and introduction of appropriate technologies. Particular attention is given to the study of groundwater resources of sub-regional extent which are essential sources of water for domestic supply and irrigation in particular in the vast dry zones of the region.

The objectives of regional studies of water resources in extensive aquifer systems, being conducted by ESCWA, are:

- to establish an information base of the aquifer system and to provide related regional information to the member countries,
- to promote cooperation between ESCWA countries in the field of groundwater management,
- to formulate recommendations for technical measures for rational aquifer management in selected areas.

An important and indispensable tool for the assessment of ground water resources of sub-regional extent is the preparation of thematic maps delineating the distribution of various aquifer parameters and features related to groundwater occurrence and use. The maps serve as basis for regional evaluations and provide a medium to present the results of evaluations to the concerned institutions and authorities in the member countries.

Preparation of **thematic maps of water resources** is included in the following recent activities of ESCWA:

- A project entitled "Assessment of water resources in the ESCWA region using remote sensing and GIS techniques";
- An investigation of the regional basalt aquifer system in Jordan and Syria;
- A regional study of carbonate aquifers of the Lower Tertiary in the ESCWA region.

The project entitled "**Assessment of water resources in the ESCWA region** using remote sensing and GIS techniques" was supported by the United Nations Environment Programme (UNEP) and the Islamic Development Bank and was executed on behalf of ESCWA by the Royal Jordanian

Geographic Center. Maps prepared in the framework of the project included:

- Regional hydrological maps 1:2,500,000, presenting major catchment areas, drainage lines, rivers and other major water bodies, lakes, dams and rainfall distribution;
- A regional hydrogeologic map 1:2,500,000;
- Hydrogeologic maps at 1:1,000,000 scale for three major shared groundwater basins:
 - Paleozoic sandstone aquifers in Jordan and Saudi Arabia,
 - the Paleogene Dammam aquifer in Saudi Arabia, United Arab Emirates, Iraq and Bahrain,
 - Upper Cretaceous and Paleogene carbonate aquifers in Jordan, Saudi Arabia, Iraq and Syria.

These maps show groundwater flow pattern, water quality, aquifer boundaries, existing development areas, potential areas for future development.

The maps have been prepared using information from existing maps and reports and evaluations of images of NOAA meteorological satellites and Landsat Multispectral Scanner images.

The project was completed in early 1996.

The investigation of the regional basalt aquifer system in Jordan and Syria was carried out by the ESCWA Energy, Natural Resources and Environment Division in cooperation with the Water Authority of Jordan and the Department of Irrigation and Water Resources of the Syrian A.R., with advisory support by the Federal Institute for Geosciences and Natural Resources (BGR, Hannover, Germany).

The investigated regional basalt aquifer system of the North Arabian Volcanic Province is constituted by Neogene to Quaternary basalt flows which cover an area of around 25,000 km² in southwestern Syria and northern Jordan in a thickness of up to several hundred meters. The basalt flows contain groundwater resources of regional extent and, in some areas, local perched groundwater occurrences. The basalt aquifer system provides important sources for water supply and irrigation on local scale and also for town and city water supply through extensive pipeline systems.

The main immediate objectives of the ESCWA study of the basalt aquifer system are:

- to establish an information base on the hydrogeological conditions of the basalt aquifer region, which is needed for sustainable management of the groundwater resources;
- to formulate proposals for further studies and technical measures for water resources development, management and conservation in specific areas;
- to introduce appropriate methods, such as remote sensing and isotope hydrology, for groundwater exploration and management in the basalt aquifer area.

The long-term objective of the project is to achieve an optimized sustainable management of the available water resources in the basalt aquifer region.

The study included preparation of 15 thematic maps at 1:500,000 to 1:1,000,000 scale in addition

to numerous draft maps as working documents and A3 size maps for data presentation. The methods of data compilation and processing and of map preparation are discussed in more detail in the next chapter.

The study was completed recently.

A regional study of carbonate aquifers of the Lower Tertiary (Paleogene) in the ESCWA region has just started. Activities planned for 1996-97 in that connection are intended to initiate an improved regional assessment of groundwater resources in Mesozoic to Tertiary carbonate formations which extend over wide parts of the Arabian Peninsula and the northern Arabian countries. The carbonate formations may be considered to constitute, besides the Paleozoic sandstones, the geological sequence comprising the most extensive and most important aquifers of the ESCWA region.

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 prevailinglly 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 eastern Saudi Arabia, the Gulf region, southwestern Oman and southeastern Yemen,
 - parts of the semi-arid to sub-humid region in Syria, Lebanon and Palestine.

As a first step to an assessment of the groundwater resources of the Mesozoic to Tertiary aquifers, an evaluation of available information on the Paleogene aquifers has been initiated, which will be accompanied by a presentation of an outline of hydrogeologic features on thematic maps. The maps will comprise the area of extent of the Paleogene aquifers in the northern and northeastern parts of the ESCWA region (Jordan, West Bank, Lebanon, Syria, southwestern Iraq, northwestern Saudi Arabia) and in the central and eastern parts of the Arabian Peninsula. Techniques of data processing and map preparation will be similar to methods described in the next Chapter. Mapping scales will be 1:1,000,000 to 1:5,000,000.

Thematic maps for groundwater development and management in the regional basalt aquifer system of Jordan and Syria

For conducting an investigation of the regional basalt aquifer system in Jordan and Syria, the following situation had to be considered:

- Resources of manpower, which are available for regional studies of water resources to an UN agency like ESCWA, are very restricted;
- A limited time frame had to be observed;

- A considerable amount of geologic and hydrogeologic data was available, but the density of observations in different parts of the study area is highly inhomogeneous.

Considering these conditions, the evaluations were based on an integration of information available from earlier studies in different parts of the area, application of computer techniques for data processing and map preparation and on statistical data evaluation in a wider areal context rather than interpretation of individual data.

Hydrogeologic data were supplied by the participating institutions of the both countries as digital files or data lists and were retrieved from documents, reports and publications. Interpretation of satellite images was used for mapping of geological units of the basalt field and of land use, in particular irrigation areas.

Thematic maps prepared for the study comprise:

- Topographic map of the basalt complex and its surroundings
- Main lithostratigraphic units of the basalt complex and its surroundings
- Geological map of the basalt complex
- Drainage system
- Mean annual precipitation
- Groundwater contours
- Depth to groundwater
- Well yield
- Groundwater salinity
- Thickness of Neogene to Quaternary basalt
- Structural contours of base of basalt
- Structural contours of base of Paleogene chalk formation
- Saturated thickness of the aquifer
- Irrigation areas.

Additionally, geological sections and maps (A3 size) presenting ranges of values of hydrochemical and isotope hydrologic parameters were prepared.

Interpretation of Landsat 5 Thematic Mapper **satellite images** was used for mapping of geological units of the basalt field and of land use, in particular irrigation areas.

Preparation of a new uniform geological map appeared necessary, as an adequate correlation of geological units of the basalt complex, shown on existing maps of Syria and Jordan, was not achievable. For the geological interpretation, satellite image data were processed through various combinations of the 7 spectral bands of Thematic Mapper in the visible, infrared and thermal infrared sections of the spectral range and application of color filters. The processing provided an enhancement of differences in the reflectance of various basalt units with different age and mineralogical composition. Hard copies in the scales 1:100,000 to 1:500,000 were then produced for visual interpretation.

The main results of the geological interpretation are:

A synoptic model of the Neogene to Quaternary basalts was developed at 1:250,000 scale and a differentiation of the basalt series and mapping of the outcrops of different units was achieved in adequate detail over the whole study area. The basalt sequence was subdivided into a sequence of various Neogene plateau basalts and of Quaternary shield basalts and valley-filling lava flows. Particular hydrogeologic features can be attributed to different types of basalt flows, e.g.: specific drainage patterns on the surface of basalt flows indicate particular infiltration conditions, occurrences of perched groundwater at shallow or intermediate depth are prevalingly related to alternating sequences of pervious and low-permeability layers in extensive plateau or shield basalt flows.

The geological map produced from satellite image interpretation was digitized and converted with AutoCAD into a reproducible colored map at 1:500,000 scale.

Compilation of most maps presenting hydrogeologic features comprised:

- an evaluation of data stored in digital files including coordinates of observation points,
- transfer of relevant features shown on existing maps from various parts of the study area into computer files through digitizing: e.g. groundwater contours or structural contours.

Main **hardware** units used for data processing included:

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

The following commercial **software** was applied for data processing and map preparation:

- AutoCAD,
- Data bank: Access
- Spread sheets: QuattroPro, Excel,
- Graphics programs: Surfer, Designer,
- Word processor: WordPerfect,
- Statistic data processing: Statgraphics,
- Hydrogeologic and hydrochemic data application: GWW - Groundwater Software for Windows.

A rather simple digitized topographic base map was used as background for the maps for geographic orientation.

The maps were plotted initially as working documents presenting e.g. data values or statistically classified ranges of values. After scientific interpretation of data distributions, maps presenting generalized hydrogeologic features, such as contour lines or distribution of ranges of different parameter values, were plotted as drafts for review and discussion with specialists of the concerned national institutions. After required corrections and modifications, the final maps were produced.

The cartographic quality of PC produced maps certainly has still its limitations. The applied procedure has, however, significant advantages in particular for the purpose of map preparation within relatively short lived projects:

- Data compilation, data input into digital files, plotting of draft maps or working sheet and data interpretation are made simultaneously in an iterative process.
- As soon as data and relevant geometric parameters, such as lines or areas, are stored in digital files, repeated plotting and modification of the contents and appearance of the maps can be made without high effort.
- Relevant features already shown on existing maps with highly varying scales can be incorporated through digitizing and automatic adaption to the desired mapping scale.
- For the final printing of maps, no additional cartographic work is required.

The applied procedure involves the following **technical requirements and expertise**:

- Relative advanced computer hardware and software as listed above with an investment of around 20,000 US \$ at present duty-free prices;
- a hydrogeologist - or, more generally, a scientist specialized in the field to be treated by the maps - with particular experience in application of AutoCAD for map preparation and extensive experience in the handling of computer software: data bank management, graphics and data processing programs, digitizing,

or

- a team of a scientist - or several scientists - and a technician highly skilled in application of the above cited software.

Purchase of plotter supplies: special plotter paper, ink cartridges, constitutes a considerable cost factor.

Reproduction of final map copies from the plotter is considered competitive with regard to cost and time for limited numbers of copies, say some tens of copies of one map. Plotting of one copy of an A3 size colored map with a modern plotter using ink jet technology takes between 5 and 15 minutes in addition to the time required for transmission of the plot file for the first copy of one map.

Development and management of groundwater resources are responsibilities within the national scope of each country. The joint evaluation of information and data from aquifers or groundwater basins shared by two or more countries and the presentation of the information on maps can be very useful tools for conveying the existing knowledge for planning and management of groundwater exploitation. The exchange of technical and scientific knowledge between neighboring countries can support the national activities and can provide information directly applicable for the planning and execution of measures of groundwater development and management. Some examples can be given from the basalt aquifer study in Jordan and Syria:

Experience from Jordan proves that intensive irrigation on the basalt can have a severe impact on the groundwater quality even in areas where the groundwater surface is situated

at more than 100 m depth below the surface. The necessary rehabilitation of soil and water leads to high costs which can be avoided if irrigation schemes are, from the beginning, designed adequately.

Isotope hydrological studies across the national boundaries provide a reliable information basis on regional groundwater flow conditions, which is essential in particular for the quantitative assessment of groundwater resources in the Jordanian part of the area.

Results of exploratory drilling in Jordan together with the regional hydrogeologic evaluation permit the delineation of prospective areas in the Syrian part of the basalt field, related to the possible extent of a particularly productive aquifer sequence of basalt and underlying Upper Cretaceous limestones and dolomites.

From satellite image interpretation and the regional hydrogeological evaluation, areas can be delineated where infiltration conditions and the geological structure favor the occurrence of exploitable groundwater at shallow to intermediate depth.

References

- ESCWA, 1996: Investigation of the regional basalt aquifer system in Jordan and Syria. Report Economic and Social Commission for Western Asia, Amman.
- RJGC, 1996: Assessment of water resources in the ESCWA region using remote sensing and GIS techniques. Report Royal Jordanian Geographic Center, Amman.
- United Nations, 1982: Ground water in the eastern Mediterranean and Western Asia. Natural Resources Water Series, 9, New York.

Figure 1
Water resources mapping in the ESCWA region, location sketch map

