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REPORT ON THE IMPLEMENTATION OF PAP IN 1992 AND ACTIVITIES SCHEDULED FOR 1993:

WATER RESOURCES MANAGEMENT

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1. BACKGROUND

Already at the launching of PAP activities, the water resources management was defined by the Contracting Parties to the Barcelona Convention as one of the priority areas. At that basis, PAP has developed the concept and programme of the priority action "Water Resources Management in Mediterranean islands and Water Deficient Coastal Areas".

In the course of PAP development, the priority action relative to water resources management was steered to the water supply problems of smaller Mediterranean islands. As a result, the 1984-85 PAP workplan relative to water resources issues envisaged the launching and implementation of the action entitled "Water Resources Development of Islands and Isolated Coastal Areas". At the end of that period, PAP organized, in collaboration with WHO/EURO and Gobierno de la Comunidad Autonoma de las Islas Baleares, Consejeria de Obras Publicas y Ordenacion del Territorio, the Seminar on Water and Sanitation in Small Mediterranean Islands and Isolated Coastal Areas, which discussed the development of the programme. In the period 1986-1987, this action was extended to water resources development of large Mediterranean islands and coastal zones. The results of that period were presented and discussed at the seminar "Water and Sanitation Problems in Big Mediterranean Islands and Isolated Coastal Zones with Fluctuating Population Due to Tourism", Malta 1986. After that, the major activities within this action were related to wastewater reuse for agricultural and other purposes. One of the activities was also the preparation of the Malta Water Resources Project.

At the seminars (Palma de Mallorca, October 1986, and Malta, December 1986) it was recommended that, in the course of the future activities within the priority action, several pilot projects should be organized in order to analyze the methodology and gather the necessary knowledge and experience of interest for the Mediterranean and wider areas.

Departing from those recommendations, the Government of Malta suggested that the island of Malta be considered a pilot area for the development of the technology related mathematical model relative to water resources management.

Consequently, PAP suggested the project to last four years; within that project methodologies for an integrated water management system were to be developed, both for the watershed and the water supply system. In order to realize that Project, the Government of Malta, with the support of the EC, secured the necessary funds for the work performed in Malta, while international support was secured by PAP, mainly through the international consulting, development of software, training, and some necessary equipment. The Project proposal had been worked out by Maltese experts in collaboration with PAP/RAC, Split.

The Project proposal was submitted for international competition, and preliminary proposals for the study were received from four companies. Upon a review of the preliminary proposals, the company "Bureau de Recherches Geologiques et Minieres" (BRGM) of Orleans, France, was selected as the most appropriate one.

The agreement relative to the "Study of the Fresh Water Resources of Malta" was signed at the Secretariat for Water and Energy in Valetta on June 17, 1989.

2. PROJECT HISTORY, CONCEPT AND OBJECTIVES

Malta is one of the smallest islands in the Mediterranean with a surface area of 280 sq km and a population density of 1,000 inhabitants per sq km. The provision of adequate water supplies has always been a major problem since water is one of the elements needed to support the country's rapidly developing economy. However, the geology of the island, its climate and topography do not easily favour the occurrence of natural groundwater in sufficient amounts to cater for all the needs of the island. Furthermore, the quality of these natural resources is constantly threatened by overwithdrawal and surface pollution. The island consumes an average of 118,000 m^3/day, which is obtained from groundwater sources (46%) and Reverse Osmosis Plants (54%).

Faced with this situation, the Water Corporation, within the cooperative programme with PAP, decided that an assessment of the quality and quantity of all available groundwater was a necessary element in the formulation of a long-term policy of global water development and management. The Government, therefore, embarked on a detailed aquifer study with two main objectives:

(i) to optimize the exploitable groundwater resources in terms of quantity and quality;

(ii) to protect the aquifers from pollution.

The study was conducted within the frame of PAP activities and was earmarked as a pilot project for other Mediterranean islands. It was implemented by BRGM who provided the necessary expertise, together with the Water Services Corporation.

The optimization of the various available production sources, including desalination, was examined in connection with quality and economic constraints. Groundwater is the cheapest source, but its inferior quality arising from a long record of overextraction and pollution suggests the need to rehabilitate the hydrodynamic equilibrium of the mean sea level aquifer in order to secure improvements for health and environmental reasons (especially in the light of the country's application to join the EC, when stringent quality standards would need to be meet). These were the general terms of reference of the whole project.

General Project objectives can be summarized as follows:

- To safeguard human health by the protection of the natural resources of the Malta island.

- To protect the quality of the environment, particularly the fresh water resources, by introducing the necessary administration and infrastructure to ensure the continuing operational control of fresh water utilization.

- To promote the introduction of system engineering practice made suitable for the optimal control of fresh water utilization.

- To develop mathematical models which will permit effective management of aquifers, particularly with regard to: minimization of salt water intrusion; maximization of net recharge of the aquifer; identification of a wellfield configuration which will maximize groundwater extraction for the supply; development of a management strategy for the protection of water quality from the surface sources of pollution.

- To provide expertise capable of monitoring the previously mentioned items.

- To secure protection of water supply sources against pollution by unidentified factors to be taken into account in the national land-use policy.

- To propose a suitable organization, and advise appropriate legislative and other measures to meet the objectives of the project.

PAP objectives. The proposal concerns the development of the model for the study of the groundwater management in small islands, with the ultimate goal of providing a generalized model applicable in the Mediterranean conditions, useful in determining appropriate solutions for such problems.

Specifically, the objective of the proposal was to develop a computer model for the simulation of groundwater flow by utilizing the island of Malta as a case study, and to examine the ways by which research findings can be applied to other islands similar to Malta.

The development of this model and its application on the example of Malta will significantly improve the knowledge of the characteristics of the groundwater in islands, and will make possible for its efficient application ensuring the protection of the human health by the protection of the natural resources.

UNEP-PAP will be using the Study of the Fresh Water Resources of Malta as a pilot for training and for similar studies of aquifers

in other countries. Malta would in future become a centre for training and other activities relative to groundwater management organized by UNEP-PAP/RAC.

The Project document was formulated by PAP and the Water Services Corporation, envisaging the following activities:

(a) assessment and evaluation of existing data and bibliography;

(b) collection and compilation of reliable aquifer parameters that could be later used to feed the mathematical models;

(c) setting up a databank having databases for time-dependent and time-independent data;

(d) formulation of policies of groundwater protection against pollution;

(e) mathematical modelling; these models were to be used as management tools, and, within the PAP framework, as training tools for Mediterranean experts and institutions;

(f) training of local staff.

The Project programme and activities are presented in detail in the Project document and in the Contract between the Maltese authorities and the BRGM.

3. INSTITUTIONAL ARRANGEMENT

The Project involved various experts, such as hydrogeologists, databank specialists, geochemists, and geophysicists. The expertise was provided by the BRGM as the implementing institution, in close cooperation with the Water Services Corporation staff.

During the preparation and implementation of the Project, PAP acted as consultants to the Maltese institutions.

In course of the Project implementation, the availability of water resources was thoroughly assessed in terms of quantity and quality, as well as the environmental impacts of the existing water management policies. In order to identify the present water utilization policies and future demand, various Government institutions were consulted, such as: the Ministry of Agriculture, the Ministry of the Environment, the Malta Development Corporation, the Ministry of Public Works, and the Ministry of Tourism.

4. TIME SCHEDULE

The Project started in 1990 and was completed in May 1992.

5. PRINCIPAL TECHNICAL RESULTS OF THE PROJECT

The principal technical results of the Project can be listed as follows:

5.1 Hydrology

Geophysical survey of 51 wells to identify the different contrasting lithologic units, zones of different porosity and possibly to locate the depth of the fresh/saline water interface. The following parameters were logged:

i resistivity and spontaneous potential

ii temperature and salinity

iii Gamma Ray and neutron log

iv magnetic susceptibility

On the basis of those geophysical measurements it was possible to:

(a) identify a geophysical marker corresponding to the boundary between the Globigerina Limestone and the Lower Coralline Limestone better known as the transition bed; this marker facilitates correlations with several wells which have not been geophysically locked;

(b) reveal the brackishness of the Mean Sea Level Aquifer; only the first few metres in the fresh water lands show a salinity content ranging from 200 to 500 ppm.

5.2 Fracture pattern

By examining aerial photographs together with spot satellite images, it was possible to locate fissure alignments which so far had not been detected. Karstification mostly occurs along these features, but it has now been confirmed that transmissivity variations do not depend only on fracture alignments.

5.3 Hydrodynamical parameter survey

To have a good insight into the aquifer behaviour it is necessary to determine transmissivity and storage coefficient variations, and to know accurately the piezometry. Twenty four wells were pump tested and interpreted by a special software provided by BRGM, which facilitated the calculation of transmissivity. By correlating the specific capacity and transmissivity on a graph, it was possible to obtain more than one hundred transmissivity values

which allowed the drawing of a transmissivity map as a basic document for the mathematical model.

5.4 Water quality survey

An intensive sampling campaign was carried out on a multitude of wells located in both aquifers. This survey was integrated with the water point inventory survey, so that all the related data of each respective well could be registered on a standard form and, later, entered in the databank. Specific tests were also carried out, particularly near industrial estates where pollution by heavy metals and other toxic wastes was suspected. Earlier collected data were also carefully examined, and salinity and nitrate trends of each source analyzed.

The compilation of these chemical parameters matched with land-use and hydrogeological maps made possible for the preparation of a pollution vulnerability map of groundwater resources.

5.5 Coastal discharge

The results of a recent themographic survey were interpreted and compared with fissure alignments and piezometric data. Various coastal springs were identified. However, quantification of these outlets proved practically impossible, and this has to be taken into account during the calibration of the model.

5.6 Recharge estimation

(a) *Rainfall*

An analysis was made of the records coming from 15 stations run by the Water Works, and 19 stations run by the Meteorological Office. The records date back to 1841. All those data were processed to obtain a homogeneous monthly series. The yearly totals range from 193 to 931 mm, whereas the average annual value is 506 mm, showing a high interannual variability.

(b) *Surface run-off*

Records from Burmarrad and Mtahleb stations were analyzed. It was established that the average run-off is approximately 1%.

(c) *Potential evapotranspiration*

This parameter was calculated by both the Turc and Penman formulae from climatological data recorded at the Meteorological Office Luqa. The calculations were made using daily and monthly values. It was found that the Penman formula was more representative since it took into consideration relative humidity and wind speed.

The average value of the potential evapotranspiration for the period 1947-1990 was 1390 mm with a low interannual variability (variation coefficient is 3%).

5.7 Infiltration

A humped hydrological rainfall discharge model was calibrated for the Wignacourt Springs from 1884 to 1909, during which period natural conditions prevailed. From this calibration it was possible to extrapolate the elements of the hydrological balance as computed for the Wignacourt catchment to the entire perched aquifer of the Rabat Plateau.

5.8 Land-use survey

A multitemporal land-use study was made by analyzing three sets of aerial photographs shot respectively in 1958, 1971 and 1991, together with one spot satellite image. Land use was classified in six categories, and it was possible to study the evolution of the land use with time, as well as to assess surface permeability variations.

5.9 Identification of pollution sources

Whenever field work was carried out, field technicians took note, on appropriate forms, of any source of pollution, particularly in the proximity of groundwater production sources. Valuable information was thus obtained for the formulation of protective measures.

5.10 Data banking

The Water Department has an abundance of good quality data dating back for over a century. The first rainfall figures were recorded in 1857, whereas production has been regularly recorded since 1868. All these data were formerly stored in numerous libraries at various officer, which made it practically impossible for a decision maker to use comfortably any of the data for management purposes. Hence, one of the objectives of the databank was the collection of all this wealth of information in a centralized file which can be used as and when required.

The process of data banking started in the very first days of the Project implementation, and data entry took 11 man-months to complete. Details of the various databases are beyond the scope of this paper and will be presented in a separate session. The types of data collected and stored are as follows:

i climatological data since 1841

ii inventory of wells, public and private

iii groundwater production data since 1868

iv piezometric data

v geological logs and technical details of wells and galleries

vi water quality data

Retrieval of data is now possible for all necessary purposes.

These values were used for the processing of the hydrodynamic models of the mean sea level aquifer, for which the effective rainfall was calculated from the Luqa Meteorological Office rainfall series (1949-1990), using daily timestep intervals for different values of maximum soil water retention capacity.

5.11 Water production

The Water Works hold records of water production since 1868, those from 1941 on being on a daily basis. The production trends of various sources were analyzed singularly and cumulatively, these documents in turn being correlated with quality trends and rainfall figures. During the course of this Project it was established that whereas aquifer, production and salinity were directly related, the same did not relate to the nitrate content. This varied in relation to the rainfall.

Three hundred private wells from the Mean Sea Level Aquifer and 100 from the perched aquifers were inventoried and surveyed in two representative areas to estimate the figure of private extraction. During these surveys, the field technicians were also taking note of pollution in the surroundings of the wells.

5.12 Environmental hydrogeology

The interaction between water resources development and the geo-environment requires a thorough knowledge of all variables affecting the watershed. Of particular importance are human activities (industry, agriculture, etc.), and man-induced processes that can permanently damage the water resources. The impact of these activities on the environment was assessed in two stages.

5.13 Modelling

This activity had three principal objectives:

(a) to calculate the present water balance

(b) to propose the redistribution of extraction points in order to improve the quality

(c) to assess consequences of pollution incidents

The Mean Sea Level Aquifer has been represented by a 2D model discretized by 900 square meshes having sides of 500 x 500 m. This model required various parameters, which had been obtained or estimated in the first phase of the project, namely:

- aquifer geometry
- recharge values
- piezometric fluctuations
- depth of fresh/saline interface
- values of transmissiveness and storage coefficient
- abstraction figures

The main difficulty in fitting a model to a fresh water lens within a karstic aquifer is the practical impossibility of quantifying the amount which is discharged into the sea, thus rendering the precise determination of the water balance a very arduous task. To overcome this constraint, the recharge was carefully estimated and the transmissivities adjusted to be able to fit the observed piezometries, or *vice versa*, recharge figures were adjusted to obtain the best fit. Model calibration was carried out on conventional personal computers, and both steady and unsteady state fittings were obtained. In-depth knowledge of field conditions was necessary during the calibration, so that the models could represent the real situation.

Various scenarios have been simulated in this model, and the authorities are now studying the best of these to formulate the future exploitation policy and to optimize extraction.

5.14 Global water development and management

A multicriterial analysis incorporating technical, social, economic and financial aspects was carried out in order to identify the best combination of water producing sources (groundwater and desalinated water) that will feasibly satisfy future demand. Special attention was paid to quality standards which should conform to the EC standards.

The integrated result of these works confirmed that groundwater extraction has to be drastically curtailed to control salinity intrusion. The present extraction facilities have to be reorganized and redistributed to decentralize production and prevent heavy drawdowns in concentrated sectors of the aquifer where a pronounced depletion is under way. Also, groundwater has to be protected against contamination by surface pollutants (such as fertilizers,

pesticides, heavy metals and other micro pollutants) by formulating appropriate policies and legal procedures.

6. PAP INTERPRETATION OF THE PROJECT RESULTS

From the point of view of the MAP-PAP goals and objectives, and specifically those of the priority action on water resources management, the most important results of the Project are the following:

- A complex project relevant to the use of water resources and their protection against pollution was developed with direct practical results which are of a vital importance for the Government of Malta.

- For the time being, this is the only such project in the Mediterranean. By its format, approach, contents and results it provides a valuable pilot experience for MAP-PAP and all Mediterranean countries.

- Through the implementation of the Project, the level was upgraded of knowledge and experience of the national experts and PAP consultants, and the institutional arrangement for water resources management in Malta was greatly improved.

- The Project and its results will be used in further activities of PAP within the priority action on water resources management in the following way:

  - as an example of formulation, preparation and implementation of similar projects, as a part of the process of exchange of experience within the PAP framework;

  - as a basis and a document for exchange of experience, and, especially, for training of Mediterranean experts in the following fields: (a) water resources management - approach, policy, tools and techniques, implementation; (b)establishment of database for water resources management; (c) use of hydrological models in the process of water resources management.

- After the completion of this Project, conditions have been created in Malta for the establishment of a MAP-PAP training centre in the field of water resources management, within and with a significant support of the existing Maltese institutions, without a need of hiring additional permanent staff. It must be pointed out that this was one of the strategic objectives of this action.

7. FOLLOW UP OF THE PROJECT

The Maltese Government and its institution Water Services Corporation will define their actions as immediate follow up of the Project.

Meanwhile, within PAP, in cooperation with the Water Services Corporation and BRGM, using the results of the Project and the gained experience, and bearing in mind the conclusions of the 7th Conference of the Contracting Parties to the Barcelona Convention (especially those relevant to the PAP Workplan and the priority action on water resources management), the follow-up activities will be oriented at:

7.1 Immediate activities:

- formulation, preparation and implementation of the water resources conservation project for the island of Malta, as a direct logical continuation of the first project, at the same time a pilot project for other Mediterranean countries;

- organization of training courses for Mediterranean experts at the regional and national levels;

- establishment of a permanent centre in Malta for training of Mediterranean experts in the field of water resources management, without creating new administrative structures.

7.2 Refocusing on integrated drought water management

Departing from the results of the Maltese project, experience gained in the eight-year involvement with the problems of water management in the Mediterranean, and the conclusions of the World Water Conference held in Dublin last January, which brought together most of national and international bodies concerned with water problems, integrated drought water management stands out as a long-term strategic orientation in this field in the Mediterranean.

Water resources, although renewable natural resources, result ever more often insufficient, due to both increased demand and the changing environment (because of pollution, devastation and consequences of the expected climate change). Water scarcity has become an important ecological and socio-economic problem which can be successfully resolved only through the development and implementation of a comprehensive water management, ecosystemic interdependencies, and risk-based management approaches.

Water scarcity is permanently present in a large part of the Mediterranean. Therefore, water managers must overcome the complexity of the problem in order to have a chance to successfully apply management methods. Our task is to help the water managers and policy makers to solve such a complex task which includes ecological, economic and political areas.

Solution of the problem has to be searched primarily in an integrated approach to drought management, which MAP has to apply in all on-going and future CAMPs, since those projects are based on an integrated approach to the solution of coastal area management problems, which includes the water resources related ones. It is, therefore, necessary to prepare appropriate guidelines and, preferably, and expert system model which would adequately present the methodology. Expert system model for integrated drought management is the fastest and most purposeful method of transferring new knowledge to water managers, which should be realized by all means. In order to prepare the guidelines and the expert system model according to the actual needs of the region, the PAP programme should include the organization of expert meetings and workshops on the subject in which the guidelines and the model would be presented and adapted, and in which transfer of knowledge would occur. Finally, in order to transfer the knowledge to all countries of the region, appropriate training courses should be organized, both at the regional and national levels. Apart from the above, a continuous assistance would be provided to individual countries in resolving the problems of water scarcity and rational management of water resources, through expert missions and other appropriate ways.