MEDITERRANEAN ACTION PLAN
PRIORITY ACTIONS PROGRAMME

UNITED NATIONS ENVIRONMENT PROGRAMME

SPECIFIC TOPICS RELATED TO WATER RESOURCES DEVELOPMENT OF LARGE MEDITERRANEAN ISLANDS

THEMES SPECIFIQUES CONCERNANT LE DEVELOPPEMENT DES RESSOURCES EN EAU DES GRANDES ILES MEDITERRANEENNES

DOCUMENTS PRODUCED IN THE SECOND PHASE
OF THE PRIORITY ACTION (1985-1986)

TEXTES REDIGES AU COURS DE LA DEUXIEME PHASE
DE L'ACTION PRIORITAIRE (1985 - 1986)

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This volume is the thirteenth issue of the Mediterranean Action Plan Technical Report Series.

This Series will collect and disseminate selected scientific reports obtained through the implementation of the various MAP components: Pollution Monitoring and Research Programme (MED POL), Blue Plan, Priority Actions Programme, Specially Protected Areas and Regional Oil Combating Centre.

Ce volume constitue le treizième numéro de la série des Rapports techniques du Plan d'action pour la Méditerranée.

Cette série permettra de rassembler et de diffuser certains des rapports scientifiques établis dans le cadre de la mise en oeuvre des diverses composantes du PAM: Programme de surveillance continue et de recherche en matière de pollution (MED POL), Plan Bleu, Programme d'actions prioritaires, Aires spécialement protégées et Centre régional de lutte contre la pollution par les hydrocarbures.

PREFACE

The United Nations Environment Programme (UNEP) convened an intergovernmental Meeting on the Protection of the Mediterranean (Barcelona, 28 January - 4 February 1975), which was attended by the representatives of 16 Mediterranean coastal states. The meeting discussed the various measures necessary for the prevention and control of pollution of the Mediterranean Sea, and concluded by adopting an Action Plan consisting of three main components:

- Integrated planning of the development and management of the resources of the Mediterranean Basin (management component);
- Co-ordinated programme for research, monitoring and exchange of information and assessment of the state of pollution and of protection measures (assessment component);
- Framework convention and related protocols with their technical annecces for the protection of the Mediterranean environment (legislative component).

All components of the Action Plan are interdependent and provide a framework for comprehensive action to promote both, the protection and the continued development of the Mediterranean eco-region. No component is an end in itself. The Action Plan is intended to assist the Mediterranean Governments in formulating their national policies related to the continuous development and protection of the Mediterranean Region and to improve their ability to identify options for alternative patterns of development and to make appropriate allocations of resources.

The Priority Actions Programme (PAP), a component of the integrated programme of the Mediterranean Action Plan (MAP) promotes the exchange of experience in the fields of integrated planning and management of resources in the Mediterranean Region.

The starting point of the PAP activities is the awareness that the protection and sound management of the environment can only be implemented by means of a rational development which implies optimum exploitation of natural resources.

Within the framework of the definition of the PAP activities, the representatives of the Mediterranean governments, the Contracting Parties of the Barcelona Convention, have established the following priorities for the PAP:

- human settlements
- water resources management
- soil protection against erosion
- tourism
- aquaculture
- renewable sources of energy

In the abovementioned areas, the following activities are being completed:

- directories of Mediterranean institutions and experts
- water resources management
- integrated planning and management of Mediterranean coastal zones
- protection and rehabilitation of historic settlements
- land-use planning in earthquake zones
- soil protection against erosion
- solid and liquid waste management, collection and disposal
- development of tourism harmonized with the environment
- aquaculture
- renewable sources of energy
- environmental impact assessment
- balance between the hinterland and the coastal zones.

The United Nations agencies, many international organizations and almost all Mediterranean countries take active part in all these activities.

This volume, which is the 13th in the Mediterranean Action Plan Technical Reports Series, contains selected documents concerning the Priority Action entitled "Water Resources Development in Mediterranean Islands and Coastal Areas", prepared within the Phase II of the action, implemented in the period 1985-1986, dealing with water resources in big Mediterranean islands and coastal zones.

PREFACE

Le Programme des Nations Unies pour l'environnement (PNUE) a convoqué une réunion intergouvernementale sur la protection de la Méditerranée (Barcelone, 28 janvier - 4 février 1975) à laquelle ont pris part des représentants de 16 Etats riverains de la mer Méditerranée. La réunion a examiné les diverses mesures nécessaires à la prévention et à la lutte antipollution en mer Méditerranée, et elle s'est conclue sur l'adoption d'un Plan d'action comportant trois éléments fondamentaux:

- Planification intégrée du développement et de la gestion des ressources du bassin méditerranéen (élément "gestion");

- Programme coordonné de surveillance continue, de recherche, d'échange de renseignements et d'évaluation de l'état de la pollution et des mesures de protection (élément "évaluation");

- Convention cadre et protocoles y relatifs avec leurs annexes techniques pour la protection du milieu méditerranéen (élément juridique).

Tous les éléments du Plan d'action étaient interdépendants et fournissaient le cadre d'une action d'ensemble en vue de promouvoir tant la protection que le développement continu de l'écorégion méditerranéenne. Aucun élément ne constituait une fin à lui seul. Le Plan d'action était destiné à aider les gouvernements méditerranéens à formuler leurs politiques nationales en matière de développement continu et de protection de zone de la Méditerranée et à accroître leur faculté d'identifier les diverses options s'offrant pour les schémas de développement, d'arrêter leurs choix et d'y affecter les ressources appropriées.

Le Programme d'Actions Prioritaires (PAP), partie du plan intégré du Plan d'Action pour la Méditerranée (PAM), a pour but de promouvoir des échanges d'expériences dans les domaines de la planification intégrée et de la gestion des ressources des zones côtières méditerranéennes.

Le point de départ des activités du PAP est la connaissance que la protection et la promotion de l'environnement ne peuvent être réalisées que grâce à un développement raisonné qui se traduit par une exploitation optimale des ressources naturelles. La notion même de l'environnement, conçue dans un sens plus large, et tout particulièrement dans des conditions méditerranéennes, constitue en même temps la plus précieuse ressource de la Région.

Dans la phase de la définition des activités du PAP, les représentants des Gouvernements meditérranéens, Parties Contractantes de la Convention de Barcelone, ont précisé les domaines prioritaires du PAP, notamment:

- établissements humains;
- gestion des ressources en eau;
- protection des sols contre l'érosion;
- tourisme;
- aquaculture;
- sources d'énergie renouvelables.

Dans les limites des domaines précités, les actions suivantes sont en voie d'achèvement:

- répertoires des institutions et experts méditerranéens;
- gestion des ressources en eau;
- planification intégrée et gestion des zones côtières méditerranéennes;
- protection et réhabilitation des sites historiques;
- aménagement du territoire dans les zones sismiques;
- protection des sols contre l'érosion;
- gestion, collecte et élimination des déchets solides et liquides;
- développement du tourisme en harmonie avec l'environnement;
- aquaculture;
- sources d'énergie renouvelables;
- évaluation des impacts sur l'environnement;
- interrelation côte - arrière-pays.

A toutes les actions prennent part les organismes des N.U. et de nombreuses organisations internationales, y compris la participation active de presque la totalité des pays méditerranéens.

Le présent volume, le 13ème de la Série des rapports techniques du PAM, englobe un choix de documents relatifs à l'action prioritaire intitulée "Développement des ressources en eau des îles et zones côtières méditerranéennes", préparés à l'intérieur de la Phase II de l'action, mis en oeuvre dans la période 1985-1986, et concernant les problèmes des grandes îles et zones côtières en Méditerranée.

EDITORIAL

The subject of this technical paper is "Water resources development of large Mediterranean islands". It is based on the documents prepared and presented in the meeting on "Water and Sanitation Problems in Big Mediterranean Islands and Isolated Coastal Areas with Fluctuating Population Due to Tourism", Malta, December 1986, within the activities of the Priority Actions Programme (PAP) of the Mediterranean Action Plan (MAP).

The project "Water Resources Development of Large Mediterranean Islands", within the priority action "Water Resources Development in Mediterranean Islands and Coastal Areas" has been implemented in cooperation with WHO/EURO. The documents of the above mentioned working meeting dealing with the problems of water resources and prepared by PAP/RAC are presented in the Part I of this volume, while those dealing with sanitation problems in islands and coastal areas, prepared by WHO, are presented in the Part II. We belive that the documents, reviewed and approved by WHO/EURO, could represent a significant contribution of WHO/EURO to the quality of this publication.

The principal aim of this paper is to concisely describe the techniques and methods used, and to briefly review the situation in this field, with special reference to the big islands with fluctuating population due to tourism.

The purpose of this volume is to produce a paper useful to local water authorities, as well as to decision makers and technicians in the field of water resources development in the Region, in order to give information on the situation in other areas, as well as to present experience and possibilities for resolving the problems of water resources development of Mediterranean islands and isolated coastal areas.

Prof. Jure Margeta
Coordinator of the priority action on
Water Resources Development

EDITORIAL

Cette communication technique a pour thème "Développement des ressources en eau des grandes îles méditerranéennes". Elle repose sur les documents préparés et présentés au groupe de travail "Problèmes d'eau et d'assainissement dans les grandes îles et zones côtières isolées méditerranéennes à population variable due au tourisme" (Malte, décembre 1986), dans le cadre des activités du Programme d'Actions Prioritaires (PAP) du Plan d'Action pour la Méditerranée (PAM).

Le projet intitulé "Développement des ressources en eau dans les grandes îles méditerranéennes", coordonné dans le cadre de l'action prioritaire "Développement des ressources en eau dans les îles et zones côtières méditerranéennes", se concrétise en coopération avec l'OMS/EURO. Les documents du groupe de travail précité relatifs aux problèmes d'eau et préparés par le PAP/CAR sont reproduits dans la Partie I de ce volume, tandis que ceux traitant de problèmes d'assainissement des îles et zones côtières préparés par l'OMS, figurent dans la Partie II. L'ensemble de ces communications, examinées et approuvées par l'OMS/EURO, pourraient constituer une contribution valable de l'OMS/EURO à la qualité de cette publication.

La présente communication vise avant tout à exposer avec concision les techniques et méthodes utilisées ainsi qu'à examiner brièvement la situation dans le domaine, avec accent sur les grandes îles à population variable due au tourisme.

Le but de ce volume est de produire un document utile pour les autorités locales compétentes dans le région, de même que pour les décideurs et techniciens en matière de développement des ressources en eau dans la Région, leur permettant ainsi d'appréhender la situation dans d'autres régions et d'acquérir des enseignements et des moyens de trouver des solutions aux problèmes posés par le développement des ressources en eau des îles et zones côtières isolées méditerranéennes.

Prof. Jure Margeta
Coordonnateur de l'action prioritaire
sur le développement des ressources
en eau

CONTENTS/TABLE DES MATIERES

PART I

WATER RESOURCES DEVELOPMENT OF LARGE MEDITERRANEAN ISLANDS

PART II

SANITATION IN LARGE MEDITERRANEAN ISLANDS AND ISOLATED COASTAL AREAS OF FLUCTUATING POPULATION DUE TO TOURISM

PART I

WATER RESOURCES DEVELOPMENT OF LARGE MEDITERRANEAN ISLANDS

SYNTHESES OF QUESTIONNAIRES ON THE KNOWLEDGE AND PROBLEMS RELATED TO WATER RESOURCES MANAGEMENT ON LARGE MEDITERRANEAN ISLANDS

by

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1. INTRODUCTION

The Regional Activity Centre for the Priority Actions Programme of the UNEP's Meditteranean Action Plan is carrying out a project entitled "Water Resources Management on Large Meditteranean islands" in addition to other priority activities.

Problems related to small Mediterranean islands were dealy with during the period 1984 - 1986, whereas the programme for 1986 - 1987 concentrates on the problems of large islands.

At the beginning of the programme, an inquiry by questionnaires was carried out in order to get the necessary information to help launch the project.

The questionnaire was prepared in cooperation with WHO/EURO. Answers received from the questionnaires related to positive experiences of some islands which were then, selected as topics for the presentation at the PAP/RAC - WHO/EURO Working Meeting in December 1986.

The following of the questionnaires summarises the obtained information, and presents the existing state of the water resources management on these large Mediterranean islands.

The report does not deal with the sanitary and health aspects of the problem which will be presented in a seperate report to WHO/EURO.

2. QUESTIONNAIRE - MAIN CHARACTERISTICS

The objective of the questionnaire was to establish the basic characteristics and problems related to water resources management on these large Mediterranean islands and, thus, to help launch a project on the development of their water resources.

The questionnaire consists of the five basic parts with 54 questions:

(a) water resources on the island (5 questions),
(b) water resources management (26 questions),
(c) sanitary and health aspects (10 questions),
(d) availability of basic data (9 questions),
(e) major problems of the island and the proposals for Mediterranean co-operation (4 questions).

Chapter "a" serves to establish the main elements of the water resources (springs, water courses, aquifers, etc.) and their dimensions.

Chapter "b" includes the water-uses, water management problems, water management characteristics, water and waste water development.

Chapter "c" deals with the sanitary and health espects. The questions refer to the problems of water and waste water treatment, water pollution, as well as water and waste water related diseases.

Questions in chapter "d" serve to determine the existance of basic data (meteorological, hydrogeological, demographic, water quality) and if existent, how detailed. As well, the questions establish some basic characteristics of the island related to the data, such as: average rainfall, population and geology.

The last chapter "e" relates to some information which could serve as a basis for the solution of the common problems, as well as to establish the guidelines fora long-term plan of cooperation.

The questionnaire was sent to all Mediterranean countries consisting, in part, of large islands; answers have been received from the following islands: Sicily, Sardinia, Mallorca, Cyprus, Brac, Malta and Hvar.

The task requested was to fill in the questionnaire according to available data, without any detailed analyses or investigations.

3. ANALYSIS

3.1 Water Resources of the Islands

Permanent streamflows appear only on Sicily, the largest island, whereas on all other islands there are temporary water courses appearing during rainy seasons. Considering other forms of surface water, natural lakes appear only on Sicily, whereas on some other islands there are coastal marshes.

On most islands, there exist springs with a significant capacity. There are also aquifers on all the islands, and their sizes generally correspond to the size of the island. Reservoirs have been built on all islands; most of them on Sicily, while on Cyprus the capacity of the reservoirs is greatest in comparison to the available quantity of water resources.

According to the answers, it can be concluded that on most islands there are water sources of considerable capacity, whose distribution and type depend upon the geological and meteorological characteristics of the area. On large islands, a more complex geological structure results in richer water resources, although the total quantity of rainfall is less than on some smaller northern islands characterised by simple geological structures (mostly karst).

The construction of reservoirs should be an indicator in future development of the exploitation and management of water resources, as water can only be used during the dry periods if it is stored during the wet periods. In some cases, however, (Hvar, Brac) storage takes place on the mainland, and then the water is delivered to the islands by submarine pipelines. Cyprus is certainly an example in its intensive development of water resources, as its quantity of storage is the highest if compared to its input (average precipitation is 500 mm/year).

Since the greatest part of available water resources is already being used up (70-100 per cent) it is to be expected that in the future it will be difficult to provide sufficient quantities of water. This will undoubtedly call for a more efficient management of existing water resources, and the exploitation of other sources of fresh water supply such as: desalination, reuse of waste water and other procedures.

3.2 Water resources management

3.2.1 Water supply

The water supply is mainly provided by available water resources. In most cases, these resources are so exploited that other sources have to be exploited as well. Other sources include desalination, reuse of waste water and water piped from the mainland.

On smaller islands, the water supply is solved by a unique system, unlike the water supply of large islands. Generally, these single (unique) systems of water supply make it possible to use the water resources more efficiently and to protect them. As the system becomes larger, it becomes more complex and the costs of its construction increase; hence large systems are rarely constructed.

The majority of the population on the islands uses the water from the water supply system; on most islands, there is a shortage of water during the summer.

The consumption of water per person per day varies from one island to another, ranging from 80-250 litres/person/day, and in summer from 160-630 litres/person/day.

The variation in consumption between winter and summer periods is generally proportional to the ratio between the population living permanently on the island and that of tourists. It is influenced by a larger number of people and the character of consumption. Consumption is also proportional to the available quantities of water; it is greatest where the available quantities are large (Hvar, Brac) and lowest in those areas with little available water (Cyprus).

The cost of water is similar on various islands and generally does not significantly influence the family budget.

On all of the islands, problems related to the distribution system are encountered, such as: reservoir volume, capacity of water pipes, quality of the system, maintenance, operation and the available quantity.

Although there are certain problems it can be concluded, according to the obtained data, that the water supply is mainly satisfactory; however, increasing water demands will probably cause problems in providing necessary water quantities in the future.

3.2.2 Irrigation

Irrigation is effected on all of the islands mainly for non-industrial plants. The greatest sources for irrigation are reservoirs and aquifers. Since the capacity of the aquifers is limited, greater quantities for irrigation can be provided only by building reservoirs and by exploiting non-conventional sources, such as reuse of waste water.

3.2.3 Industry

Industry, as a significant consumer of water, appears only on Sicily and Sardinia, the largest islands. The water supply for industry uses available water resources, as well as desalination and reused water.

3.2.4 Other uses and water-related problems

Drainage problems appear exclusively on the largest islands, but they are not significant. On these islands only, water is also used for the production of electric energy.

Problems related to the stream regulation of permanent and temporary water courses are encountered on most islands and, thus, represent a common problem. A similar case is land erosion due to rainwater or due to the action of the water courses. Erosion occurs on all of the islands and is prevalently caused by the action of water courses, but not to the same extent on all islands.

Flood problems in urban areas are characteristic of most islands (with the exception of Cyprus), whereas the flood problems of non-urban areas are significant only for the largest islands.

3.2.5 Sewer systems and waste water treatment

The collection and disposal of waste water and storm runoff has been solved only in large towns on most islands, leaving most small settlements with no sewer systems for storm runoff, and some islands without a sewer system for waste water at all (Brac, Hvar, Cyprus).

On most islands, waste water is only partly and incompletely treated before it is released into the recipient. The purified water is generally released into the sea (permanently), and only a small quantity is reused for agriculture. On most islands, flood problems appear as the result of the absence of systems for collection and the disposal of storm runoff.

Consequently, it can be concluded that the treatment of the waste water is not satisfactory, particularly considering the fact that the water resources of the island are limited by its size and that the recipient of waste water is simultaneously used as a source of drinking water.

3.2.6 Operation and management

On smaller islands, water management is the responsibility of a single authority, whereas on large islands, the situation is different. This can be explained by the greater quantity of water resources on large islands and by the influence of the government. Thus, on these islands, there are considerable problems related to the operation of the system due to inadequate organisation. Similarly, there are problems related to the operation of the system due to a shortage of financial means and trained personnel. However, the problems related to the operation of the system are insignificant only on Cyprus.

3.2.7 Quality of water resources

According to the data taken from the questionnaire, available water quantities are within tolerable limits of quality. This situation was to be expected taking into account the present state of waste water treatment. However, in order to draw final conclusions, it is necessary to undertake a detailed analysis.

3.2.8 Availability of basic data

There is complete, detailed meteorological and demographic data for all islands. However, on most islands, with the exception of Cyprus, the hydrogeological, hydrological and water quality data are incomplete. Geological data exist only for the large islands, because the smaller islands have not yet been investigated enough from a geological aspect.

Since certain important data are not available for the majority of islands, the actual condition and quality of the water resources are not yet completely known.

The average precipitation quantities range from 996 mm (Brac) to 500 mm (Cyprus) and its distribution corresponds to the geographical position of the island. Geographical composition varies, generally becoming more complex as the size of the island increases.

All of the islands have a considerable fluctuation in population between winter and summer periods. This fluctuation is greater on the small islands than on the large ones. The ratio between the number of people in summer and winter ranges from 5:1 to 1,33:1.

3.3 Major problems of the islands and proposals for the Mediterranean cooperation

Although acute problems differ from one island to another, they can still be categorised as follows:

- pollution of the water resources and the water quality problems;
- unified management of the water resources and optimal utilisation;
- seasonal variation in water consumption and related operation problems.

These topics have been stated as long-term problems, but the greatest problem is the shortage of sufficient water quantities and hence, conservation of water resources.

The proposed topics of special interest for cooperation within the project of water resources management of those large Mediterranean islands are as follows: eutrophication of reservoirs, water for agriculture, sea intrusion, reuse of the treated water, water conservation, pollution aspects, development of the management programmes and inventory of resources.

Because of positive experience in the islands' water management (suitable for exchange of information in the project), several topics have been suggested, some of them mentioned previously.

Consequently, it can be concluded that on some islands there has been positive experience in solving the problems of water resources management and, thus, there is a basis of exchanging experiences in order to improve the water resources management of these large Mediterranean islands.

4. CONCLUSION

This survey, although not very detailed in considering the importance of the problems, has proved to be valuable as a starting place for planned action, particularly due to the authors who completed the questionnaire in detail, adding useful information not specifically.

It has been noted that there are numerous problems of common interest on all the islands, some of which are specific because of the specific features of each island. It has also been concluded that there are examples of positive experiences on the islands in solving the problem of water resources management, which can help engineers on other islands to solve similar problems. Thus, wide cooperation in solving these problems would be of interest.

(a) Water resources

On the majority of islands, the available quantities of water resources have almost completely been exploited; hence, the shortage of water is the main problem and a limiting factor in the development of the islands. Water is mostly used for domestic purposes, followed by agriculture, with only a small part for industry. The shortage of sufficient water quantities is characteristic for all islands on a temporary basis, while the lack of water for agriculture is permanent during the dry period.

(b) Water resources management

Exploitation and management of intensive water resources has resulted in a great number of structures which should be connected into a unique management system to optimally exploit the available quantities and infrastructure in order to satisfy increasing demands. The essential condition for the optimal management of water resources, in addition to good organisation, is the availability of necessary basic data, which is still missing on most islands. Consequently, special attention should be paid to gathering and processing this necessary data.

Non-conventional sources of fresh water are already being used, and in the future, will represent the only additional sources of water supply along with measures for water conservation. A special problem in water exploitation is the unfavourable distribution of precipitation with respect to demand which is much greater during the dry period (summer) due to tourism and climatic conditions. This situation makes it difficult to provide sufficient quantities of water and requires the construction of reservoirs for water storage, as well as a more complex organisation of management which is still non-existent on most islands.

(c) Protection of the water resources

The protection of water resources from pollution is not satisfactory, primarily due to insufficient sewer systems and treatment plants. This problem together with the problem of over-use of aquifers, and the problem of sea intrusion, represent the greatest constant dangers and threats to these islands' water resources.

(d) Other uses and water-related problems

Protection from floods is not a significant problem although some problems related to this field can be considerable on some large islands. A special problem is the temporary flooding of an urban area caused by the absence of a system for storm runoff disposal.

A GENERAL WATER RESOURCES MASTER PLAN FOR THE ISLAND OF SARDINIA

by

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ABSTRACT

The water resources master plan of Sardinia has recently been drawn up for the purpose of estimating water resources and demand and for planning the waterworks and infrastructures required for supplying the resident and tourist populations and for agricultural and industrial use. A major scientific and technical effort is now under way to evaluate water allocation and demand, and to plan water schemes and infrastructures.

Owing to climatic and hydrogeological factors, ground water can be used for local consumption, whereas the allocation for large consumers is secured from surface waters accumulated in reservoirs. Thus, large amounts of water stored in the rainy season may be diverted from one watershed to another and later, conveyed from the mountains to the plains where most human activities are concentrated. Particular attention has been paid to the demand of tourists which has its peak in July and August, the driest period. Non-conventional water resources such as mine ground water and treated urban industrial waters have been regarded as a future reserve.

The water resources master plan highlights the need for reviewing the organisation of water resources management in Sardinia.

1. INTRODUCTION

Sardinia, which covers an area of some 24,000 km^2, is the second largest island in the Mediterranean. Her resident population of 1.6 million inhabitants is unequally distributed in 309 communes. Nearly one quarter of the population is concentrated in the urban area and hinterland of Cagliari, the capital; another quarter in the chief towns; the remainder dispersed throughout the island in villages, often several kilometres apart.

Over the last 20 years, on account of the rapid expansion of tourism, particularly in coastal zones, large hotels and tourist resorts have sprung up, especially by the sea. As a result, there is an ever-growing demand for water during the summer, with peaks in July and August.

As will be seen in the sequel, predictions of tourist population and estimates of water demand have posed a serious problem in drawing up a general aqueducts plan of Sardinia. Furthermore, the morphology of the island is very irregular. The plateaux where inland villages are often situated are interrupted by deep valleys, rendering the organisation of communications and services difficult and very expensive.

In order to find a solution to these complex problems, the Regional Government of Sardinia decided that a study of the water resources master plan was imperative due to the various and complex decisions to be made during future interventions.

The master plan is now in its final stages and will be completed by June 1987. However, a general picture of water resources has been defined and the estimate of water demand is practically concluded. The planning of infrastructure and work schemes is still under study and the system analysis for the definition of the final plan has just been outlined.

2. MAIN FACTORS AFFECTING THE USE OF WATER RESOURCES

The average annual rainfall in Sardinia is 780 mm. Although this is less than the average 900 mm for Italy as a whole, it is not low equalling a volume of nearly 19 billion m^3 for the whole island. Unfortunately, precipitation varies substantially both temporally and spatially. In fact, average annual rainfall ranges, depending on the region, from 500 mm to 1250 mm as can be seen from the isohyete map of Sardinia compiled by the Hydrographic Service of Italy for the period 1921-1950 (Fig.1).

The annual rainfall varies to such an extent in certain areas of the island that minimum annual values of as little as 200 mm have been recorded while regions having an annual rainfall equal to 40 per cent of the 1921-50 average are not rare. On average, nearly 70 per cent of annual precipitation occurs between October and March and the remaining 30 per cent in the months of April, May and September; June, July and August are almost completely dry.

The hydrogeological features of the island, for the most part consisting of poor permeable formations, highlight the effects of varying climatic factors on runoff. There are no factors regulating water resources such as natural lakes, glaciers or major aquifers, so that the only possible source of adequate water supply is artificial lakes. As a result, water collected in the numerous reservoirs during the rainy season can be used in dry season and years when rainfall is low.

The damming of rivers in mountainous areas in central Sardinia has necessitated the construction of long aqueducts for conveying and sometimes diverting water from one catchment area to another and to the plains where the majority of human activities are concentrated. The most significant example of such a construction is the Flumendosa water system, designed to collect the abundant water resources of the River Flumendosa catchment area in central eastern Sardinia, to supply the Campidano plain together with the urban area of Cagliari. At present, the Flumendosa system consists of six reservoirs, three weirs and 160 km of main canals and pipelines of which more than 20 km are in tunnels. Consequently, the island's water resources, at least in some areas, are not sufficient to satisfy demand, with the result that the location of water resources and conflicts between potential users often pose technical and economic problems, not easily solved.

3. THE REGIONAL WATER MASTER PLAN OF SARDINIA

The regional water master plan has been entrusted by the Regional Authority to the Autonomous Flumendosa Board (E.A.F.) which has preliminarily conducted an investigation of surface water resources and of all irrigable areas. Furthermore, a study of all the boards involved in water resources management, the register of all concessions and the rates systems have also been conducted.

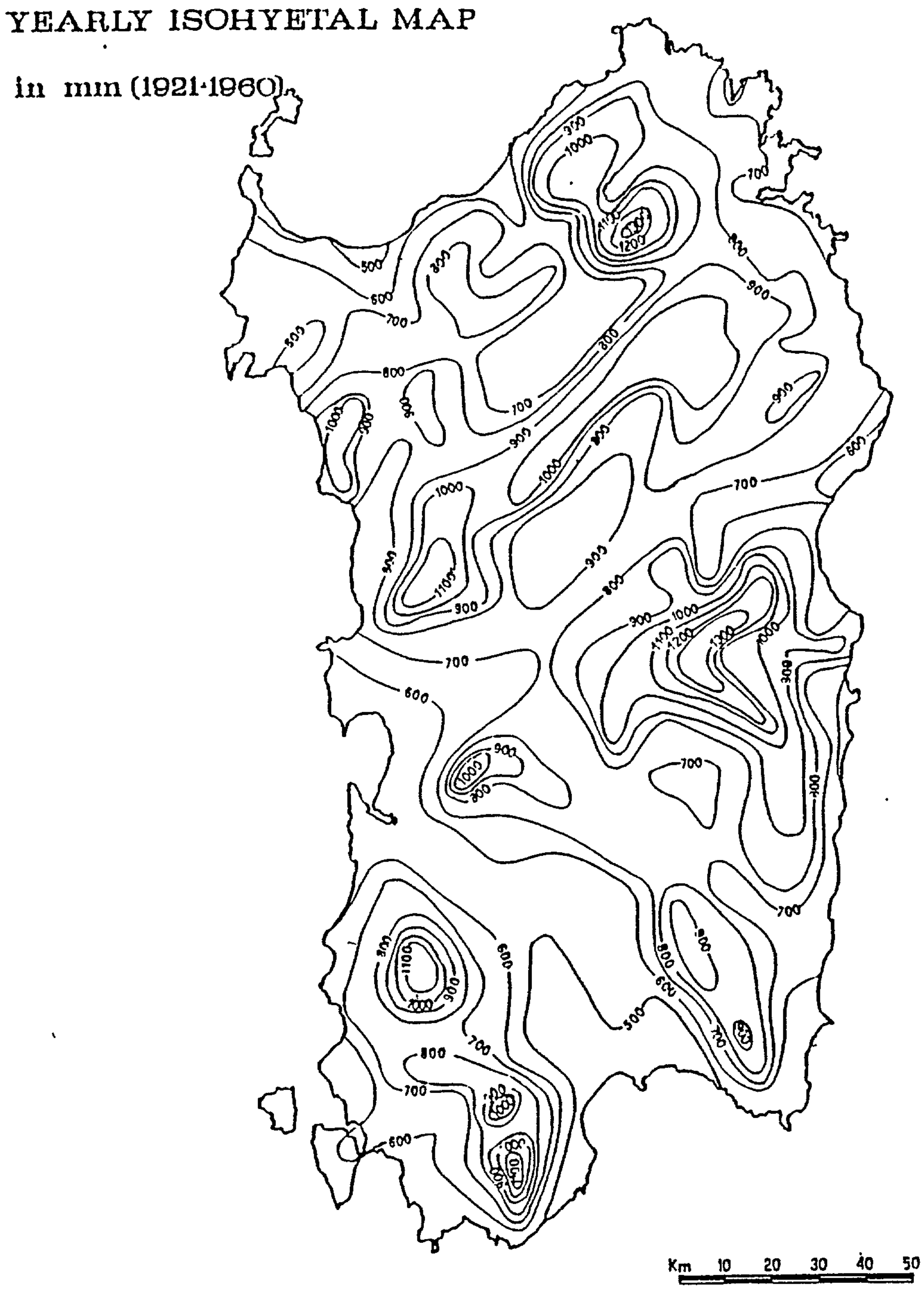

Fig.1 Yearly isohyetal map in mm (1921-1960)

As a first step, for reasons of urgency, the regional aqueduct master plan has also been drawn up in collaboration with the Regional Aqueduct and Sewers Board (E.S.A.F.). At the same time, the Department Fund for Southern Italy, in accordance with the regional administration, appointed the University of Sassari to conduct a survey of ground water resources. Subsequently, after a public competition between a number of engineering firms, the E.A.F. entrusted the study of the water resources master plan to the Engineering Company C. Lotti & Ass., after setting up a work group to take care of the technical management of the plan. The technical work group consists of E.A.F. technicians and experts from the Faculty of Engineering of Cagliari. The time horizon fixed for predictions is the year 2031.

4. ESTIMATE OF WATER DAMAND

The study of water demand embraced all possible sectors of use, especially civil, industrial, irrigation and hydroelectric and the so-called miscellaneous uses, including recreative and environmental, as well as fish farming in lagoons.

The estimate of water demand for civil purposes has been made in the Regional Aqueduct Master Plan (P.R.G.A.). First of all, a previsional study of the resident population growth in all the 309 communes of Sardinia has been made from 1981 to 2031 at 5-year intervals. The previsional deterministic "revised cohort survival model" has been adopted, dividing the population by sex and age for all the communes. Birth and death rates have been considered constant, while the migration balance has been taken as asymptotically decreasing down to zero from a positive value of the period 1971-1976. The total resident population predicted for the year 2031 is 2,821,580 inhabitants, against 1.6 million resulting from the last census taken in 1981.

The prediction of the fluctuating seasonal population in the tourist resorts, especially by the sea, is more difficult and random. In fact, no reliable assessment of long term tourist development can be made. The fluctuating seasonal population in communes by the coast in 2031 has been determined as a function of the hypothetical seaside tourist load, depending on the development and type of coast of each commune, also taking into account the population employed in infrastructures and services management.

The town-planning estimate has been employed in those communes where resulting demand was higher than that calculated in the above manner, as well as in mountain regions where the tourist population is very small. A total fluctuating seasonal population of 1,375,855 tourists has been predicted. This value is rather high since it accounts for 84.5 per cent of the resident population.

The water consumption per capita has been estimated by sub-dividing the inhabited areas into six bands, according to their populations. In each band, a survey has been made of the present situation forming the basis for the predictions to the year 2031. The following assumptions have been made:

(a) domestic use: variable increments have been considered which rise according to the populations of the different bands. Depending on the increment in number and quality of the services sector, values can range between 33 and 140 litres per capita per day;

(b) commerce, handicraft and small industries use: a demand of 10-170 litres per capita per day has been predicted along the same lines as point (a);

(c) losses in the distribution network: a 10 per cent incidence has been maintained;

(d) nuclei and isolated houses: domestic consumption has been increased to 200 litres per capita per day to make allowance for water requirements for livestock.

Peak yields for the different bands have been estimated in the P.R.G.A. on the basis of present values, assuming that in the future, the variation of difference in seasonal consumption between the monthly peak and yearly average values will diminish. The ratio applied to the different bands varies from 1.30 to 1.15. Furthermore, the ratio of 1.15 between the daily maximum and monthly demand has been maintained.

The final amount of water available, averaged over the year and the maximum daily consumption in the year 2031 are given in Table I for resident and fluctuating seasonal populations.

Table I

Amount of water available for resident and fluctuating populations

Population	Average amount available in 2031 l per capita per day	Maximum daily consumption amount available l per capital per day
Resident population up to 5,000 inhabitants	235	350
5,001 - 10,000	280	400
10,000 - 50,000	325	450
50,001 - 100,000	415	550
100,001 - 250,000	450	600
Major towns	530	700
Isolated houses	200	300
Fluctuating population	500	500

The water available for the fluctuating seasonal population has been determined after analysing consumption in some tourist resorts along the coasts of Sardinia. The investigation concerned in particular two different types of resorts, hotels and villas in large plots of land. A study of camping sites was not possible.

On the basis of the findings, an average consumption of 750 litres per capita per day for hotels and 435 litres per capital per day for villas has been calculated; a value of 300 litres per capita per day has been assumed for camping sites.

An allocation of 500 litres per capital per day has been calculated by averaging the weights of the values assumed for future hypothetical conditions in the three types of tourist resorts. This value has been adopted for tourist use throughout the island.

The total seasonal demand has been estimated by considering a tourist season of four months with constant consumption. In reality, the tourist season is longer, but the main flux takes place in July and August; numbers diminish in June and September and are lower still in April, May and October.

The total water demand in Sardinia for civil use is 457,6 million m^3 per year of which the tourist population accounts for 82.5 million m^3.

Industrial water requirements have been determined by considering possible sector alternatives both on a regional level and on the level of single local units of significance in planning water resources, and as well, by taking into account on the one hand, the different types of production already located or locatable in single areas, and on the other, water availability. The technical and economical possibilities of recycling waste waters have also been examined.

The method of analysis employed for the various types of industry defines a series of average demands (F), withdrawals (P), consumption (C), recycling (R) and discharge (S) coefficients.

The different coefficients are related as follows:

$$F = C+S+R$$
$$P = F - R$$

Of course, these coefficients vary in function according to the type of industry, the technological features of the various production processes and sometimes, plant size and allocation.

Water coefficients for industrial activities have been calculated on the basis of both a systematic review of the specific literature and a field analysis of direct observations on the regional industrial reality. Generally, water demand has been related to the employment parameter, m^3 per capital per year.

In estimating industrial water demand, the unit technical withdrawal coefficients have been defined, in reference to the present distribution of various industrial enterprises and their development on a regional scale. The prediction, based on the analysis of demand and demographic situation, has been referred to 2031 in accordance with the water master plan. Present consumption, referring only to the industries concentrated in the industrial areas of the region, is 91 million m^3/year.

The consumption of the production plants scattered throughout the island amounts to 51 million m^3/year. The average yearly consumption per capita employed is 3.177 m^3 and 1350 m^3 respectively. The industrial water requirements for the year 2031 have been determined bearing in mind employment alternatives and diffent hypotheses of water withdrawal coefficients. In particular, two different hypotheses of industrial employment forecasts and two different hypotheses on the average unit withdrawal coefficients have been made.

The industrial needs for the different hypotheses put forward, range between 413 and 464 million m^3/year and 236 and 272 million m^3/year respectively, for the high and low unit withdrawal and population hypotheses.

The irrigation water demand has been determined on the basis of an accurate geopedologic survey of all the areas suitable for irrigation. Land classification has played an indispensable role in defining all the irrigated zones, totalling 451,059 ha, distributed over 30 irrigation districts. Irrigation equipment has already been, or is to be, installed in nearly 145,000 ha, of which roughly 120,000 ha are provided with sprinklers and 25,000 ha with gravity systems.

An investigation has been carried out in the irrigation districts with wellknown geopedological characteristics in order to evaluate in each case the general and specific conditions of irrigation districts in Sardinia. As a result, different cultivation arrangements have been proposed, representing the wide range of local situations, making allowances where possible for adaptations required by single cases.

Water requirements for irrigation have not yet been completely defined, since some general criteria of the agronomic study are still under discussion. Only an approximate figure of the total irrigation need may be given here. Assuming that the land actually irrigated is 72 per cent of the irrigable area and an average requirement of 500 m^3/ha, a total of nearly 1600 million m^3 can be estimated.

Figure 2 shows the irrigable areas of Sardinia together with the hydrographical network, industrial areas and inhabited zones.

5. *EVALUATION OF AVAILABLE WATER*

5.1 Surface water

In the water master plan, the quantity and quality of surface, ground and treated waters are determined and their regional distribution evaluated. Non-conventional resources have also been considered, i.e. brackish and seawater to be desalinated. A study of the surface hydrology of Sardinia, elaborating the basic hydrologic data using suitable mathematical models, has allowed the finding of the historical and stochastic monthly and yearly flows for watershed and irrigated areas as well as the runoff at the measuring stations and all the "sections of interest".

The study embraced the following:

- collection and preliminary elaboration of hydrological and climatological data;

- acquisition of soil and vegetation data and definition of "sections of interest" and irrigated districts;

- determination of areal parameters regarding watersheds and irrigated districts;

- inflow-outflow transformation model;

- model for the generation of synthetic series;
- model for the generation of flood events;
- model for the determination of water shortages in irrigated areas.

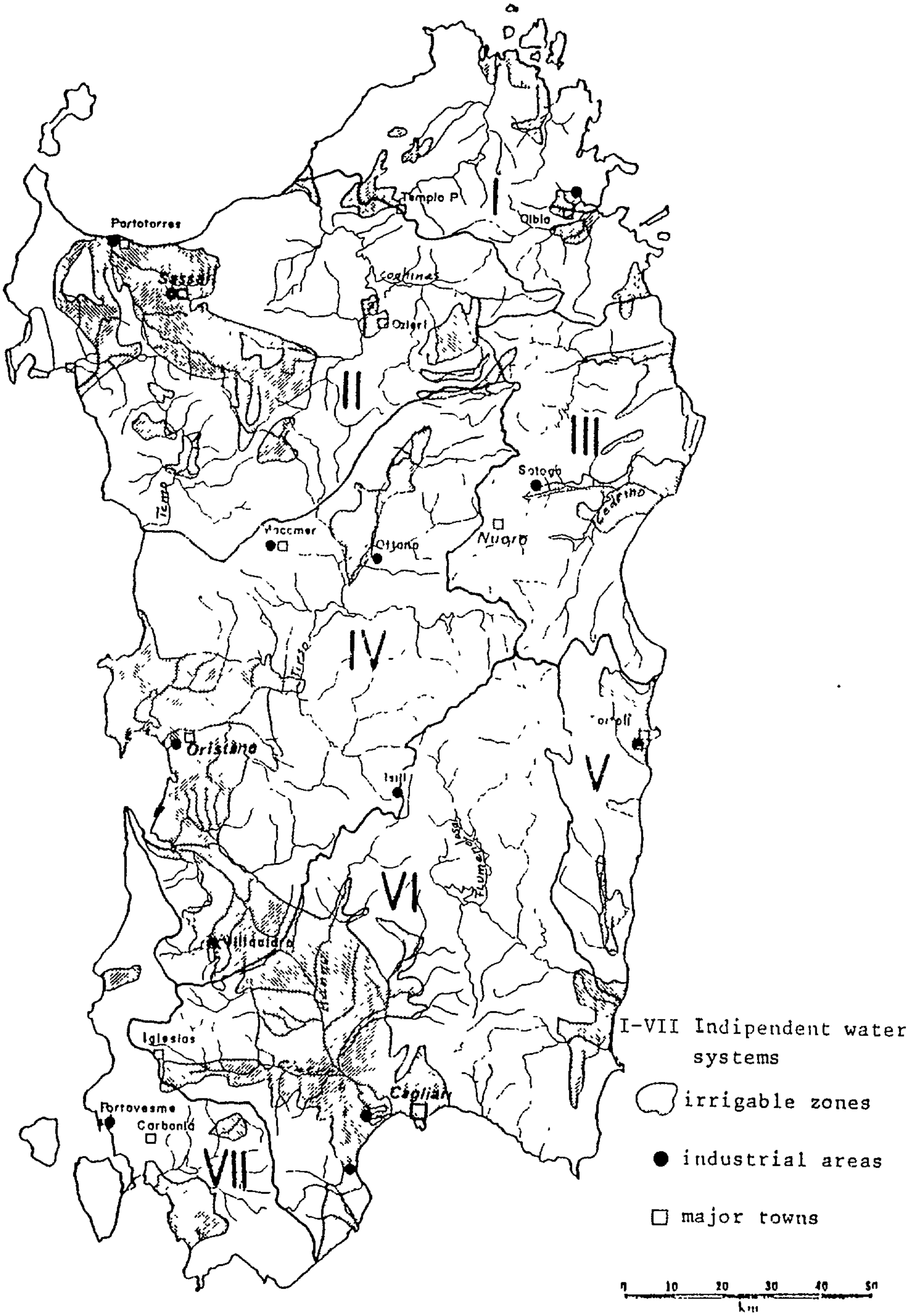

Fig. 2 Irrigable areas of Sardinia

Furthermore, the hydrologic study also concerned the evaluation of flood events in those areas with a high flood risk.

5.2 Ground water

The directive of the general study of ground water hydrology was to gain a better hydrological knowledge and to develop existing information through a systematic ground water survey, in order to evaluate the available resources and their potention use, particularly in areas where demand is difficult to satisfy with surface water.

The Institute of Mineralogy and Geology of the University of Sassari was appointed to conduct the investigation.

5.3 Non-conventional water resources

The evaluation of non-conventional water resources is based on the hypothesis that mine ground water might be withdrawn and used, as well as treated urban and industrial waste waters. Furthermore, information has been gathered on the development of applied studies and experiences regarding seawater desalination in Italy and elsewhere.

The study comprised:

- census and evaluation of ground water available from mines;
- census and evaluation of the present and predictable urban and industrial waste water;
- acquisition and analysis of experiences and information on technology and costs of using treated desalinated waters;
- collection of information and data on studies and knowledge of artificial rainfall.

Technologies, resource allocation and costs are analysed in the light of possible utilisation schemes especially with a view to integrating traditional resources.

The evaluation of the total amount of water available is not yet complete but on the basis of preliminary calculations, a total yearly runoff of 4,000 million m^3 has been estimated for all the island's water courses. This figure has been obtained considering all the sections where waterworks, generally consisting of reservoirs, are feasible. A preliminary estimation of available ground water resources gives a figure of nearly 500 million m^3/year. In addition, the treated waters from all the treatment plants of towns, isolated houses and industries are also to be considered. Mine ground waters and artificial rainfall are not expected to contribute to any significant extent.

However, these are only potential resources and the amounts that can be used will definitely be lower than expected. Furthermore, it must be considered that the amount of water available, as well as demand, differ from place to place. Therefore, in certain parts of the island, the water demand will not be completely satisfied, whereas in others, available resources will exceed demand.

Of course, where feasible, water will be transferred from those areas where water is plentiful to those where there is a shortage of resources but, it is unlikely that all the problems will be solved in the near future.

6. SECTORAL AND INTERSECTORAL WATER INFRASTRUCTURES

On the basis of the findings of investigations to date regarding available resources and the hypothetical demands, preliminary indications are drawn concerning existing or needed reservoirs, schemes, alternatives for sectoral and intersectoral conveyance and distribution infrastructures and their construction and management costs.

The main indications regard:

- the census, examination and dimension and reliability control of reservoirs and water collection, production, conveyance and distribution works;
- the study of any possible adaptation and completion and cost estimates;
- the study of the structures forseeable for the "sections of interest" in relation to the results of the preliminary investigations. Costs of any alternative hypotheses in relation to variations in dimensional characteristics are evaluated as well;
- the study of intersectoral water conveyance schemes even in alternative hypotheses and evaluation of construction and operating costs;
- the preliminary study of sectoral structures of public competence for agriculture, industrial, civil or other sectors, with the evaluation of the relative construction and operating costs.

7. SYSTEM ANALYSIS

The system analysis has been employed in choosing the optimal organisation of the works of any one scheme and/or interconnected schemes identified, as well as the satisfaction of water demand under the hypothesis of variable allocation, dimensions and resource availability.

The system or systems use the parameters identified in the previous work stages, i.e. resources, demand centres (existing and possible), collection and distribution structures, control sections, costs and socio-economic results. The relationships between the system components are quantitative, qualitative and economic. The former represent the constraints deriving from the relation between available resources and demand centres. The qualitative relationship represents the constraints imposed by the quality characteristics required by the user type and those available or obtainable from the works. The economic constraints are related to the benefits ensuing from the various uses in relation to the costs involved in the construction of infrastructures and their operation.

The optimisation model will have the prime objective of identifying the allocation of the various resources to the demand centres, the reservoir and conveyance works to be constructed and their possible priority and preliminary dimensions.

The system will have the constraint of integrally satisfying the civil needs forecasted for the different deadlines. The satisfaction of the agricultural and industrial demand will be total in the long run and partial in the near future. Priority will be determined with economic criteria, by considering costs and indexes of irrigation productivity and industrial use in the object functions provided by the sector regional plan.

The optimisation process should be capable of accepting as constraints and benefits, the production of electric power in existing or foreseen plants. As for flood protection in the optimisation process, the benefits secured from containing flood damage will be considered together with the costs of any work for reducing it. The result of the optimisation process will be the allocation of each resource to satisfy one or more needs, the identification of the works required and the preliminary determination of their functional dimensions.

On the basis of the results of the optimisation process, sub-systems will not be considered as interacting. For each sub-system the main works will be dimensioned and optimum management criteria will be determined with simulation models. The simulation models will be operated on a monthly basis in order to evaluate the evaporation effects in reservoirs, the potential evapotranspiration in the irrigated areas and, where necessary, aquifer behaviour.

Thus, it will be possible to evaluate the management results on a probabilistic basis and to make a sensitivity analysis by evaluating both the technical and economical effects of varying parameters.

8. CONCLUSIONS

The water resources master plan is an indispensable tool for the harmonic solution of the water problems in Sardinia, which pose particular difficulties arising from the hydrogeological and climatic conditions.

Ground water resources are only sufficient to satisfy local demands, with the result that surface water had to be especially exploited for the social and economic development of the island. Already 35 reservoirs are in operation with a density of 1 reservoir per 686 km^2, the highest in the Mediterranean, and a useful storage capacity of 1,685 million m^3. The master plan has evidenced the need for more than 60 new reservoirs with a useful storage capacity of over 2 billion m^3, and a network of main supply canals totalling nearly 15,000 km.

Under these circumstances, a major scientific, technical and political interest has been launched involving highly qualified experts. The enormous economic and social problems highlighted by the water resources master plan can no longer be solved by local and sectoral boards alone. Administrators are already aware that a new organisation has to be created in order to manage water resources.

9. ACKNOWLEDGEMENTS

The authors are indebted to the Autonomous Flumendosa Board and Engineering Co. C. Lotti & Ass., who kindly produced the data for the present report.

WATER SUPPLY OF ISLANDS IN YUGOSLAVIA BY WAY OF REGIONAL SYSTEMS CONNECTED BY SUBMARINE PIPELINES TO THE MAINLAND USING THE ISLANDS OF BRAC AND HVAR AS EXAMPLES

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1. INTRODUCTION

Since 1970, Yugoslavia has started to develop the water supply of the Adriatic Sea islands using regional systems connecting the islands to the mainland by submarine pipelines.

The Adriatic Sea islands, with the exception of the Island of Cres in the northern part of the Adriatic Sea, generally lack water or, strictly speaking, do not have sufficient quantities of good quality water to satisfy the demands during the summer months.

The general characteristics of all these islands is the development of tourism; thus even those islands with sufficient quantities of water to meet the requirements of their inhabitants must have greater quantities to meet the requirements of a large number of tourists.

Since the end of the 1960's, water has become the limiting factor in the further development of tourism; consequently, the problem is being considered more carefully. In the following text, the examples of the islands of Brac and Hvar illustrate a possible solution to water supply on the islands using regional systems.

2. GENERAL DATA ON THE ISLANDS

The Island of Brac

(a) General data

The Island of Brac is the largest island in middle Dalmatia with an area covering 394 km^2, situated between Latitude 16°30' - 17° and Longitude 43°30'. The length of the island is ca 40 km, and the width varies from 4-13 km. The highest point of the island, 778 m a.s.l., is the highest peak of all the Adriatic Sea islands.

From the geological standpoint, the island consists of carbonate rocks, mostly limestone and less of dolomites. Along the southern coastline of the island, in the area of Bol, a small part consists of impermeable rocks of the eocen (marl and sandstone). In the valley bottoms there are quaternary deposits consisting prevalently of karst rocks and terra rossa. The depth of these layers hardly ever exceeds 1 m.

The distance of the island from the mainland is from 5 km to 12 km, which means that from a geological aspect, the island resembles the mainland. The average yearly precipitation of Brac is ca 850 mm, and thus, it does not differ significantly from the mainland. There are no permanent streamflows, but after heavy precipitation, temporary flows are formed (currents), which can cause significant damage to the agricultural areas. The population is mainly oriented toward tourism, partly engaged in agriculture and only a small number in industry.

(b) Essential elements for the existing and planned water demands

Presently, there are 12,577 inhabitants living permanently in 22 settlements, whereas during the summer season this number increases five times. Thus, although the average water consumption is about 250 l/day, it is necessary to provide 100 litres per second.

In the near future, i.e. by 2010, this number should increase according to available data, to 20,000 permanent inhabitants, i.e. during high season 100,000 consumers. According to the same criteria, the maximum water consumption would be ca 300 l/sec or 25,920 m^3/day.

The above quantity includes water for watering plants, industry and cattle and, accordingly, the total water demand in the year 2010 would be 300 l/sec or 25,920 m^3/day.

(c) Previously used water supply systems

The current water supply has been provided in different ways, i.e:

(i) Rain - harvesting from the roofs in the settlements where no other mode of water supply was possible (this refers to the settlements which are situated either far from the coast or in higher zones not reachable by tankers or boat-cisterns);

(ii) Nerezisce, a former administrative and cultural centre of the island, which is at +350 m elevation solved its problem of water supply in the last century by controlled catchment of rainwater in surface reservoirs;

(iii) In quaternary deposits, near Dol, several drillings were made and about 10 l/s of a good-quality water was secured for the water supply of Postira, Supetar (the present administrative centre of the island) and Sutivan. However, the demand for water soon exceeded the available amount, requiring an additional supply by tankers or boat-cisterns in summer;

(iv) For settlements situated along the coastline (Bol, Milna, Povlja, Sumartin) water was regularly transferred by tankers from the mainland.

The Island of Hvar

(a) General data

Next to Brac, the Island of Hvar is the largest of the Dalmatian islands, covering an area of 289 km^2, situated between Latitude 16°20'-17°10' and Longitude 43°10'-43°15'. The length of the island is ca 65 km, and its width varies from 2 to 10 km. The island is of an elongated form, particularly in its eastern part and it lies in an East-West direction.

From the geological, and especially from the lithological standpoint, it is very similar to the island of Brac. It consists mostly of limestone and dolomites, but its structural composition differs from Brac, creating the possibility for the gathering of rainfall in the western, i.e. middle part of the island. The island of Hvar has an anticlinical composition with limestone in the middle and dolomites along the edges of the anticline. In the largest section of the western past, groundwater flows from the middle of the anticline toward the East. When the groundwater reaches the transversal fault, it turns to the North, i.e. to Jelsa where the water is collected for the existing waterworks.

Hvar is situated southerly from Brac with the shortest distance between the two islands of ca 4.5 km; the point farthest in the East is equally distant from the mainland.

The average quantity of precipitation during thirty years recorded on Hvar is somewhat lower than on Brac, amounting to 722 mm.

There are no permanent streamflows on the island, and owing to its elongated shape, strong currents are not formed even after heavy precipitation.

The main and practically only branch of the island's economy is tourism; however, the greatest problem for the further development of tourism is posed by the limited quantities of water.

There is a group water supply system which supplies the settlements in the western part of the island, but the situation is becoming more serious due to conditions of the network, and the quality and quantity of water.

(b) Essential elements for the existing and planned water demand

There are 11,059 inhabitants living permanently on the island, mainly in the western part. In summer, this number is increased several times due to a great number of tourists, so that with the average consumption of 250 litres per consumer/day, the island should have over 100 l/sec. of water; however, presently, Hvar has only 70 l/sec of its own groundwater.

According to the feasibility study, in the long run, the consumption on the island will be 196 l/sec., which means that in addition to the existing 70 l/sec to be used, it will be necessary to ensure another 226 l/sec, i.e. 20,000 m^3/day.

(c) The existing systems of water supply

The present and future water supply of Hvar can be divided into the eastern and western parts of the islands. The eastern part has practically no organised supply, therefore the inhabitants have always collected rainfall in used cisterns. The shortage of water during the summer period is compensated by delivery of water by tankers or cistern-boats.

As previously mentioned the western part of the island has a water supply system. However, it does not satisfy the demands of all consumers.

The aquiferous water is captured in galleries and is pumped in three main directions to supply the settlements of the western half of the island. A pipeline about 25 km long supplies Hvar, the largest settlement on the island,

and the settlements along its southern coast. In addition to the pumping station at Jelsa, four reservoirs have been installed and tunnels have been cut through the mountain connecting the northern and the southern side of the island. In the most critical period the shortage of water in Hvar is compensated for by delivering water by tankers, i.e. boat-cisterns.

In addition to the central intake works in Jelsa, several wells had been drilled in this part of the island, from which all the available quantities of water will be used until its connection to the regional system. In the driest period of the year, however, the quality of this water is not satisfactory considering its degree of salinity.

3. POSSIBLE SOLUTIONS FOR THE WATER SUPPLY OF THE ISLANDS BRAC AND HVAR

Before making a decision regarding the methods of supplying water to the islands Brac and Hvar, several alternative solutions have been considered. The following text presents a short review of these solutions stressing the essential conditions for the selection of the most appropriate one, i.e. to ensure sufficient quantities of good quality drinking water for all settlements, at any time of the year, in accordance with the consumption standards, as applied in the Dalmatian region.

1. Rain harvesting from the catchment surface has been readily eliminated as an old-fashioned and uneconomical solution compared to the other alternatives. This way of water supply could not satisfy the previously mentioned condition. In two settlements of an elevation between 350 and 400 m.a.s.l., which are among the smallest on Brac, the area of the calculated gathering surface is 377,000 + 279,000 = 666,000 m^2, while the volume of the required tank is 98,000 + 73,000 m^3.

2. Exploitation of the groundwater. The quantity of the groundwater on both islands, as previously stated, is ca 80 l/sec, which from the sanitary aspect, satisfies the required conditions. This solution, however, due to the limited quantities of water, cannot be taken into account without ensuring other sources. This solution was, nevertheless, considered in combination with some other alternatives particularly on Hvar which, owing to its more favourable geological composition has greater quantities of groundwater (ca 70 l/sec).

3. Water supply from the mainland by delivering water by tankers-boat cisterns. This alternative has been used by a great number of the Adriatic Sea Islands over many years and it is still used by a small number of islands situated at a great distance from the mainland. It could not be selected as a final solution since the required water quantities are great (for Brac and Hvar ca 550 l/sec) and because of high investments costs (large number of boats-tankers) and also due to high exploitation costs (the distance to Hvar being over 20 miles). Considering the above mentioned facts, the delivery of water to islands the size of Brac and Hvar, which are the same distance from the mainland, by means of tankers, remains only a potential solution for emergency cases.

4. Desalination of the sea (or brackish) water has also been considered, but it has been eliminated because of high energy costs and the great quantities of water required. According to the present situation, 1 m^3 of water obtained by desalination costs $5.00, and the same quantity of water from the

regional system costs ca $0.25; thus, it is evident that the ratio is 1:20 on behalf of the regional system.

5. The construction of surface storage reservoirs. This alternative has been carefully considered especially for Hvar, and it seemed for a time it was going to be realised. However, when all costs were analysed (the construction of dam, grouting, treatment plants, the problem of filtration and evaporation) it was eliminated. This alternative could not guarantee sufficient quantities of good quality water, from the sanitary standpoint, at any time of the year, and particularly in the summer period.

6. Since none of the considered alternatives could satisfy the proposed criterion, i.e. ensured sufficient quantities of good quality water, from the sanitary aspect, the only alternative was the water supply from the regional systems by means of submarine pipelines.

The next chapter presents a detailed description of the adopted alternative.

4. THE DESCRIPTION OF THE SELECTED SOLUTION

The economical water supply of any island by means of a submarine pipeline implies an essential condition, i.e. that there are available quantities of water on the mainland at the shortest possible distance from the island.

The largest Dalmatian river, the Cetina, flows in the hinterland of the Adriatic Sea. The Cetina is 105 km long. The difference in height between the level of the spring and its estuary near Omis is 380 m from the energy standpoint, the river is well-exploited, with one of its hydroenergetic structures, the water lock at an elevation of 250 m a.s.l. being used as intake for the regional system.

Since the Omis Riviera and the island of Brac have not solved their water supply in a satisfactory way, it has been decided to construct a common regional system for the mainland and the islands.

The Cetina River is surface water, making it necessary to construct a treatment plant. The water is delivered from the treatment plant by a steel pipeline (calculated by the total demands of Omis and of the islands) down to the sea where it branches into the eastern and western part of the Omis coastal region and another branch for the islands. During the construction of this pipeline, special attention was paid to the stages of its building, as presented in the following text.

The water is delivered to Brac by a submarine pipeline. During the periods where less water is consumed, the water flows into the central reservoir, "Brac", at an elevation of 150 m a.s.l., which, due to gravitational force, flows at a rate of 80 l/sec.

From this reservoir, the water flows in three directions, i.e. to the East, West and South so that it supplies all the coastal settlements. At the Southern branch, a special pressure pipeline is diverted for raising water and delivering it to the central part of the island.

In order to deliver water to Bol, on the island of Brac, and to the island of Hvar, a tunnel 8.5 km has been drilled under the Vidova gora mountain. The decision to drill a tunnel of that length was determined after a detailed economic analysis.

It has been shown that for the water supply of Bol (52 l/sec), it is more suitable from the economic aspect to bring the water from Milna; whereas, for the water supply for the island of Hvar (226 l/sec), the alternative of a tunnel was more convenient and thus carried out.

The catchment facilities and the mainland distribution network were designed and constructed for the final solution all at once, whereas, the treatment plant, the submarine pipeline, the pumping station on Brac (necessary for overcoming the linear losses from the submarine pipeline in the days of increased consumption), and the central reservoir were built in stages, so that they will be completed with the increasing water demands. This particularly applied to the decision on the profile and type of the submarine pipeline.

In 1970, when the first submarine pipeline was laid out, the essential problem consisted in the selection of the type and profile of the pipeline. Two alternatives were considered: one with a steel pipeline of greater profile (diameter) for the final demands and the other with a reinforced-plastic pipeline of a smaller profile for satisfying the demands of the first stage. After carrying out a detailed analysis, it was decided to accept the latter alternative, since it was possible to effect it in phases. In 1978, another pipeline parallel to the first one was laid out, and in November 1986, the third pipeline was laid out.

The water was delivered from Brac to the islands of Hvar and Solta, through the submarine pipelines.

The island of Hvar, as previously mentioned, is about 65 km long, and the population as well as the tourist facilities are distributed mostly in its western part, less in its Eastern part, and practically none in the middle part of the island.

Considering this distribution of inhabitants and tourism, it would not be economically justifiable to bring water from the Western part to the Eastern part; thus, the Eastern part is supplied by water from the regional system of the Makarska Riviera. This regional system was constructed at the end of the 1960's and has many similar characteristics with the regional Omis-Brac-Hvar system (Figure 2).

This system also delivers the water of the Cetina River, using a system of pipeline, pumping stations and reservoirs, to the Makarska Riviera. In projecting the structure of this system, it was necessary to take into account the demands of the Eastern part of the island of Hvar where the water is delivered via a submarine pipeline.

Thus, it will be possible, in the near future, to solve the problems of water supply in the coastal belt in the Eastern part of Hvar. However, the settlements situated at an elevation of about 300 m a.s.l. in the near future will have to collect rainfall or water will be brought in by car-cisterns during very dry periods. In the final solution this part of the island will be connected to the group system by the pumping stations.

The water supply on the island of Hvar and the method of effecting it in the future has already been solved in a similar way to that of the island of Brac. The problems encountered in solving the water supply of Brac were very similar to those for Hvar. This primarily refers to the submarine pipeline and the dilemma of whether or not to install the pipeline with those dimensions which satisfy the final demands or in stages depending upon the increasing consumption.

This dilemma does not apply to the Eastern part of the island since the consumption is relatively low. In the western part, where it is necessary to deliver over 200 l/sec (more exactly 226 l/sec) the same economical analysis as for Brac had to be effected. Understandably, the same results were obtained as the problems were being solved at the same time. Accordingly, the previously mentioned economic analysis is valid for the island of Hvar, so that one pipeline for the first phase was laid out in June 1986, where 40 l/sec will be obtained by gravity.

In solving the water supply for the Western part of Hvar, the proposed alternatives were very interesting, i.e. how to transport the water from the northern to the southern part of the island.

The essential dilemma was whether or not to use the existing tunnel built for one-way traffic or to build a new tunnel, as a multipurpose structure, which would at the same time be used as a traffic-tunnel and would serve for delivering water to the greatest number of consumers (the town of Hvar).

After a detailed economic analysis, considering the general development of the island and its demands, the latter alternative was chosen, although the construction of the traffic tunnel is more expensive (ca 100%) than that of the water supply tunnel.

The water is transported from the Western part of Brac, using the submarine pipelines to the island of Solta in addition to Hvar. This pipeline was laid out in 1970, i.e. at the same time as the Omis-Brac pipeline. It presents only the first stage of the future supply since three similar pipelines will be necessary for the consumption of this island.

On the island of Hvar the construction of the pipeline for the western part of the island is presently being completed. It should be noted that all structures are intended for the water quality of 50 l/sec which satisfies the demands of Vis.

The island of Vis is (apart from the Lastovo which has already been connected to the mainland by submarine pipeline) located at the greatest distance from the mainland of all inhabited islands. Thus, it will be necessary to lay out 34 km of submarine pipelines to deliver water from the mainland. Presently, this island has sufficient quantities of water from the deep walls (ca 40 l/sec); however, the development of tourism and agriculture will entail a higher consumption to bring water from the mainland.

5. OPERATION OF THE SYSTEM

The system described in the previous chapter has the following parts already in operation: the branch for the Omis coastal area on the mainland, a complete system on the island of Brac and one part of the system on the island of Solta. By the beginning of 1987, the water supply system on Hvar will be in operation.

This system including Hvar, connects four municipalities. Every municipality since the beginning of the construction, has managed and operated its respective part of the system and is responsible for the corresponding investment and exploitation costs. Considering the group water supply systems, all participants share the expenses according to criterion of l/sec, i.e. the percentage of the expenses corresponds to the percentage of the water quantity in l/sec consumed by that participant.

After 16 years of operation and exploitation of the system, it can be concluded that no significant problems have been encountered, either related to the operation of the system or the relations between the users.

This regional system is a typical "tourist system" which means the consumption between the winter and summer months varies and increases in the peak tourist season, sometimes as much as five times.

The mentioned difference in water consumption between the high season (lasting 2-3 months) and off season, has entailed the installation of pumping stations at each point of sea entrance or exit, in order to decrease the profile of the pipelines and reduce their number. This station increases the water velocity and pressure in the pipe, and hence the flow during the days of maximum consumption.

These structures make possible a uniform water supply. With cuts in electric energy and without a built-in diesel alternator, water delivery is reduced. Consequently, when designing the entire system, special attention was paid to ensuring a sufficient capacity of the reservoirs, so that they could provide the consumption until the normal supply of the islands by electric energy was effected.

Nevertheless, each pumping station should have an automatic diesel-alternator in order to make the operation of the system more efficient.

6. HIGHPRESSURE REINFORCED-PLASTIC SUBMARINE PIPELINES

General data

According to the previously mentioned facts, it is evident that the water supply of arid islands cannot be effected without the submarine pipelines which are an exceptionally expensive part of the system.

In the realisation of each project related to the submarine pipelines in the Adriatic Sea area, the most favourable offer was selected at an international auction with the presented documentation worked out in advance.

The tender documentation included the following parameters to be satisfied by the bidder:

- water quality
- length of pipeline
- protection of the pipeline from the waves' influence
- chambers for the connection of the submarine and mainland pipelines
- testing the pipeline, pressure control, etc.

It should be stressed that the tender did not specify the type of pipeline, so that all bidders were in the same position.

The following three types of pipelines appeared at the auctions:

(a) steel pipeline
(b) highpressure PEHD reinforced pipelines
(c) PEHD lowpressure pipelines

(a) Steel pipelines are very suitable according to their physical qualities, particularly since they ensure the delivery of great quantities of water; however, their installation, i.e. laying out, requires a long period of stable weather, namely calm sea, which is sometimes difficult to achieve. Another drawback is the necessary protection against corrosion, since cathodic should be ensured without regard to the internal and external isolation.

The roughness coefficient is also much greater than in other types of pipelines.

(b) The advantage of these pipelines is that they can be quickly laid out. They are quite safe from hazards and mechanical damage. Their disadvantage is the limiting size of the cross-sectional area, as the largest one produced so far is 350 mm.

(c) HDPE lowpressure pipelines. These types of pipelines are the cheapest to buy, but their drawback is that they cannot withstand pressures higher than 10 bars. If the pressure in the system is higher, it has to be reduced before entering the sea, whereas, at the location of the exit from the sea, a pumping station has to be installed to increase the reduced pressure.

When considering the project, the Committee selected the highpressure reinforced-plastic pipelines for connecting the mainland and Brac, as well as for the connection between Brac and Hvar, stating the following reasons:

- the construction in phases eliminated the greatest drawback of these pipelines (maximum profile) since sufficient water quantities were provided in the first stage with the interpolation of the pumping station on the island of Brac.

- HDPE lowpressure pipelines could not be taken into account due to a very high pressure at the entrance.

- the steel pipeline, which could ensure greater quantities, was so expensive that it was impossible to provide the necessary financial means.

- at the auction, it was assumed that the installation of a steel pipeline would take about six months, which would hinder the traffic in the Brac channel. The installation of the highpressure polyethylene-reinforced pipeline took practically only one day.

Among the bidders offering this type of pipeline (Pirelli-Milano, NKT Kopenhagen, Coflexip-Paris) the most favourable and hence the offer finally selected was the one presented by the firm NKT Kopenhagen. The description of that pipeline and the method of its laying out are presented.

Description of the pipeline and its production

The enclosed presentation of the cross-sectional areas (Figure 3) shows that it consists of several layers; the following being the most important:

- pipe of HDPE 202/220 mm used only for water flow and reduction of roughness to a minimum;

- two layers of cotton tape serving as protection for the pipe from the possible damage by the tectyled steel tape;

- tectyled steel take is that part of the pipe changeable depending upon internal pressure;

- the layer of PVC tape and jute with asphalt serving as isolation of the steel tapes;

- galvanised steel wires spirally winding around the pipe used to take over the longitudinal forces during installation, and after the pipe has been laid out to take over the function of a mechanical protection;

- layer of jute, PVC tape and a layer of impregnated glassfibre roving which serves as the isolation of the spiral wires;

- coating of PHDE around the entire pipeline serving as external protection of the pipeline.

The production of the pipes is completely automatic. The pipe is produced in one piece up to the length of 13 km corresponding to the length of the vessel from which the pipes are being laid out.

The first step in the production is the extrusion wherefrom the pipe is wound onto a large turntable. From the turntable, the pipe is returned to the armouring machines, where one process involves the winding of all the previously mentioned layers.

Subsequently, the pipe is returned back to the big turntable wherefrom it goes to the extrusion line where it is coated by the external polyethylene protection.

Transportation and installation of the pipeline

Once the pipeline has been completed, the pressure test carried out and the pipe would to the turntable, it is then taken to the laying out vessel, which is built as a self-baling pontoon without its own propulsion machinery.

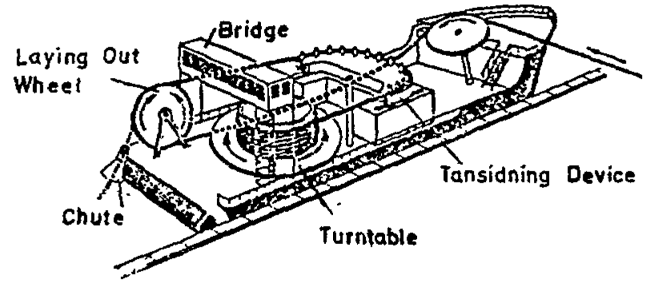
The enclosed drawing and figure show the most important parts of the laying out vessel:

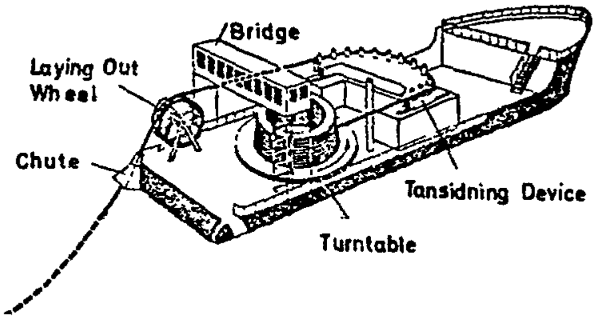
- a turntable on which the pipe has been wound

- a laying out wheel (capstan) for laying out the pipe into the sea

- a tension regulator, which regulates the pressure in the pipe during the laying out of the pipeline.

Since the laying out vessel does not have its own propulsion machinery, it is towed from the harbour in Copenhagen to the site of laying out by a tow boat. The laying out is effected so that, after all preliminary operations on the mainland, the tow boat slowly tows the vessel along a designated route to the other shore. The operation of laying out is completely automated, so that at any second the following data are known: the distance from the mainland, the depth of the sea, the pressure in the pipeline and the other necessary parameters.





The time of the laying out in normal maritime conditions is no longer than one day.

It should be noted, however, that it is necessary to provide more time for the operations on the mainland. These works include the excavation of the trench in the sea as far as the influence of the waves is felt, the construction of the chambers, and the other works necessary for the transportation of the pipe to the coast, and markings for the navigation of the vessel.

After finishing the laying out and pressure tests, it is necessary to complete the civil engineering works on the mainland which refer to the placement of concrete around the pipeline in the sea.

7. CONCLUSION

Water supply by regional (group) systems transferring water from the mainland to the islands needs considerable financial resources, but is the only way of securing a permanent supply of good quality water to arid islands.

However, special attention should be given to appropriate staging of works. It would be economically unjustifiable to install consumption facilities on the islands for a demand in 20-30 years, and especially for developing tourist areas, where water consumption shows high oscillations between summer months and the rest of the year.

In the case of Brac and Hvar, before proceeding with further phases of construction, the growth and dynamics of consumption should be carefully studied and assessed, so that parameters designed for various phases are eventually corrected. This particularly refers to purchasing and laying submarine pipelines, the most expensive part of the system, without which the construction of the island distribution system is impossible.

Considering the technical aspect, special attention in the design should be paid to the selection of the appropriate type of the submarine pipeline. The general data in chapter 6.1. refers to the characteristic features of various submarine pipelines to be considered for application. It should be noted that there is a possibility of writing down detailed regulations for the application of each particular type of pipeline in addition to the essential parameters in chapter 6. Consequently, it is necessary to study in detail, for each project, all the relevant parameters and to select the most appropriate pipeline.

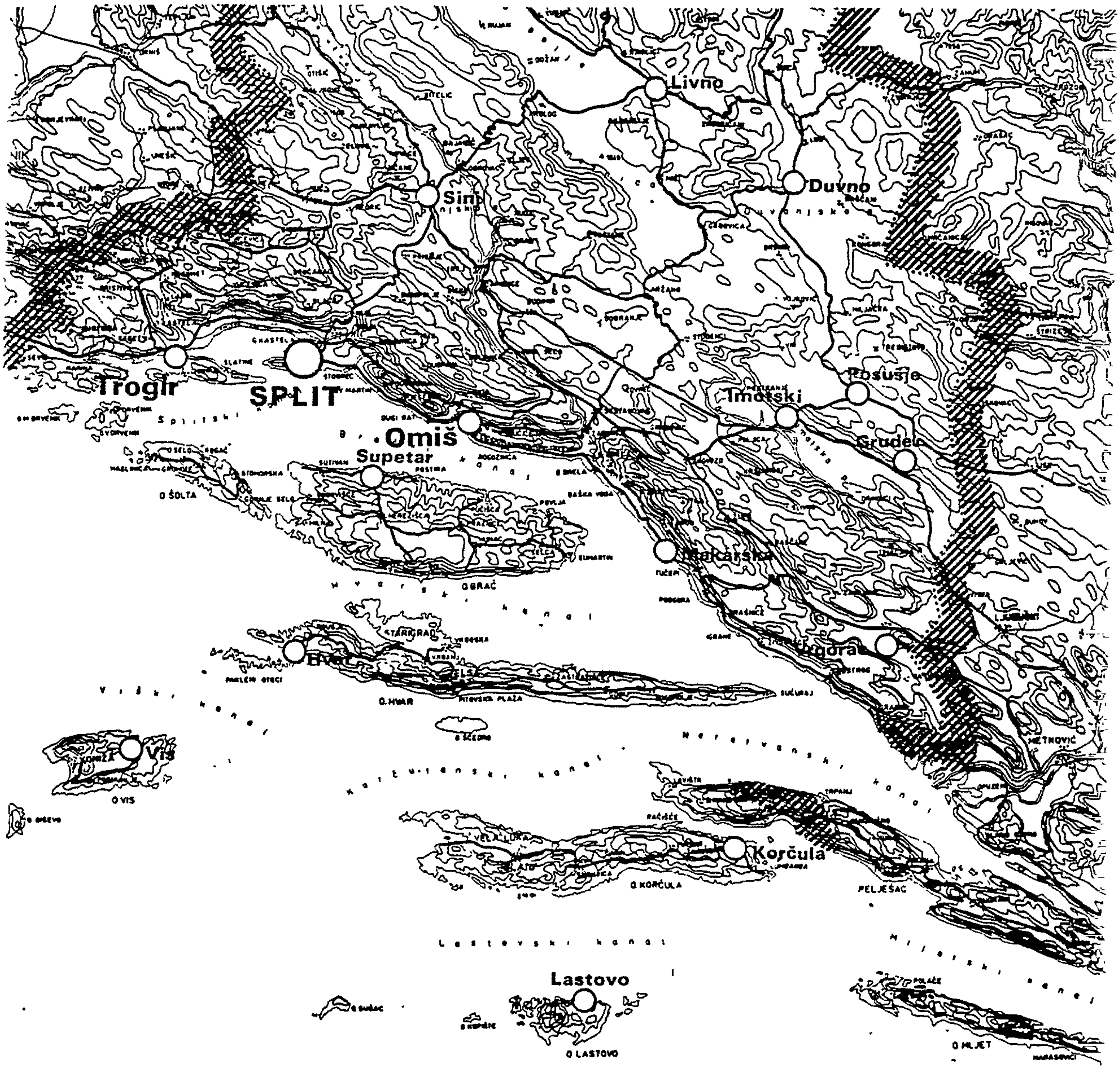


Fig. 1 Location of the islands

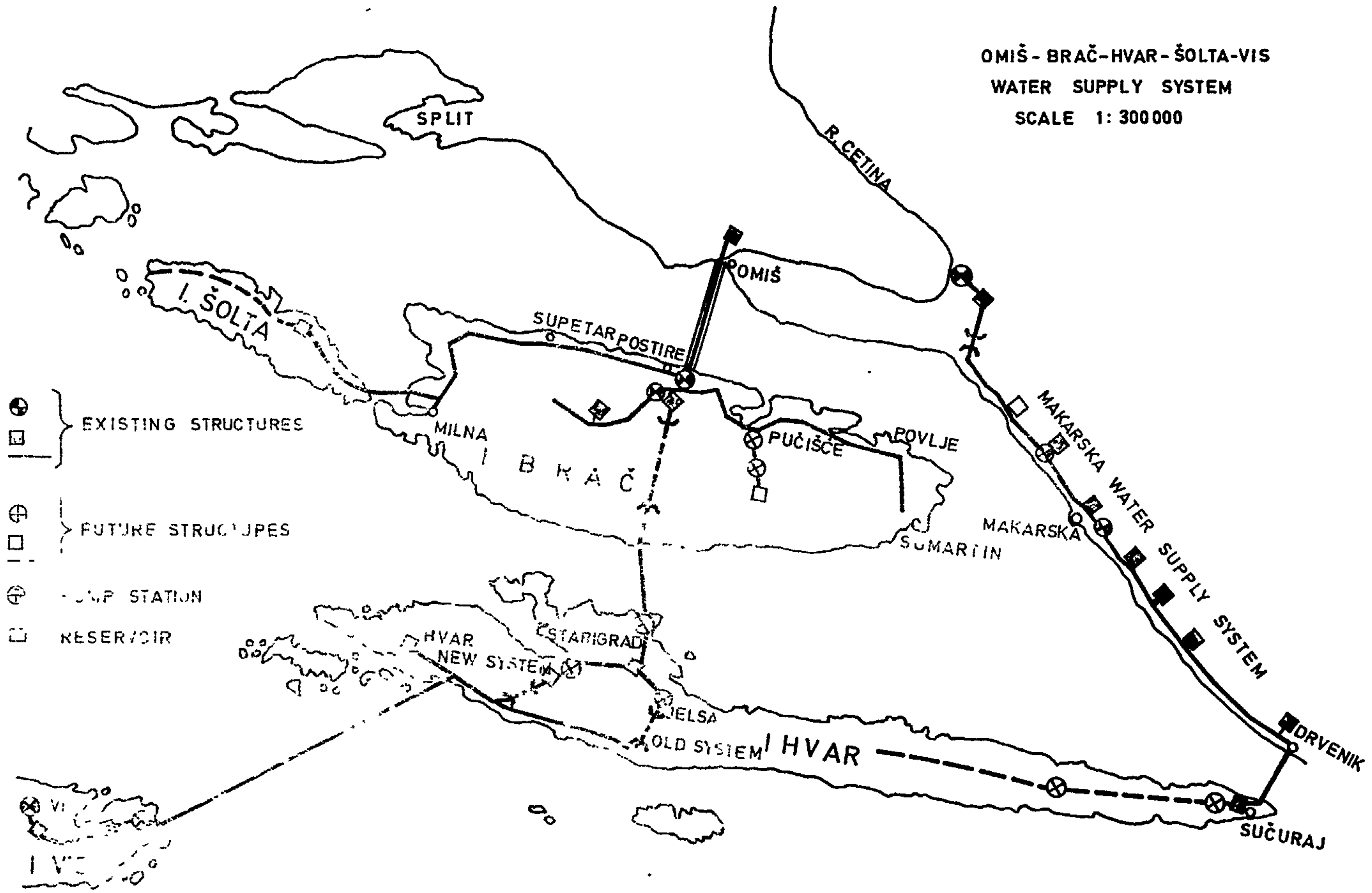


Fig. 2 Regional water supply sistem

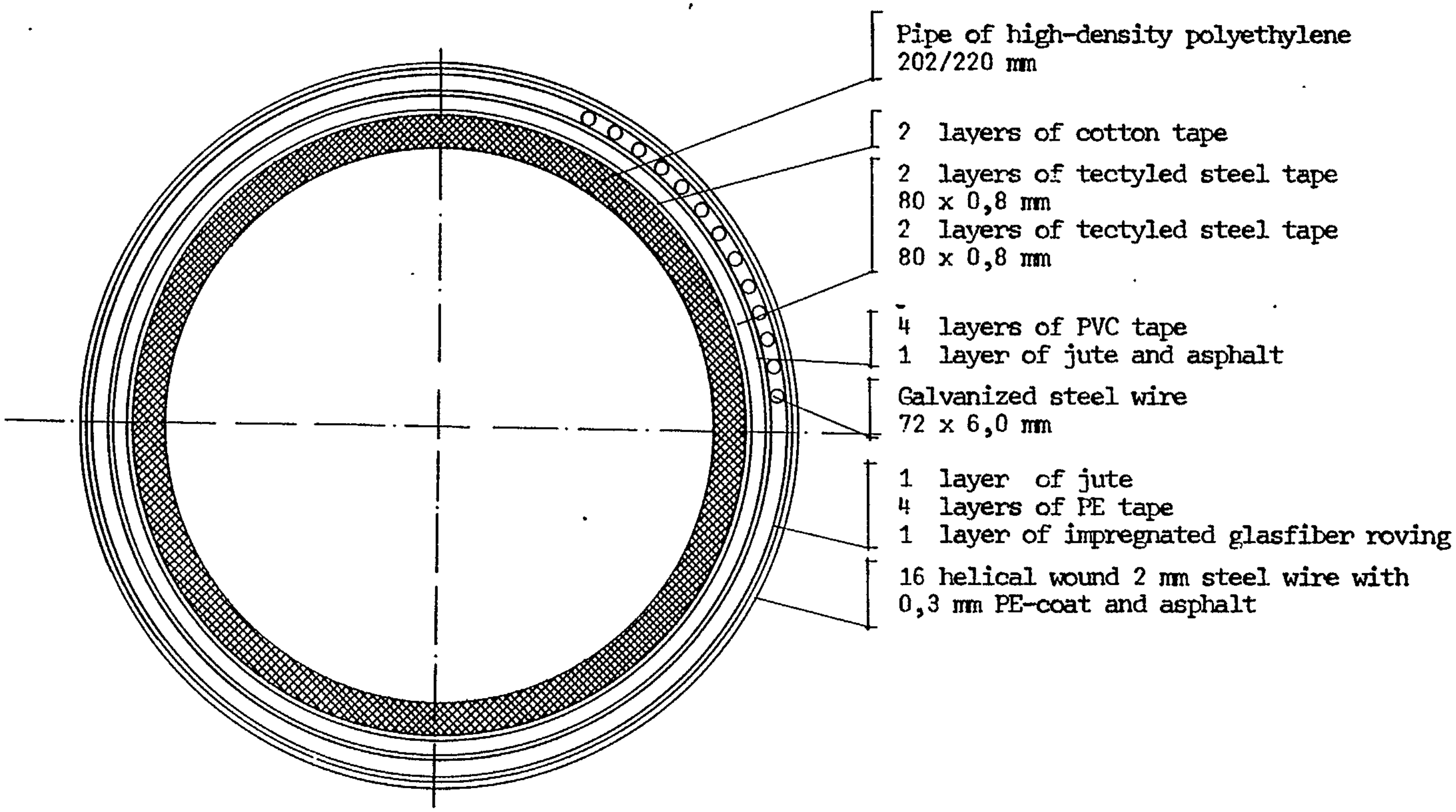


Fig. 3 Cross-section of HDPE pipe

CONJUNCTIVE USE OF SURFACE AND GROUNDWATER IN AREAS OF FLUCTUATING DEMAND (CYPRUS)

by

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A B S T R A C T

In semi-arid regions and in areas of great fluctuation of demand, conjunctive use of surface and groundwater storage is often relied upon to offset deficits in the dry season and accommodate storage and recharge of excess water in the wet season.

The term "conjunctive use of surface and groundwater" is defined as the coordinated use of both these sources for the supply of waters as distinct from the separate development of each source without regard to the other.

The optimum development and management of scarse water resources is of great importance. This is more accentuated in areas where there is a large fluctuation of the water demand either due to climatological reasons or seasonal influx of tourists. Such optimisation effort often requires mathematical descriptions of the behaviour of complex water resources systems and their conjunctive use.

This article aims at presenting in brief, a case study of analysing such a water resources system comprising a surface reservoir and a riverbed aquifer and to outline the experience obtained from the use of such conjunctive use operations in Cyprus.

1. INTRODUCTION

In semi-arid climates, periods of drought are quite frequent. In addition, in the small to medium size islands, the economic size of dams is usually small whilst the water supply demand in tourist areas increases disproportionally due to the seasonal character of the tourist activity. The ability to incorporate the groundwater storages associated mainly with riverbed aquifers at the lower reaches, attains significant importance. A small groundwater storage which can be relied upon in years of drought or during the season of increased water demand, could result in a considerable increase in the reliability of securing the supply to satisfy a defined demand.

The quest for a better use of the available water, which is by far exceeded by the demand, calls for well planned monitoring programmes of hydrological information and the application of descriptive and optimising models.

Inherent to the advantages of multiple resource systems, which can rely on components with different hydrological and economic characteristics like surface reservoirs, aquifers and/or desalination units etc., is the selection of a set of component sizes and operation rules which may lead to acceptable performance at minimal capital and operation costs.

This paper describes some of the above techniques, as applied to the efficient operation of a system which consists of a surface reservoir and a groundwater storage. Such a system is the Yermasoyia river basin dam and aquifer shown in Fig.1 and Fig.2.

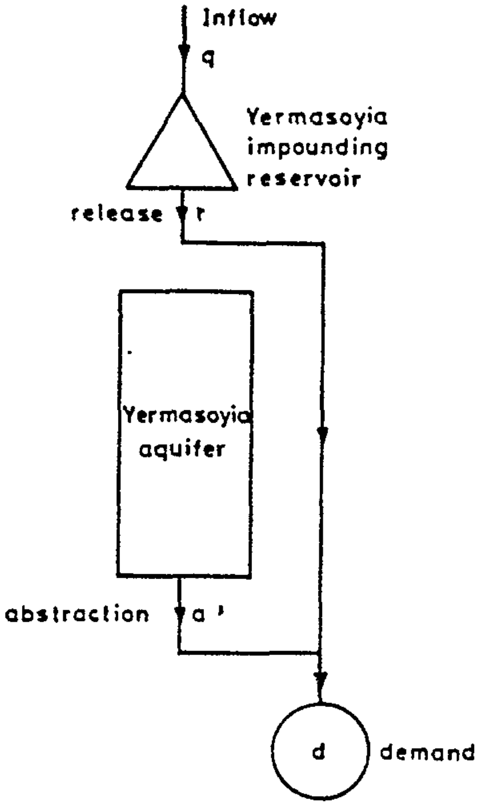

Fig.1 Simplified representation of the Yermasoyia system

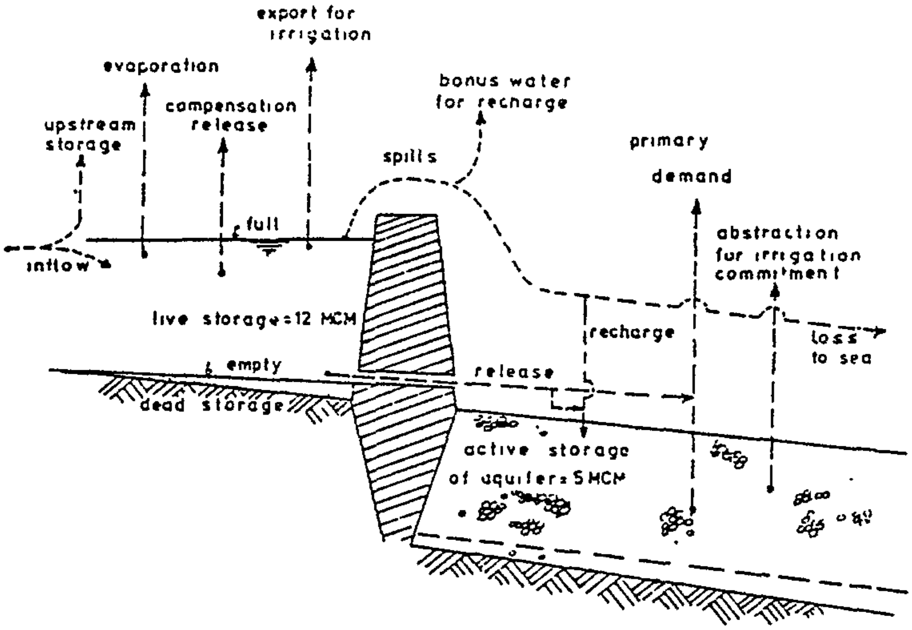

Fig.2 Vertical cross-section of the Yermasoyia system

The objective is to find the best way to operate the existing system by determining an operating policy resulting in minimising operating costs and satisfying a certain demand at a prescribed reliability of supply. A dynamic programming routine is used for this purpose. Furthermore, practical cases where conjunctive use operation is performed in Cyprus are presented.

2. THE CONJUNCTIVE OPERATION OF A SURFACE RESERVOIR AND AN AQUIFER

General description of the Yermasoyia River basin

The river basin is located in the southern flank of the Troodos mountain range draining to the sea at a point just 5 km east of the town of Limassol. It drains an area of 175 km^2 which rises to elevations of 1,400 m above m.s.l. About 80 per cent of the basin consists of igneous rocks, diabase and pillow lavas, whilst the lower parts are of chalks, marly chalks and alluvium. The annual average precipitation over the catchment is 638 mm, varying from 450 mm near the coast to 850 mm in the uplands. The annual average runoff of Yermasoyia River is estimated to be 22,5 million m^3, 65 per cent of which occurs during the winter. The river is basically dry in the summer months. Within 5 km from the coast, a gravel aquifer develops with alluvium of sufficient thickness to render it of considerable local importance.

An earthfill dam of 13,6 million m^3 storage capacity was completed in 1969 cutting off completely the subsurface recharge to the downstream alluvium aquifer (Figs. 1 and 2). The thickness of the alluvial deposits varies from 20 m near the dam to about 30 m just upstream of the very short delta fan near the coast. The width of the aquifer is about 250 m near the dam, expanding to 500 m just before the delta and up to 3 km wide on the delta. Only the upper part of the aquifer is used for abstraction because of urbanisation of the delta.

The aquifer below the dam had been relied upon for many years for local irrigation and for the water supply requirements of Limassol and neighbouring villages. At present, the aquifer depends exclusively on releases and on occasional spills from the reservoir for recharge since the dam has cut off any recharge through the subsurface, by a successful grout curtain. The aquifer now provides a natural filtering medium for releasing reservoir water pumped for the water supply of Limassol and constitutes an additional storage which could be operated conjunctively with the dam. The present abstraction from the aquifer is used to meet 5,6 million m^3/a of Limassol's domestic water requirements while 2,5 million m^3/a is for Yermasoyia and other villages in the area. Only about 0,05 million m^3/a is used for irrigation. The yield of the boreholes ranges from 80 to 150 m^3/h. The permeability varies from 110 to 150 m/day whilst the specific yield is about 20 per cent.

The storage capacity of the aquifer between the dam and the coastal delta has been estimated at 6,5 million m^3. Provided that the aquifer is not full, it is considered that some 2,5 million m^3/month could infiltrate and recharge the aquifer if the rate of release is uniform. Some 5 million m^3 could thence be pumped from the aquifer out of its total storage.

The rainfall runoff model

The existing record of observed stream flows is not sufficiently long enough (15 years) to enable a meaningful application to simulation such as reservoir operation studies, etc. This is often the case in most developing countries. Cyprus is fortunate to have a long rainfall record (68 years) derived from a sufficiently dense rainguage network. This long rainfall record combined with the relatively short record of stream flows was used through a catchment model which generates an extended runoff record using the long history of climatic data. The calibration of this model is based on the short runoff record.

The rainfall runoff model, adapted to local conditions is a conceptual one and it is a simplified version of the Stanford Model, which basically uses the hydrological cycle process and involves most of its parameters. It is of the storage type. The input consists of the 24 hour area precipitation data and mean daily evaporation. The model synthesises daily stream flow whilst the output is expressed as monthly runoff as well as daily flow duration.

The processes of the hydrological cycle and the interaction between them are expressed by both empirical and conceptual relationships. These are modified and adjusted during calibration to give the best possible fit to the short record of observed streamflows. A sample of a calibration run is shown in Fig.3.

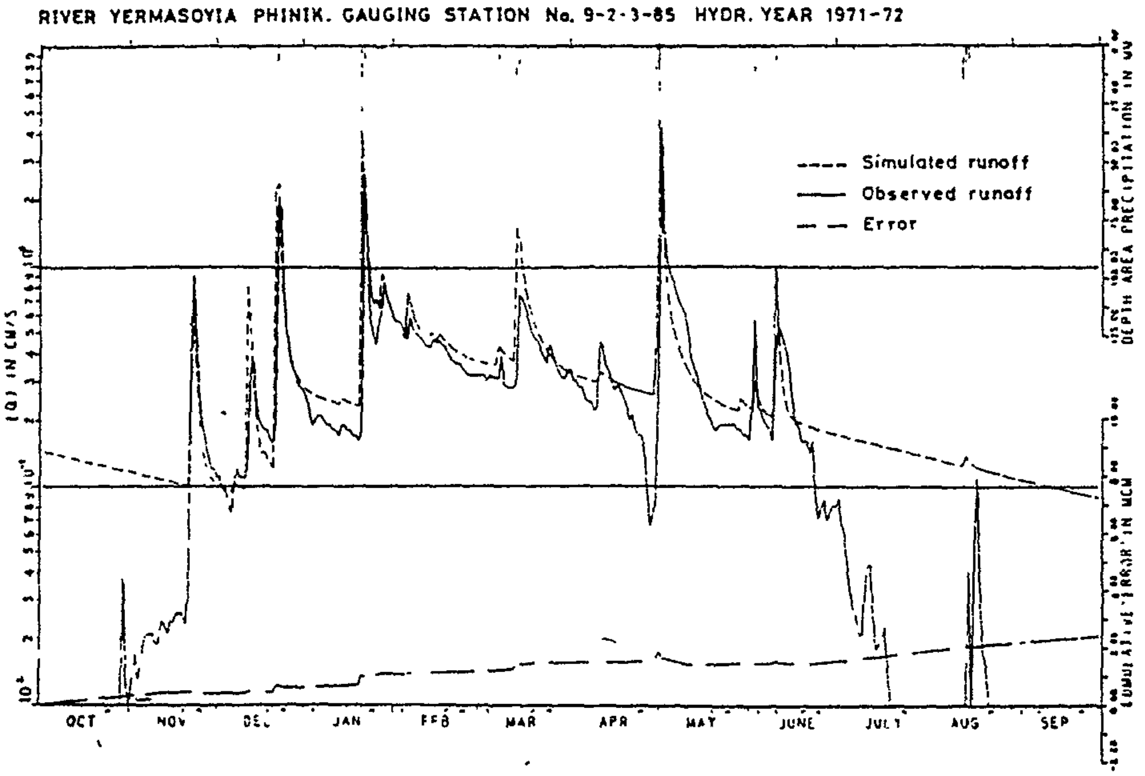

Fig.3 Sample of output during calibration for 1971-72

The generated historic series of monthly runoff are used for the operation study of the Yermasoyia reservoir which is discussed further below.

<u>The groundwater mathematical model</u>

A groundwater model was employed for studying the performance of the aquifer and its characteristics and for assessing its capacity and response to natural and artificial recharge. Once calibrated, over a number of periods during which controlled releases from the dam were made and detailed monitoring of hydrologic data pertinent to the operation of the aquifer was carried out, the model was incorporated in the simulation routine of the operation of the system when evaluating the operation rule derived by the Dynamic Programming. The model which was adapted from a general groundwater model applied in Cyprus earlier, solves the general groundwater flow equations for a two-dimensional flow by replacing them with an equivalent system of finite difference equations, the simulteneous solution of which gives the water levels at a finite number of nodes within the boundaries of the aquifer.

The basic input data requirements consist of the initial water level in each nodal area, the aquifer geometry, topographic and bedrock elevation, the aquifer characteristics of transmissivity and storage coefficients and the vertical exchange of water, recharge and abstraction over each time step. Observed water levels in the aquifer throughout the calibration period are used for matching to the simulated water levels the fit of which gives a measure of the calibration.

A sample of the output is shown in Fig.4.

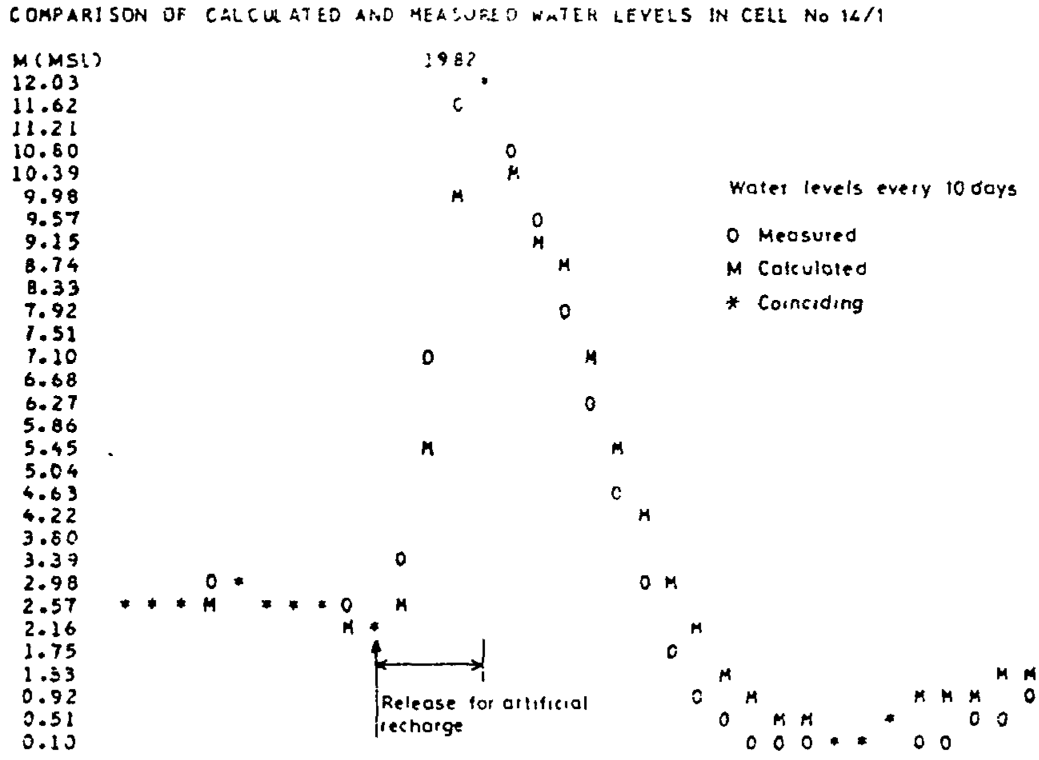

Fig.4 Sample of the model output for a nodal area

A calibrated groundwater model of an aquifer is a useful tool for evaluating the effects that may result from management decisions regarding the abstraction or operation of the surface reservoir, etc., on the water-table configuration. In the present case study, the analysis of the groundwater resource plays an important role in the total development of a water resource system.

The derivation of the Operation Rule for the Conjunctive Use

Conjunctive use

The physical constraints pertaining to the water resources system which make the conjunctive use of its components desirable and useful are as follows:

(i) The demand is greater than the surface reservoir yield;

(ii) The maximum borehole abstraction rate is less than the demand;

(iii) The combined yield of the reservoir and the aquifer is greater than the demand;

Also the following basic assumptions are valid:

(i) The pumping costs of borehole water are higher than those of the reservoir water; and

(ii) A financial penalty is incurred whenever the demand cannot be met.

In the system shown in Fig.1, the aquifer is a source of water and a storage facility for the best use of which the pumpage must be co-ordinated with releases of water from the surface reservoir. For this, an operating policy of a set of control rules is required indicating volumes of water to be kept in storage or released at given points in time, as shown in Fig.5.

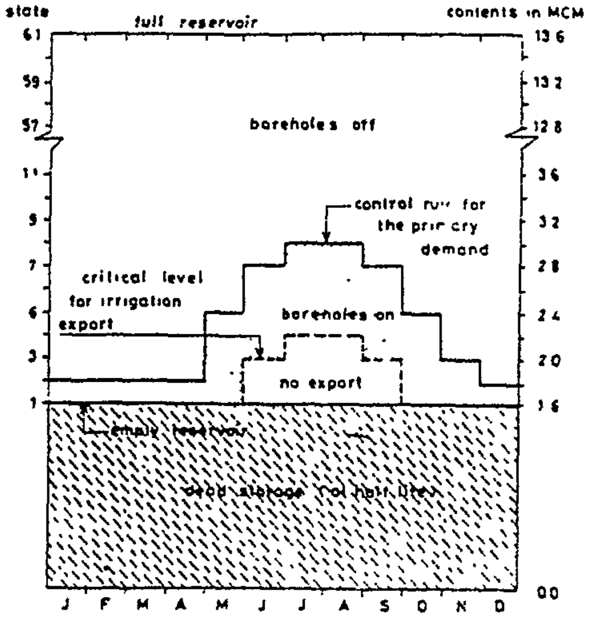

Fig.5 Operation rule for the existing Yermasoyia system

Such a policy should minimise the operating costs, subject to maintaining the necessary reliable yield and other commitments to the system. The difference in the cost per cubic metre of water gives preference to the use of the surface reservoir.

An optimisation algorithm using value iteration dynamic programming and simulation together with penal costs is employed to derive such long-term operating policies. Mawer et al.[3] used the value iteration technique introduced by Howard[4] and developed an efficient computational procedure which involves value iteration and simulation together with penalty costs as shown in Fig.6. The penalty cost in this method acts as a feedback device from the simulation to the value iteration routine.

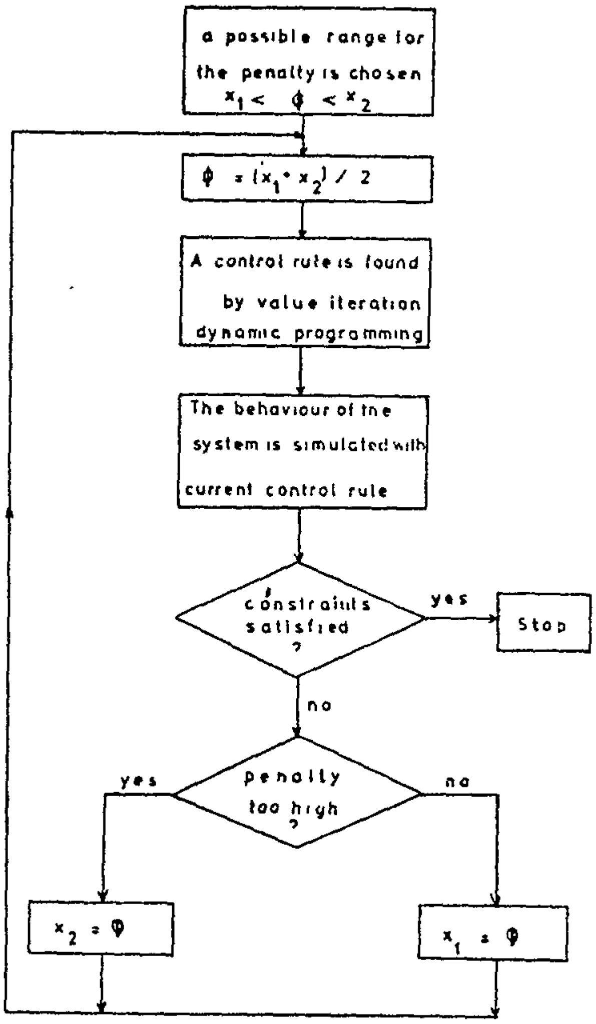

Fig.6 Dynamic programming procedure

The penalty cost value is self-adjusted until the optimum control rule is found that gives the required yield at minimum long-term running cost. In the present case study, the procedure used for the derivation of the control rule has been broadly based on the above work[3] whilst the simulation programme has been set up accordingly for the Yermasoyia reservoir utilising the historic runoff series generated by the rainfall runoff model and the aquifer performance as described by the groundwater model.

A full description of the technique for the derivation of the control rule is beyond the scope of this article and thus the reader is referred to the available literature[3]. A brief outline is presented here only.

The reservoir is devided into a set of compartments each with the same volume called the "states" of the system. Similarly all the other quantities of water, inflow, releases, etc. are expressed in "state" increments.

A decision to change these state variables is made at certain points of time called "stages". Each month is divided into two parts. From an initial state the reservoir makes a transition to a new state due to a release of water. The remaining demand is made up, as far as possible, by the aquifer and the remaining demand not satisfied is treated as a deficit. The running costs for the month comprise the costs incurred for the release, the pumping from the aquifer and the penalty due to any deficit. In the second part of the month, a transition from the last state is made to final state caused by the stream inflow. This final state becomes the initial state for the next month. Because the stream inflow is unknown at the time of making a release, the probabilities of a range of inflows for the month considered are estimated from the historic stream flow record.

The long-term operational sequence and the value iteration recurrence relationship is used backward in time. In effect, if at some future month the system is to be changed or cease to operate then the releases in the previous month must be made with due regard to both the present and the future operating conditions. As progress is made further back in time, in this fashion, the change in the operating conditions of that last "future" month becomes successively more remote influencing successively less and as the number of months becomes sufficiently large, it has no effect on the reservoir releases. The dynamic programming is used in a similar manner backward in time to find control rules for years successively distant from some arbitrary month.

The optimal rule is found when this remains steady for successive years, which in effect means that this rule is unaffected by any future change in the operating conditions[3]. Such an operation was worked out for the Yermasoyia system and is shown in Fig.5; each month of the year is assigned a critical reservoir content. When the reservoir contents are greater than the critical level of the month under consideration, the demand is met by releases from the reservoir, preference due to the running cost, but when lower, part of the demand is met by borehole abstraction and the remainder, to as much as possible, by the reservoir. Because of the penalty cost on deficits, these are minimised.

Simulation of the operation of the system and results

The operation rule derived by the Dynamic Programming procedure for the conjunctive use of the two sources, reservoir and aquifer shown in Fig.5 is evaluated by simulation using the long historic series of runoff. If the predefined constraints, reliability of demand, maximum yield of boreholes, etc., are not met, then the penalty cost is adjusted and the procedure is repeated for a new operation rule.

By the eighth trial, the operation rule was proven by simulation that it satisfied all the constraints. The primary demands of 6,0 million m^3/a were provided at 97,3 per cent reliability. A secondary demand for irrigation of 4,5 million m^3/a was met at 91,5 per cent reliability which is acceptable for citrus orchards. The upstream use of 2,0 million m^3/a was satisfied at 99.4 per cent. In addition, some 4,6 million m^3/a at 50 per cent reliability was transported to another aquifer for artificial recharge on the occasion of spills from the reservoir through the same pipe used for the secondary demand during winter when this is not used for irrigation. Also on the average, some 1,1 million m^3/a of the spills had infiltrated in the local aquifer and some 3,2 million m^3/a were lost to the sea. The annual evaporation loss on the average has been 1,1 million m^3/a.

The average use of the aquifer has been 0,23 million m^3/a, the frequency of using the aquifer being higher in the Autumn months when the contents of the reservoir are low. From the above results, it may be concluded that by using the operation rule in Fig.5 and the surface reservoir and aquifer conjunctively, out of the 22,5 million m^3/a of average flow, some 14,5 million m^3/a could be provided at an acceptable high reliability and about 4,6 million m^3/a on the average, could be put into use for recharge purposes outside the system.

The efficiency of water utilisation by such an operation policy has proved to be quite high since some 65 per cent of the average annual flow is provided at a high reliability. This is very important if compared to the coefficient of variation of the runoff of the Yermasoyia River which is about 0,4, which means that the average flow is about 22,5 $\pm$ 9 million m^3/a.

As the scarcity of water increases, due to the increasing and competing demands, so does the necessity for more wide-ranging and comprehensive methods for conjunctive use of more than one source. The optimisation of water usage through operating policies, that not only maximise the water availability but also minimise the operating costs, has far reaching effects in successfully meeting the increasing demands in countries where water is a constraint to further development.

One of the main objectives of this paper has been to show the variability of the techniques required for managing the water resources of a typical case and the degree of water utilisation that could be achieved by such methods. It should be emphasised here that the same approach could practically be employed in the conjunctive use of any two sources, surface reservoir and aquifer or desalination plant, etc. In the latter case where the desalination costs are very high, this source could be used only when the other source (surface or groundwater) cannot meet the demand. Thus, only the capital investment of setting up such a plan should be considered since this plant will be switched on and off according to the need for supplementing the demand. Thus, the other source could be relied upon to its maximum with the expensive sources called upon only to maintain the high reliability normally required for water supply. Such an approach could make desalination an attractive proposition.

In the remaining part of the paper, some case studies of conjunctive use in Cyprus are presented.

3. CASE STUDIES OF CONJUNCTIVE USE IN CYPRUS

General

In the discussion so far, an approach has been presented in deriving an optimal operation rule for a surface reservoir to be used conjunctively with an aquifer in meeting a prescribed demand. None of the two sources could meet the demand on its own but the joint use of them could satisfy it at an acceptable reliability level. In addition, an optimisation of the use of the two sources has been made so that the cheapest source could be used at its maximum. This is in essence the basic objective of the conjunctive use. At the same time though, with the example shown for the Yermasoyia reservoir and aquifer, a maximisation of the utilisation of the water resources system of this area has been achieved.

In practice, the application of the conjunctive use in Cyprus is somewhat different than above, in an effort to meet the growing and competitive demand for water by various sectors, domestic, irrigation, etc., with a water supply infrastructure which is still under development. In other words, the operation rule derived as per Fig.5 is not strictly applied yet, since the demand and other constraints are still in the process of being changed. This rule will eventually be utilised once a steady state is reached; the use of it would secure the maximum and most economic use of the water resources available which can be achieved through conjunctive use.

Three case studies will be briefly presented which are at various stages of development:

1. <u>The Yermasoyia riverbed case</u>

The Yermasoyia river basin has already been described. The 13,6 million m^3 storage dam has completely cut off the recharge to the downstream riverbed aquifer. The aquifer can thus continue to operate only from recharge occurring during infrequent spills of the dam or from releases from the dam.

The Yermasoyia aquifer used to supply some 2,4 million m^3/a or 32 per cent of the total domestic water for the nearby major town of Limassol. Since then, another major wellfield on the fringe of the town has shown high nitrate content due to urbanisation. This, together with the general increase in tourism, has resulted in the Yermasoyia aquifer having to meet some 63 per cent of the total water supply of the town or about 5,6 million m^3/a. In addition, a number of nearby villages and tourist developments tap some 2,5 million m^3/a from the same aquifer.

The monthly water supply requirement throughout the year varies dramatically due to climatological reasons and mainly due to the influx of tourists in the summer season. In the winter months, the demand is about 10,000 m^3/day whilst in the summer it more than doubles, to 25,000 m^3/day. The water supply problem of the town of Limassol could be solved either:

(a) by the construction of a surface reservoir in addition to the Yermasoyia dam, which concurrently meets irrigation demands, and a water treatment plant, or

(b) by making controlled releases into the Yermasoyia aquifer and tapping the filtered groundwater whereby by chlorination only could be provided to the town and nearby village and tourist complexes.

The long-term solution under (a) is under implementation and the new dam of 120 million m^3 capacity will be completed by 1988. This dam will eventually meet also the growing demand of Limassol. The short-term solution under (b) was also attractive and was put into implementation since 1982. It is expected to continue until 1993, pushing the requirement for a considerable investment for a water treatment plant far into the future.

Managing the operation of the small riverbed aquifer of 5 km length and a width varying from 250 m to 500 m at 1 km from the coast is quite an intricate problem. On the one hand, sea intrusion must be avoided and on the other, the losses of precious fresh water to the sea must be minimised.

Gradually, the operation of the aquifer has been learned through the dense observation network and intensive monitoring during the release which allowed the development of a groundwater model. At present, sea intrusion has been controlled to a predefined point inland while the releases are made upstream of the wellfield and downstream of it in such a way as to maintain the required pumpage and control the sea intrusion, reducing the losses to the sea to practically nil. The problem becomes more delicate as the maximum yield of the aquifer (physical groundwater through-flow) is approached, this being estimated to be about 30,000 m^3/day.

Table I presents the total quantities of groundwater extraction and releases for recharge made during the years of 1982 to 1985.

Table I

Extraction and releases in the Yermasoyia aquifer (in Mm^3).

Item	Year 1982	1983	1984	1985	1986*
Extraction	4.1	4.6	4.9	6.6	8.1
Releases	2.1	3.0	3.4	3.8	4.9
No. of releases	1	3	5	6	9
Average duration of each release (days)	28	15	12	12	12

* Forecast, based on the values of August 1986

From Table I, it can be observed that the extraction is greater than the releases. This is because the recharge is supplemented from leakage from the dam, local rainfall, inflow from the waste water of the urbanised area near the coast (negative gradient due to pumping) and sea intrusion. Also in the years of 1982 and 1983, water was retrieved from the storage of the aquifer.

The hydrograph of a typical observation borehole shown in Fig.7 shows the response of the aquifer to the water releases and the recharge. The experience gained from this case study, especially in developing the groundwater model, controlling the sea-intrusion and in the practical application of conjunctive use has led us to start two more similar cases.

2. The Xeropotamos riverbed case

This is a similar case to the one at Yermasoyia. The riverbed of Xeropotamos develops into an aquifer within 3,5 km from the coast with an average width of 500 m and an average thickness of 42 m. The first 2 km are phreatic and the last 1,5 km is overlaid with a semipervious cover of silty sands and clays attaining gradually a thickness of 35 m at the coast.

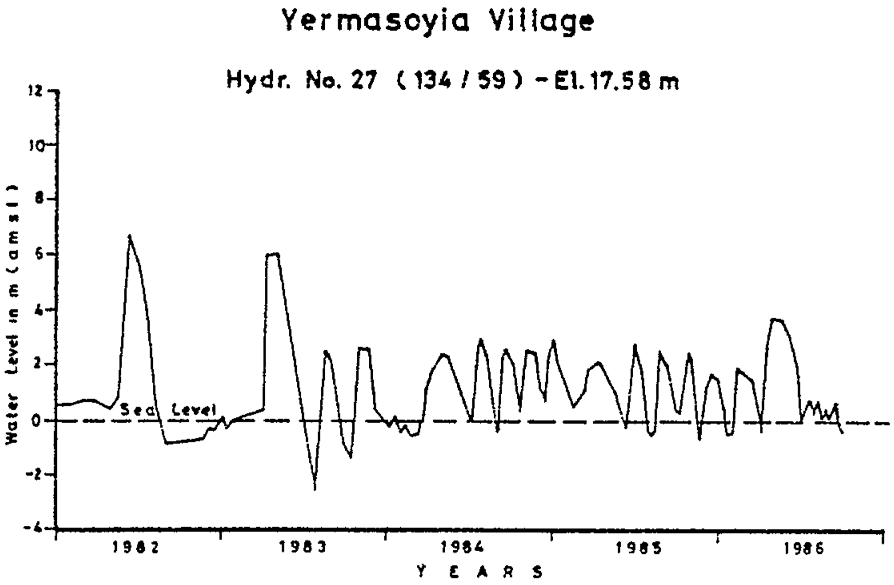

Fig.7 Groundwater response to releases

This aquifer has been traditionally pumped for the water supply of Paphos and for irrigation. The recharge to the aquifer was cut off by a 51 million m^3 storage dam which is used for the irrigation needs of the coastal plain. The present storage (September 1986) is 13,5 million m^3.

For the increased water demand of the town of Paphos and nearby villages, a new wellfield was established in the upstream part of the dam whilst the one downstream continued to be pumped. In addition, 3 project wells were established and pumped for the early needs of the project until the water impoundment in the dam attained a specified level. The result was that sea intrusion occurred in the first 1800 m including the 2 project wells and the most downstream well of the Paphos wellfield.

In addition to this, the drought being experienced in the island in the last 3-4 years and the increase of demand due to tourism has rendered the upstream wellfield inadequate. The current estimated volume in storage in the aquifer is about 1,4 million m^3 all being below the mean sea level. The active storage (above mean sea level) is about 1,8 million m^3. The 1985 extraction from the downstream aquifer was 1,1 million m^3 but this is expected to increase in 1986 due to the increase in demand.

In order to maintain the downstream wellfield and to enable the aquifer to continue to provide groundwater for the water supply of Paphos, it was decided to proceed with controlled releases from the Asprokremmos dam. These releases have the objective:

(a) of checking the propagating sea intrusion and reversing the inland flow of saline water, and

(b) of maintaining the water-table in the aquifer at such a level so as to enable increased extraction for the domestic needs of Paphos. The aquifer is thus being used as a filtration medium of surface water and as an additional storage to the surface reservoir.

The initial release of 5,000 to 30,000 m^3/day resulted in a surface flow in the riverbed of up to 2,5 km from the dam. This was due to the low infiltration rates of the alluvium in the first 1 km and the appearance of the semipervious layer from this point onwards. The low permeability near the dam is attributed to the compaction and finer material that was produced in the area during the construction of the dam.

Thus, at a small cost of US $2,000 four shallow ponds were set up of average size of 50 by 50 metres and 1 m depth. These ponds are constructed on terraces of the riverbed and are in series so that the overflow from the upper pond is the inflow to the lower one. The present releases (September 1986) of 22,000 m^3/d have filled the first pond in 3 days and inflow started into the second. The infiltration rate is about 5 m^3 per m^2 per day.

Within 10 days of these releases, a rise of 8 m, dropping to 3 m in 400 m and 1000 m downstream, respectively, was observed. The effect has just been monitored at 1300 m near the wellfield. The present plans for this case are to continue the release until the water level rises and quality improvement is monitored just downstream of the wellfield (1700 m from the dam) and then to attempt increased recharge through the existing project borehole.

During the winter, base flows from Dhiarizos, a nearby river, will be diverted and released in the ponds until the sea-intruded part of the aquifer is cleaned of the saline water. Once this is accomplished, occasional releases from the dam in the ponds, and through a borehole near the coast for establishing a fresh water barrier, will continue to be made.

Continuous monitoring of the developing conditions will enable the set up of a groundwater model which will allow the future conjunctive use of this aquifer with the surface reservoir.

3. The Tremithios riverbed case

This riverbed, although of limited potential, is of considerable local importance. The aquifer is about 3 km long and 150 to 200 m wide with an average thickness of 15 m. The Larnaca water supply is partly met from this area through a wellfield of 5 boreholes providing currently about 0,7 million m^3/a. The recharge of this aquifer is accomplished in winter from the infiltration of part of the 3,7 million m^3/a average flow of the Tremithios stream. An investigations programme is currently being carried out involving seismic, geoelectric survey and drilling of observation boreholes. The intention is to formulate the way releases can be made in the future from a pipeline traversing the aquifer carrying water from the Kouris dam (50 km to the west). The problem faced with this quifer is that groundwater gradually drains downstream, depleting the aquifer by the summer period when the demand is considerable. The possibility of constructing a subsurface dam or slurry trench is being considered in the downstream part so that the aquifer can be used as a controlled storage. In this case again, the effort is to use the aquifer as an extra storage and as a surface water treatment medium for domestic water supply.

4. REFERENCES

1. Phanartzis, C.A. Simulation of watershed runoff in the Morphou-Tylliria area. A.G.L.S.F./CYP513 Technical Report WDD, Nicosia, Cyprus (1972).

2. Kitching, R.A. Mathematical model of the Akrotiri Plio-Pleistocene gravel aquifer, Cyprus. Institute of Geological Sciences Report No. 75/2 (1975).

3. Mawer, P.A., _et al._ Multiple resource studies, Water Research Association Centre, T.M. 67, Medmenham (1971).

4. Howard, R.A. Dynamic programming and Markov processes, M.1.7. Press (1960).

5. Buras, N. Scientific Allocation of Water Resources. American Elsevier, New York (1972).

6. Water Development Department, Development of the Yermasoyia Resources. Consultant's report, Nicosia, Cyprus (1972).

POSSIBILITE D'EXPLOITATION DES SOURCES SOUS-MARINES EN SICILE

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R E S U M E

Les fuites en mer des aquifères côtiers en Sicile ont été évaluées proches à 23 m^3/s. Une partie de ces eaux, environ 45%, se perd en mer par porosité de manière diffuse, difficile à localiser, à partir des aquifères côtiers, tandis que tout le reste, environ 12 m^3/s, va alimenter les sources sous-marines dans les zones où sont présents des aquifères côtiers perméables par fissuration.

Dans cette relation on a illustré les 10 principales zones de Sicile où sont présents des aquifères côtiers perméables par fissuration et les sources sous-marines localisées dans chaque zone. Là où l'état des études le permettait, chaque source a été décrite de façon détaillée et on a indiqué la possibilité et l'opportunité de leur captage à terre. Les méthodes utilisées pour mener les recherches ont aussi été illustrées, mais de façon sommaire.

Le travail a été realisé avec la collaboration des rechercheurs: A. Adorni, G. Basile et F. Chiavetta dans l'Institut de Sciences de la Terre de l'Université de Catanie.

1. INTRODUCTION

Quand une nappe hydrique, contenue dans un aquifère en contact avec la mer, est en équilibre, à l'intérieur de l'aquifère même, en correspondance avec la ligne de la côte se crée une zone de transition figurativement représentée par une surface de contact (Water Table) qui sépare l'eau douce de l'eau salée de la mer. Cela est dû à la différente densité des eaux et au fait que, en l'absence de phènomènes troublants, les eaux se comportent comme des liquides non miscibles en équilibre. En réalité, plutôt que d'une séparation nette, il s'agit d'une étroite bande dans laquelle les caractéristiques des eaux passent graduellement, mais rapidement, des eaux douces aux eaux salées.

Dans ces conditions, les eaux contenues dans l'aquifère se déchargent dans la mer d'une manière différente, due essentillement aux caractéristiques de l'aquifère même:

- de façon diffuse et peu perceptible quand l'aquifère présente une certaine perméabilité par porosité;
- de façon concentrée et ponctuelle quand l'aquifère est de type karstique ou fissuré.

L'inclinaison et la profondeur auxquelles vient se placer la bande de contrat sont dues d'un côté à la densité de l'eau de mer et de l'autre à la charge hydrostatique existant dans l'aquifère. Le type et les caractéristiques de la perméabilité de l'aquifère déterminent la vitesse à laquelle l'eau douce se décharge dans la mer. Les lois physiques qui régissent ces phénomènes sont très bien connues.

Le phénomène est courant dans bien des régions du monde où il y a, le long de la côte, de grands aquifères perméables par fissuration: calcaires, vulcanites, roches cristallines, aquifères alluviaux ou de toute manière à forte perméabilité par porosité. Qu'on pense, à cet égard, aux grandes zones calcaires de la région méditerranéenne et de tant d'autres parties du globe.

Dans quelques régions, l'existance de sources sur le rivage ou en mer, pas loin de la côte, est connue depuis toujours par les populations locales aussi bien pour la possibilité de s'approvisionner en eau que pour l'abondance en poisson de ces eaux.

Quelques-unes de ces sources sont entrées dans la mythologie comme la Fons Aretusa à Syracuse (Sicile), à d'autres on a donné un nom générique comme les "citri" dans les Pouilles ou les "bugli" en Sicile.

Le débit de ces sources est trés variable: on en connaît quelques-unes avec un débit de beaucoup de m^3/s, tandis que d'autres n'atteignent même pas le 1/s.

L'évaluation des fuites en mer des nappes est techniquement incertaine encore aujourd'hui puisqu'il n'y a pas de technologies directes de mesure. Quelques expériences directes visant à évaluer par des instruments le débit de ces sources Alfirevic S. (1966); Cassinis R. (1973); Gruvel A. (1930) ont founi selement des données "indicatives".

Pour les calculs on peut avoir recours à l'expression suivante:

$$Qm = Iè - Qs - Qp + Sp \pm \Delta S \pm \Delta R$$

où

Qm = Fuites en mer des aquifères
Ie = infiltration efficace
Qp = débit extrait, pour l'exploitation de la nappe
Sp = éventuelle recharge artificielle des aquifères (irrigation)
Qs = débit des sources, sur terre
ΔS = échanges fleuve-nappe ou nappe-fleuve
ΔR = variations des réserves dans l'aquifère

Il s'agit, pourtant, d'une évaluation inductive, du moment où les méthodes de quelques-uns des paramètres qui entrent dans l'expression susdite sont encore à perfectionner. Qu'on considère par exemple les difficultés qu'on recontre pour arriver à une évaluation rationnelle et autant que possible exacte d'"Ie", de "Sp", de "S" et de "R".

La nécessité d'utiliser toutes les disponibilités hydriques existantes, particulièrement dans des régions intensément habitées où la morphologie ou la nature des terrains, accompagnée par une insuffisante pluviosité, rendent la zone pauvre en eaux superficielles, détermine un intérêt croissant pour l'étude des sources côtières ou sous-marines. Des tentatives plus ou moins réussies de captage de sources sous-marines ou côtières sont signalées en

France: Port Miou; en Gréce: Créte; en Italie: Taranto (Mortola); aux URSS: Floride; en Jamaique, mais les différentes technologies utilisées se sont révélées indiquées seulement pour le cas spécifique, non pas pour un usage généralisé.

Les tentatives de capter directement en mer les sources identifiées, en assurant un isolement suffisant de l'eau douce par rapport à l'eau de mer, semblent, pour le moment, avoir réussi seulement en partie. Evidemment, on doit excepter quelques sources à débit très important pour lesquelles il s'est avéré plus facile d'en isoler une partie à peu près non contaminée. Les recherches s'adressent essentiellement aux méthodes de captage à terre; le plus grand obstacle reste la délicatesse de l'équilibre qui s'est installé entre les eaux douces et les eaux salées, un équilibre qu'il ne faut pas troubler ou, du moins, qu'il ne faut pas compromettre pour ne pas déterminer des phénomènes souvent irréversibles selon l'échelle des temps humains, de pollution des aquifères côtiers.

En Italie le phénomène de les fuites en mer des aquifères côtiers, justement à cause des caractéristiques morphologiques de la péninsule et à cause de la présence, en tant que régions côtières, des zones perméables, a une importance spéciale.

Le long de la dorsale des Appennins, particulièrement dans la zone la plus méridionale, les cours d'eau torrentiels alimentent de grands matelas alluviaux ou cônes, parfois reliés par de courts cordons de dunes: ailleurs, la présence de roches carbonatiques, cristallines ou volcaniques, très perméables par fissuration, rend presque nulle la circulation superficielle. Dans tous ces cas, la quantité des fuites en mer, par rapport au bilan hydrique général des bassins hydrographiques, plus au moins grands, qui sont intéressés, est importante. Pour des régions comme les Pouilles, la Calabre ou la Sicile on estime que la quantité des fuites en mer est comprise, en moyenne, entre 24 et 32% du volume annuel total des eaux souterraines, ce qui correspond à dire que les fuites en mer représentent une partie extrêmement importante et non utilisée du patrimoine hydrique de ces régions.

Cette relation illustre l'importance du phénomène dans l'île de Sicile.

Les recherches et les études, menées au cours de plusieurs années, et les résultats obtenus, qui sont synthétisés ici, concernent l'inventaire des sources sous-marins de l'île et leurs caractéristiques.

Pour chacune des zones côtières intéressées par des phenomènes de fuites en mer des nappes, on a effecté les études ou recherches en détail suivantes:

- Individuation de l'aquifère intéressé;
- Reconstruction des caractéristiques géologiques et hydrogéologiques de la zone d'alimentation;
- Individuation des caractéristiques climatiques et météorologiques du bassin hydrographique et de la zone d'alimentation;
- Identification des sources existant dans l'arrière-pays;
- Rédaction du bilan d'ensemble des aquifères et des bassins du domaine, avec une évaluation de l'importance de l'infiltration efficace;

- Reconstruction, où cela est possible, des caractéristiques piézometriques de la zone d'affleurement ou de présence de l'aquifère;

- Evaluation, sur la base des différents critères qu'on peut appliquer, de l'importance des fuites en mer;

- Identification des situations démographiques locales, avec une attention spéciale pour les exigences hydriques aussi bien pour l'eau potable que pour l'irrigation, et pour les exigences de pointe provoquées par le phénomène touristique;

- Etude et considérations sur les possibilités réelles, et sur l'opportunité d'exécuter des tentatives de captage à terre des sources identifiées.

La recherche a été menée selon les phases suivantes:

A. On a identifié, par un relevé géologique, toutes les parties de la côte de l'île où il y a des aquifères en contact direct avec la mer;

B. Une première série d'inspections sur les lieux a permis d'éliminer quelques zones où les aquifères présents étaient ou bien trop limités ou bien constitués de roches à basse perméabilité et en correspondance avec lesquels on ne connaissait pas de sources sous-marines;

C. Pour les zones choisies on a exécuté, à une cote relativement basse, un relevé aéro-photographique en employant les pellicules sensibles à l'infrarouge thermique. Les photos prises de l'avion intéressaient une bande large, grosso modo, de 500 m. dont la moitié environ en mer;

D. Dans l'endroit du relevé on notait aussi pour chaque zone:

   - la température moyenne de l'air;
   - la température moyenne des eaux souterraines dans l'arrière-pays, dans des puits ou dans des sources;
   - la température moyenne de la mer.

E. L'étude du relevé à l'infrarouge permettait d'identifier:

   - les endroits où une variation thermique, déterminée par des affluents, caractérisait une portion de mer;
   - la surface de diffusion de l'affluent, influencée par le débit et par le contraste thermique entre eau affluente et eau de mer;
   - la température moyenne de l'affluent;
   - la présence de substances polluantes dans l'affluent.

F. Un contrôle successif a permis de mettre en évidence tous les affluents dus à des cours d'eau superficiels ou à des décharges artificielles (égouts, etc.);

G. Pour chaque zone, mais seulement pour les portions dans lesquelles le relevé à l'infrarouge avait mis en évidence la présence de fuites dans la mer attribuables à des eaux douces provenant des aquifères côtiers, on a exécuté toute une série di relevés en mer à des distances différentes du rivage, et à des profondeurs différentes, de 2 à 10 m, suivant les caractéristiques du fond de la mer, par des sondes thermométriques et de conductivité, qui ont permis de rédiger une série de profils thermiques et de salinité des eaux de la mer;

H. La comparaison entre le relevé à l'infrarouge et le relevé direct en mer a permis d'identifier les endroits où les contrastes entre les eaux de la mer et les eaux affluentes étaient plus grands, en permettant, pour chacun d'eux, d'exécuter des relevés ponctuels: topographiques, pour les localiser exactement; photographiques, pour la documentation; et, où les conditions de la mer le permettaient, de réaliser des observations par des plongeurs, d'exécuter des mensurations de vitesse de flux, de prélever des échantillons, d'installer des appareils d'enregistrement de quelques paramètres (température et conductivité);

I. Les données relevées ont été élaborées dans la tentative de parvenir à des évaluations faibles de la quantité de l'affluent;

J. Une fois identifiés les endroits les plus intéressants pour la quantité de l'affluent, chaque endroit a été analysé dans ses rapports avec la géologie et la tectonique observables à terre, dans la tentative d'identifier les chemins à travers lesquels l'affluent se décharge dans la mer. L'étude des nombreux relevés géophysiques, pour la plupart du type "profils de résistivité", exécutés au moyen de sondages électriques verticaux, a permis de reconstruire partiellement les caractéristiques de disposition des aquifères et de tracer, dans leurs grandes lignes, les principales lignes de fracture existantes (failles). Des relevés successifs plus détaillés, exécutés par la méthode VLF (Very Long Frequence) et du Potentiel spontané (qui sont encore en cours d'exécution) ont permis de mieux identifier le long de la côte, où fréquemment elles résultent être masquées par l'intervention de l'homme ou par des terrains quaternaires, les failles qui atteignent la mer et auxquelles pouvaient être rattachées les sources sous-marines identifiées.

K. La délimitation des aquifères intéressés, et des zones qu'ils alimentent, a consenti de rédiger des bilans hydriques soigneux et de parvenir à évaluer la quantité des pertes dans la mer pour chaque zone.

L. Maintenant sont en cours des essais à terre avec forages, creusement des tranchées, cimentations, dans la tentative d'intercepter, à terre, quelques-unes des sources sous-marines de plus grand débit identifiées.

Les zones de la Sicile où le phénomène revêt un intérêt particulier se sont avérées être dix. Dans la petite carte de la Fig.1 ces zones sont opportunément indiquées. Ici on décrit seulement les zones dans lesquelles le phénomène présente des aspects pratiques particulièrement importants; pour les autres zones on fournit seulement des données synthétiques.

Zone 1 : Fondachello (Acireale - Catane)

La zone se trouve le long de la côte orientale de l'Île. sur la mer Ionienne, sur le flanc du versant oriental de l'Etna et est comprise entre le coordonnées suivantes:

- au Nord: Lat. 37°45'46"; Long 15°13'11"
- au Sud : Lat. 37°29'47"; Long 15°06'19"

La bande de côte intéressée s'étend sur un front de 32 Km, et correspond, grosso modo, au front d'expansion en mer des vulnites produites par le volcan

Etna. La côte est haute, rocheuse; elle est constituée par les nombreuses coulées de lave produites au cours des millénaires par l'activité volcanique et qui se sont déversées sur un socle sédimentaire prévalemment argileux. Les coulées de lave les plus anciennes sont subalcalines, les plus récentes sont constituées par des déphrites phonolitiques des alcalis basaltes et des hawaites.

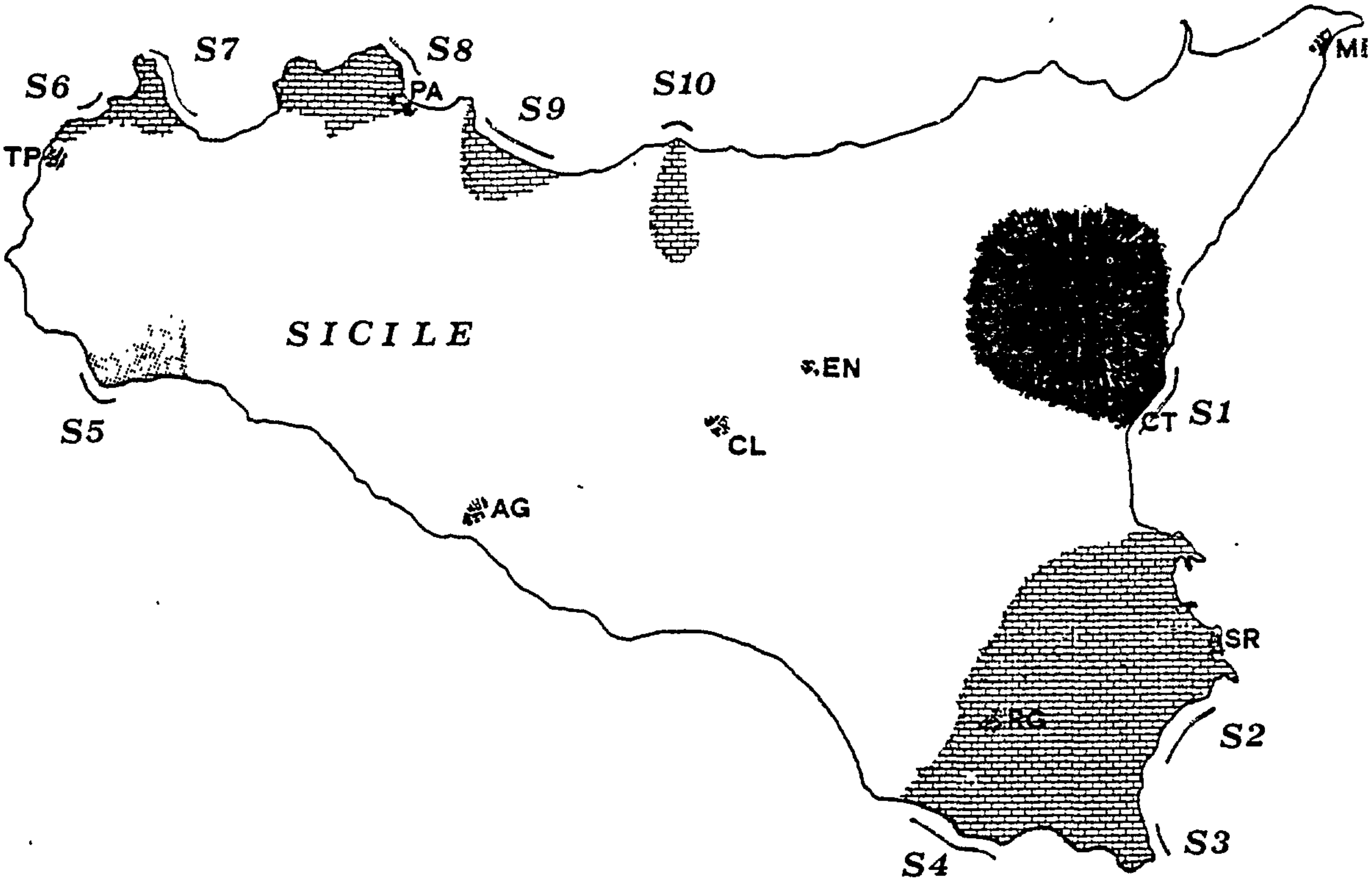

Fig.1

L'activité tectonique de la zone, à laquelle sont dus les phénomènes volcaniques, est mise en évidence par les nombreuses failles, dont quelques-unes sont masquées par des coulées de lave récentes, tandis que d'autres sont bien visibles et encore actives.

Sur la base des recherches effectuées, on a constaté que dans cette zone on observe le volume maximum de pertes dans la mer, environ 140 millions de m^3 en moyenne dans l'année. Une partie de ces pertes se manifeste par des sources sous-marines, visibles et bien identifiées, tandis qu'une autre partie, bien plus grande, se disperse de façon capillaire dans la mer même à une certaine profondeur, d'une manière bien difficilement observable. Le bassin d'alimentation s'est avéré correspondre à 496,66 Km^2.

Les terrains qui constituent l'aquifère présentent une très haute perméabilité superficielle; les eaux de pluie sont presque totalement absorbées et même quand il se forme un modeste ruissellement superficiel, celui-ci disparaît dans le lit des courts torrents de la zone, sans arriver à la mer. L'aquifère est actuellement amplement exploité par des galeries longues même de quelques kilomètres.

Le bilan hydrogéologique a fourni les données suivantes:

- infiltration efficace 248,809 $m^3 \times 10^6$
- restitution par l'irrigation 12,397 $m^3 \times 10^6$
- volume utilisé pour l'eau potable 41,154 $m^3 \times 10^6$ (correspondant à un débit extrait continu de 1.304 l/s);
- volume utilisé pour l'irrigation 79,980 $m^3 \times 10^6$ (correspondant à un débit extrait, pendant le seul semestre d'irrigation de 5,074 l/s;
- volume total des fuites en mer 140,072 $m^3 \times 10^6$ (correspondant à un débit de 4.904 l/s, dans le semestre d'irrigations, et de 6.978 l/s dans le semestre automne-hiver.

L'identification des endroits où les fuites en mer se concentrent, en créant des sources sous-marines, a été rendue plus facile par l'etude des caractéristiques de l'aquifère. Comme on l'a déjà dit, l'aquifère est constituée par des matériels volcaniques: des coulées de lave et des dépôts pyroclastiques, qui sont accumulés sur un socle préexistant de type sédimentaire, déjà modelé par l'érosion pendant des époques précédant l'activite éruptive. Les observations géophysiques ont permis de reconstruire, avec une fiabilité suffisante, l'hydrographie ensevelie et d'identifier ainsi l'aspect géneral des paléo-vallées et leur point d'issue dans la mer respectif. On a identifié, le long de la côte en question, 9 paléo-incisions, correspondent à autant de zones où les eaux sous terraines sont acheminées vers la mer. En correspondance avec ces sous-zones l'observation des sources dans la mer a permis l'identifier 24 endroits où les eaux douces se déchargent dans la mer de manière concentrée et plusieurs autres endroits où, pour des raisons différentes, tout en étant évidente et bien connue la présence d'eau douce le long de la côte, on n'a pas réussi à identifier les points de source.

Quelques-unes de ces sources, en général les sources avec un débit plus modeste, jaillissent directement sur la ligne du rivage, d'autres à quelques dizaines de mètres, en mer. Les mensurations de débit qu'il a été possible d'effectuer ont fait observer des valeurs comprises entre 1 et 20 l/s, des évaluations empiriques d'autres sources ont fourni des valeurs comprises entre 50 et 90 l/s.

Une source, la No.12 (Monara) est en partie captée à terre par une galerie de drainage placée à 4 m sur le niveau de la mer; de cette galerie on retire un débit 190 l/s.

L'eau qui se recueille dans les paléo-incisions est acheminée vers la mer à travers les matériaux scoriacés et brèches qui constituent la base des coulées de lave, et elle est maintenue sous charge hydrostatique, comme par un niveau imperméable, par le corps compact des coulées mêmes qui s'étendent dans la mer jusqu'à l'endroit où le refroidissemment brutal subi par la coulée au contact avec l'eau de mer en a provoqué la fissuration et la libération des eaux douces contenues qui s'ensuit. La charge hydrostatique dont peuvent être dotées ces eaux est, parfois, importante, mais le nombre important de fissures à travers lesquelles l'eau douce coule dans la mer en atténue ou empêche l'identification, surtout si les sources s'avèrent placées à des profondeurs supérieures à 15-20 m.

L'intérêt spécifique pour la ressource hydrique réprésentée par les pertes dans la mer est déterminée par le fait que dans cette zone de l'île se trouvent quelques centres touristiques très connus, Acireale, Acitrezza, Capo Mulini, où les phénomènes de surpopulation estivale provoquent des besoins d'eau qui sont le double ou plus des besoins des autres mois de l'année.

<u>Zone 2 : C.S. Panagia - Marina di Avola (Syracuse)</u>

La zone se trouve le long de la côte orientale de l'île, sur le flanc des Monts Iblei, et elle est comprise entre les coordonnées suivantes:

- au Nord: Lat. 37°06'23"; Long 15°17'41"
- au Sud : Lat. 36°54'00"; Long 15°08'57"

La bande de côte intéressée se développe sur un front de 37 Km, et sur cette bande se trouvent les centres de Syracuse et Fontane Bianche. Il s'agit d'une côte haute, constituée de falaises entrecoupées de petites baies sablonneuses.

Les terrains sont constitués de termes carbonatiques: calcaires, calcaires marneux, marnes, calcarénites d'un âge du Crétacé au Pleistocène, et il y a aussi des vulcanites d'âge remontant au Crétacé. La tectonique, typiquement de distension, a fortement influencé la morphologie locale, en déterminant la formation de "Horst" ou "Graben", et d'un dense réseau de failles qui mettent en contact entre elles des termes d'âge différent. La circulation hydrique est liée au réseau de fractures présent, en correspondance desquelles il s'est instauré des phénomènes de type karstique.

Le bassin d'alimentation des aquifères côtiers est très grand, 703,30 Km^2.

Le long de cette portion de côte, les sources sous-marines sont nombreuses: on en a identifié 19, mais seulement de trois d'entre elles cela vaut la peine de parler.

Les deux premières sources autrefois jaillissaient près du rivage de la mer, le long de la petite falaise qui borde, à sud-ouest, l'île sur lequelle est construite la vieille ville de Syracuse; récemment, elles ont été incluses dans les oeuvres de protection - grandes murailles - réalisées pour défendre l'agglomération. Il s'agit de sources dont la mémoire remonte à un temps immémorial, liées à des légendes mythologiques qui en font aujourd'hui un des attraits touristiques de la ville. La plus fameuse est la très célèbre "Fons Aretusa", l'autre est appelée "Fontana Conceria".

Leur débit avait été estimé à 400 l/s pour la Fons Aretusa et à 164 l/s pour la Fontana Conceria. Actuellement, leur débit a diminué et en tout il ne semble pas dépasser 450 l/s.

La présence de deux sources avec un débit d'environ un demi-mètre cube par seconde à l'extrémité d'un golfe, sur une très petite île, même si peu éloignée de la terre ferme, était un mystère qui a généré de nombreuses légendes qui les entourent.

L'étude hydrogéologique a permis de comprendre le mécanisme de leur alimentation.

Les calcaires qui constituent le grand aquifère Hybléen sont recouverts, le long de toute l'anse du golfe de Syracuse, d'argiles du Pléistocène qui maintiennent les nappes d'eau sous pression. En correspondance avec l'île de Syracuse, il y a un Horst qui a soulevé les calcaires, et les vulcanites du Crétacé sous-jacentes, à une cote supérieure de peu au niveau de la mer. La faille qui borde, vers la terre, le Horst met en contact les vulcanites altérées et imperméables avec les calcaires de l'aquifère. Le long de la faille les eaux, retenues dans les calcaires par la couverture argileuse et enterceptées par les vulcanites, remontent en générant les deux sources. Il s'est donc formé un siphon naturel qui permet aux eaux douces de passer sous le très court bras de mer qui sépare l'île de la terre ferme et de jaillir dans l'endroit où aujourd'hui on peut les voir. L'importance historique et touristique de ces sources empêche une utilisation différente de ces eaux qui aujourd'hui se déchargent dans des bassins entourés d'une végétation de papyrus, sur le rivage de la mer, et qui constituent un des attraits principaux de la ville.

En descendant le long de la côte, vers le sud, après l'embouchure du fleuve Cassibile, en correspondance avec un promotoire appelé Balata di Noto, à cinquantre mètres du rivage, on a localisé une source sous-marine, à la profondeur de 8,50 m, qui jaillit d'une bouche en forme d'entonnoir d'un diamètre de 50 cm. Sur la surface de la mer, le cercle d'eaux plus claires qui met en évidence la présence de la source, a un diamètre de trois mètres. On a effectué de nombreuses mesures sur cette source pour en identifier les caractéristiques. La température de l'eau à la bouche s'est avérée varier entre 14,8 et 15,2 °C, tandis que la température de la mer circostante résultait varier entre 22,0 et 22,3 °C. Le débit a été estimé proche de 400 l/s. L'importance de cette source est remarquable puisqu'elle jaillit près d'un centre touristique très fréquenté: Fontane Bianche.

L'étude détaillée a permis de comprendre que la source est reliée, à travers un conduit karstique branché sur une faille normale à la ligne de la côte, à une bétoire qui existe dans le lit du fleuve Cassibile, environ 4 Km avant l'embouchure. De soigneux relevés geophysiques, exécutés par différentes méthodes, ont permis d'identifier le parcours de la faille, masqué sur la surface par des terrains du Pleistocène. En particulier la mèthode de la VLF s'est avérée très indiquée à cette fin. Un contrôle exécuté par un forage, à environ 1,5 Km de la côte, a intercepté le conduit karstique à 45 m de profondeur, qui correspondent à 5 m sous le niveau de la mer.

On a aussi observé que le débit de la source subit de remarquables variations pendant l'année, des variations qui s'avèrent en relation avec les variations de débit du fleuve Cassibile et que ces variations sont en partie à attribuer aux dérivations pour des fins d'irrigation qui sont effectuées en amont de la bétoire pendant la saison estivale.

Zone 3 : Capo Passero - Isola delle Correnti (Pachino, Syracuse)

Le long de cette portion de la côte, longue de 9 Km, on a identifié 14 sources sous-marines, toutes avec un débit modeste. Le relevé à l'infrarouge a pourtant mis en évidence qu'en même temps, à côté des jaillissements des sources, il y a aussi une plus importante et diffuse perte dans la mer d'eaux douces. Au total on a estimé à 200 l/s le débit global des pertes dans la mer dans cette portion de côte.

Zone 4 : Punta di Mezzo - Pozzallo (Raguse)

La zone se trouve le long de la côte méridionale de la Sicile et elle est comprise entre les coordonnées:

- au Ouest: Lat. 36°47'48"; Long 15°28'81"
- au Est : Lat. 36°43'21"; Long 14°50'29"

La bande côtière intéressée par les pertes dans la mer s'étend sur un front de 37 Km.

Dans cette zone l'aquifère principal, en contact direct avec la mer, est constitué des calcaires de la Formazione Ragusa: des calcaires bruns-blanchâtres d'un âge entre l'Eocène et le Miocène inférieur (Membre Irminio). L'intense fracturation due aux différentes phases tectoniques qui ont intéressé la zone est mise en évidence par de nombreuses failles, presque toutes ayant une direction plus ou moins normale à la ligne de la côte.

Dans la zone se trouvent beaucoup d'agglomérations touristiques qui, pendant l'été, voient plus que doublée leur population. L'activité agricole aussi, le long de la bande côtière, est très intense; dans cette zone sont en effet adoptées sur une échelle les cultivations en serre pour la production des prémices. Les seuls obstracles à l'expansion des serres sont, d'un côté, l'augmentation du turisme, et de l'autre la carence de ressources hydriques, puisque les ressources existantes sont déjà accaparées.

Les études exécutées ont permis d'identifier aussi bien quelques caractéristiques de l'aquifère que les caractéristiques de quelques-unes des principales sources sous-marines qui ont été localisées. Le bilan de l'aquifère a fourni les estimations suivantes:

- Infiltration efficace	139,661 $m^3 \times 10^6$
- Echange nappe-fleuve	6,000 $m^3 \times 10^6$
- Débit des sources	74,645 $m^3 \times 10^6$
- Volume utilisé par des puits	29,369 $m^3 \times 10^6$
- Volume des pertes dans la mer (sources sous-marines)	29,647 $m^3 \times 10^6$

Les sources sous-marines localisées le long de cette portion sont 21 mais seulement de quelques-unes il a été possible d'effectur une étude soigneuse.

La source principale est celle qui se trouve à l'embouchure du port de Donnalucata, à environ 60 m du rivage, à la profondeur de 2,20 m. Le débit, à la suite de nombreuses mesures, s'est avéré varier entre et 355 l/s. Des échantillons d'eau, prélevés dans les points de jaillissement, ont fourni les valeurs suivantes:

- chlorures: de 1.990 mg/l à 11.980 mg/l
- sulfates: de 330 mg/l à 1.750 mg/l
- rapport Cl/SO_4: de 6,03 à 6,84

L'étude des structures tectoniques locales a permis de localiser, dans l'arrière-pays, un système de failles auxquelles la source semble reliée, mais la présence de terrains quaternaires et du centre habité masque les failles justement dans la portion de territore la plus proche de la mer. Les études en cours tendent à identifier le parcours de ces failles pour essayer d'intercepter, à terre, le conduit qui alimente la source.

Les échantillons d'eau prélevés directement dans le trou de sortie de l'eau dans la mer, de trois autres sources, ont fait observer une présence de chlorures allant de 4.610 à 13.500 mg/l, tandis que les sulfates varient entre 580 et 1.800 mg/l et le rapport Cl/SO_4 résulte compris entre 6,25 et 8,10.

Des mensurations de Vitesse de flux des eaux des sources en mer ont fait observer des valeurs comprises entre 1 et 20 cm/s.

Zone 5 : Granitola - Selinunte (Trapani)

Le long de cette portion de côte, on a identifié seulement 4 petites sources sous-marines dont le débit total peut varier entre 31 et 127 l/s. L'intérêt est modeste.

Zone 6 : Trapani - Contigliolo (Trapani)

Le long de cette portion de côte, longue de 10 Km, affleurent des termes calcaires d'âge différent, allant du Trias au Pléistocène. L'aquifère principal est constitué de calcaires dolomitiques du Trias supérieur. Les relevés directes ont permis d'identifier seulement trois petites sources sous-marines.

Le débit total des pertes dans la mer a été estimé très variable, en résultant compris entre 87 et 388 l/s.

Zone 7 : Cofano - Castellammare del Golfo (Trapani)

La zone est située à la pointe nord-ouest de la Sicile, entre les coordonnées.

- à l'ouest: Lat. 38°05'28"; Long 12°39'30"
- à l'est : Lat. 38°01'46"; Long 12°48'47"

et s'étend sur un front de 38 Km.

La géologie des lieux est très complexe puisqu'elle est le résultat de différentes phases tectoniques qui ont porté, en nappe de carriage, des terrains plus anciens à être situés sur des termes plus récents.

La morphologie de l'arrière-pays est donnée par des reliefs très accentués avec des pics et des cimes qui atteignent 1.110 m sur le niveau de la mer. La côte même est, en général, caractérisée par des falaises ou des socles très escarpés.

Les terrains qui affleurent sont donnés par des termes principalement carbonatiques d'âge compris entre le Trias et l'Eucène supérieur. La tectonique complexe qui a caractérisé cette zone a déterminé un bouleversement des formations originaires en mettant en contact des termes d'âge différents. De nombreuses failles, principalement de compression, traversent les reliefs et atteignent la mer.

Le bilan hydrologique de la zone permet d'évaluer la quantité des pertes dans la mer, quantité qui est comprise entre 1.060 et 1.460 l/s.

Le long de cette portion de côte, on a identifié 11 sources sous-marines, mais il est raisonnable de penser qu'il en existe d'autres non directement visibles à cause de la profondeur à laquelle elles débouchent dans la mer.

Sur aucune des onze sources identifiées, il n'a encore été possible de recueillir des données précises à cause de difficultés dues à la morphologie de la côte qui ne permet ni l'abordage ni des accès directes, puisqu'elle se présente avec des parois presque verticales et avec des profondeurs qui dépassent même 50 m.

Cette zone présente un grand intérêt du point de vue touristique; quelques centres balnéaires et des villages ont surgi dans les endroits où la morphologie le permettait (C. Impiso Scopello) mais la carence de ressources hydriques en a toujours conditionné les possibilités d'expansion.

L'utilisation des pertes dans la mer s'avérerait certainement déterminante, mais pour l'instant les difficultés qu'on a rencontrées se sont révélées supérieures aux moyens dont on disposait.

<u>Zone 8 : Torre S. Cataldo - Punta di Priola (Isola delle Femmine)</u>

Dans cette zone, on peut distinguer trois secteurs, et chacun d'entre eux, à son tour, peut être divisé en unités plus petites; dans l'ensemble, on a identifié 6 unités caractérisées, toutes, par des aquifères carbonatiques en contact direct avec la mer.

Dans cette zone aussi, comme dans la précédente, l'activité tectonique qui s'est manifestée en plusieurs phases, a mis en contact ou amoncelé en nappes de carriage des termes d'âge différent, du Trias à l'Aquitainien, sur lesquels se sont déposés des sédiments du Pliocène et du Pléistocène.

A chacune des unités résultent reliées quelques sources sous-marines, on en a identifié 43, mais si, dans l'ensemble, les pertes dans la mer sont estimées à 1.745 l/s les sources, prises individuellement, résultent être plutôt modestes; la plus importante ne semble pas dépasser 200 l/s. La quantité des pertes dans la mer, et le fait que Palerme, dont les carences hydriques sont notoires, n'est pas loin, rendent extrêmement intéressante l'étude de ce patrimoine hydrique qui, actuellement, s'avère inutilisable.

<u>Zone 9 : Aspra - T.re Battilamano (Termini Omerese - Palermo)</u>

La zone est située le long de la côte septentrionale de la Sicile, entre Capo Mangerbino et Buonfornello, le long d'un front de 36 Km, où sont présents de bas reliefs de nature carbonatique, profondément démembrés par une tectonique très complexe.

Les aquifères présents ne sont pas reliés entre eux et leur alimentation est modeste. Dans l'ensemble, les pertes dans la mer ont été estimées à 760 l/s mais les sources en mer qui ont été identifiée sont d'un débit modeste, tandis que le relévé à l'infrarouge a mis en évidence quelques secteurs où sont présentes des fuites diffuses.

<u>Zone 10 : Rocca di Cefalù (Palermo)</u>

Cette zone présente des aspects très particuliers. Il s'agit d'un petit éperon calcaire qui s'étend sur la mer en correspondance de l'agglomération de Cefalù. A ses pieds, en contact direct avec la mer, jaillissaient par le passé, de grandes sources d'eau douce, aujourd'hui beaucoup moins importantes parce qu'en partie elles sont captées à terre.

La dimension réduite de l'affleurement calcaire ne justifie pas la présence desdites sources, dont le débit était relativement proche de 600 l/s.

Les études géophysiques menées ont permis de relier le petit affleurement de calcaires le long de la côte avec les grands affleurements calcaires qui caractérisent les monts qui existent dans l'intérieur, les Madonie.

Les oeuvres de captage ont été réalisées en creusant des galeries drainantes, placées à peu de mètres sur le niveau de la mer, et d'autres oeuvres sont prévues pour l'exploitation totale de ces ressources.

2. CONCLUSIONS ET RECOMMANDATIONS

L'étude des sources sous-marines de l'île de Sicile a permis de parvenir aux résultats suivants:

- évaluer la quantité des fuites en mer des aquifères cotiers;
- identifier les endroits où la décharge des affluents est plus grande;
- analyser les possibilités de captage à terre des sources sous marines.

Les proportions du phénomène se sont révélées très importantes particulièrement en quelques zones où les problèmes de l'approvisionnement hydrique sont sérieux. L'utilisation de ces ressources, si elle est exécutée rationnellement, pourrait résoudre des problèmes qui, autrement, semblent insolubles.

Il faut de toute manière affirmer que toutes les tentatives de captage, sauf des cas très rares, doivent etre exécutées à terre, en tenant compte opportunément de la conservation des écosystèmes qui dans quelques cas se sont constitués justement à cause de la présence de sources sous-marines, mais en réalité il s'agit de cas très rares.

Quelques méthodes: l'infrarouge thermique et la VLF, se sont avérées très utiles pour ce type de recherches, mais ce sont les relevés systématiques et l'exactitude de ces relevés qui permettent d'obtenir des résultats appréciables.

3. BIBLIOGRAPHIE

Accerboni, E. and F. Mosetti (1967). "Localizzazione dei delussi d'acqua dolce in mare mediante un conduttometro elettrico superficiale a registrazione continua", Boll. Geofisica teorica ed Appl., Vol. IX, No.36, pp.255-268.

Accerboni, E. and F. Mosetti (1969). "Localizzazione dei deflussi d'acqua dolce in mare, ricerche eseguite lungo la costa adriatica della Puglia", C.N.R. Quaderni de "La ricerca scientifica, No.58, pp.213-225.

Alfirevic, S. (1961). "Bases géologiques tectoniques des sources sous-marines en Adriatique", Commission Internationale pour l'exploration scientifique de la mer Méditerranée. Rapports et Procès-Verbaux des Réunions, Vol. XVI (Nouvelle série), fasc. 3, Paris.

Alfirevic, S. (1966). "Hydrogeological investigations of submarine springs in the Adriatic", Association Internationale des Hydrogéologues, Congres Géologique International Tome VI, Belgrade, pp.255-264.

Aureli, A., B. Ferrara and V. Gacliano Candela (1982). "Etudes pour l'utilisation intégrale des ressources hydriques souterraines et de surface dans le sud-est de la Sicile", C.E.M.P.E. IV Conference Internationale sur la planification et la gestion des eaux, Vol.I Marseille, pp.1-9.

Calvino, F. and A. Stefanon (1963). "Osservazioni geologiche sulla Polla Rovereto e le altre sorgenti sottomarine della Mortola (Riviera di ponente)", Atti. Ist. Geologia Univ. Genova, Vol.1, Genova.

Calvino, F. and A. Stefanon (1969). "The submarine springs of fresh water and the problems of their capture", Rapp.Comm.Int.Mer Médit., Vol.19, fasc. 4, pp.609-610.

Cassinis, R. (1967). "Ricerca sugli afflussi d'acqua dolce lungo le coste siciliane mediante misure di salinità in mare", La Ricerca Scientifica, Vol.37, No.3, Roma, pp.267-280.

Cassinis, R. and I. Tobacco (1967). "La ricerca delle sorgenti sottomarine di acqua dolce mediante misure di salinità: sperimentazione sulla determinazione delle portate", La Ricerca Scientifica, Vol.37, pp.1197-1217.

Cotecchia, V. (1955-56). "Sulle caratteristiche delle sorgenti e sulla modalità di rinvenimento della falda profonda nella Penisola Salentina in rapporto alla struttura dei calcari cretacei della regione", Amm. Fac. Ing. Univ. Bari, Vol.2, pp.3-19.

Cotecchia, V. and A. Federico (1983). "An approximate evaluation of the flow rate of submarine springs", Geologia Applicata e Idrogeologia, Vol. XVIII, p.II, pp.253-255.

Gandino, A. and A.M. Tonelli (1983). "Recent remote sensing technique in fresh water submarine springs monitoring: qualitative and quantitative approach", UNESCO, TNO, Inter. Symp.: "Methods and instrumentation for the investigation of groundwater systems" - Noordwijkerhout, The Netherlands, pp.301-310.

Gunay, G. (1971). "Determination of the origin of Oracik submarine springs by means of natural isotopes". International Association of Hydrogeologists, Congress of Tokyo, Vol. IX, Tokyo, pp.136-139.

Mi tardis, G.G. (1965). "Sea level fluctuations in Pleistocene and submarine springs-whirls in Greek Central Area". Ass. Inter. des Hydrogeologues, Reunion de Hannover, Tome VII, Hannover, pp.81-83.

Mijatovic, B. (1982). "Utilisation rationelle des ressources en eau douce dans les regions karstiques littorales par les galeries de captage", C.E.M.P.E. IV Conference Internationale sur la planification et la gestion des eaux, Vol.I, Marseille, pp.797-806.

Potie, L. (1973). "Etudes et captage de résurgences d'eau douce sous-marines", 2nd International Symposium on groundwater, Palermo, pp.603-620.

Stefanon, A. and F. Cotecchia (1969). "Prime notizie sulle caratteristiche di eflusso e sulle modalità di investigazione delle sorgenti subacque ai fini di una loro captazione", C.N.R., Quaderni de "La ricerca scientifica", No.58, pp.165-195.

Zektser, I.S., R.G. Dzhamalov and T.I. Safronova (1983). "The role of submarine groundwater discharge in the water balance of Australia", UNESCO, IAH, IAHS, Congress on Groundwater in water resources planning, Vol.I, Koblenz, pp.209-221.

TANKERS USED FOR SUPPLYING FRESH WATER TO ISLANDS WITH FLUCTUATING POPULATION DUE TO TOURISM

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A B S T R A C T

In a number of islands of the Dodecannese Archipelago, the problem of satisfying domestic water supply requirements appears during the extended summer period, April to November, due to the considerable seasonal increase of population by the influx of tourists.

This problem is further aggravated by the fact that the tourist period coincides with the increase in water demand for agriculture needs and, at the same time, any local water resources that may be available are in a summer regime. The way of meeting this problem is by the importation of water transported by tankers from other neighbouring islands which have surplus supply.

This solution for seasonal water shortage presents both advantages and disadvantages and certainly there are ways and means for its further development. For these islands though, effort is being made for meeting water demands to a maximum extent by developing local water resources making these islands as much as possible independent from this solution of tankers.

1. INTRODUCTION

This paper refers to the islands of the Dodecannese Archipelago which have a very large seasonal fluctuation in their population due to the influx of tourists in the summer period, April to November; they are not self-sufficient in meeting domestic water supply demand.

The Dodecannese, a complex of a number of islands, is in the SE end of the Aegean Sea and extends from its middle, up to the Libyan Sea. Patmos is the most northern of these islands, while Kasos is the most southern. The Megisti (Kastellorizo), which is 21 km east of the island of Rhodes and 2 km from the Turkish coast is the easternmost boundary of the Greek Republic.

The Dodecannese in itself is a Prefecture unit of Greece, subdivided into four districts, the district of Kalymnos (Kalymnos, Leros, Astypalea, Patmos, Lipsi, Agathonisi), the district of Karpathos (Karpathos, Saria), the District of Kos (Kos, Nisyros, Yiali) and the district of Rhodes (Rhodes, Symi, Chalki, Telos and Megisti).

All these islands have regular boat services, while some have interconnecting air service as well as flights to and from Athens. The major islands of Rhodes and Kos, have a direct air link with Athens and other cities of Greece, as well as with some European cities.

Morphology, geology, hydrology, climate and economy of the islands

The Dodecannese islands have a total area of 2700 km^2, of which about 1100 km^2 are mountainous and the remainder is mountainous and semi-mountainous. A number of islands (Rhodes, Karpathos) have a rough relief with high mountains, whilst at the coast and in short distance from them, the topography is gentle. Other islands have low mountains and hills. Epeirogenic movements of Pleistocene age evidenced the formation of Dodecannese islands, after the submergence of broad pieces of land into the Aegean Sea.

The most abundant rocks are Metamorphics (marble, gneiss, schists). These are followed mainly by Mesozoic sediments (limestone) and Neogene marls and sandstones. Finally, the most recent (alluvium, sands and clays) are usually met mainly on terraces near the coasts.

The morphology of the islands is in relation to the rock material and mainly as a result of the tectonic effects that have occurred since their formation until the present. The islands have been affected by the pre-Alpine and Alpine movements as well as by the more recent epeirogenic vertical movements.

It is considered that the subduction of the African plate beneath the Aegean microplate, is related to the volcanicity along the Hellenic Volcanic Arc, which develops in the Southern Aegean Sea, about 1500 km long, extending from Western Greece to Southern Turkey and passing just on the south of Crete island. This volcanicity is still active and started at about 13 m.y. B.P. (Ninkovitch and Hays 1972, Fytikas et al., 1976). Products of this volcanicity (volcanic rocks) are present in some Dodecannese islands (Patmos, Telos), while Nisyros is a totally volcanic island relatively young 0.2 Ma (Fytikas et al., 1976).

A hydrographic network is practically non-existent. Streams or, in general, permanent runoff is not generated due mainly to the small catchment areas and the relatively low rainfall. The climate is typically pelagic, Mediterranean with temperatures in winter very rarely falling below zero degrees. The summer high temperatures are reduced due to the frequent seabreezes. The annual variation of temperature (high to low) is about 10 ^{o}C. The mean annual temperature is 19 ^{o}C (higher than all the other islands of the Aegean Sea). These islands have the highest rate of sunshine exceeding 200 days per year. The mean annual rainfall, mainly in winter, is in the range of 700 to 750 mm.

The Dodecannese (as a Prefecture Unit), is the greatest in extent, consisting only of islands; it is the only one which in the period of 1951-1971, maintained its population which is attributed to the fact that the mean income per capita is considerably higher than in all the other islands regions.

These favourable economic conditions have been created by the considerable development of tourism, the increase of industrial activity (Rhodes) and the favourable special revenue policy which is implemented in this area. Tourism is becoming all the time the major source of income for all the islands of the Dodecannese and only very few islands are still dependent on fishing, spongefishery, agriculture, animal husbandry and sailing.

Due to the high influx of tourists in the summer months, the seasonal population fluctuation of the islands is considerable. The summer increase of population creates a disproportionately greater demand in water supply in relation to the winter months and exerts serious pressure on the existing supply systems.

Only the islands of Rhodes and Kos can meet demand during the entire year from their own water resources and they even have the potential for supplying, during the months with peak demand, other shallow islands of the archipelago like Patmos, Symi, Nisyros, Telos, Chalki and Megisti.

The method of meeting the water demand of these islands during summer months by supplementing their own water resources by transfer of water with small capacity water - bowser boats described in this presentation as "tankers", will be further elaborated.

2. CHARACTERISTICS OF THE AREAS OF APPLIED SOLUTION

1. The Island of Patmos

General

This island has an area of 34,5 km^2 and consists of three peninsulas. Its maximum length in the North-South is 12,5 km and its maximum width is 5 km. It has a full, heavily indented coastal line of 63 km. It is a hilly island with low relief (highest peak at 279 m in the southern part) and bare of vegetation. It consists of volcanic rocks and alluvium deposits filling the valleys especially near the coast. The permanent population is 2530 living in main towns and villages, the Chora (750), Skala (1350), Kampos (400) and Grykos (30). All these villages make up a single municipality. Tourism is the basic source of income.

The major attraction of the island, besides its natural beauty, is the famous monastery of St. John Theologos, of the 11th Century, with its famous library of rare manuscripts. During the peak of the tourist season, the population of the island increases more than threefold (8000-9000) and one of the greater problems is the solution of the water deficit.

Water supply conditions

The sources of water supply of the island are:

(a) The abstracted groundwater from wells in the area of Grykos, Skala, Lefkes and Kampos;

(b) The "Synodinos" spring which dries out in the summer;

(c) Roof rain-harvesting collected in private and public cisterns;

(d) Import of water by tankers from other islands.

There are 11 concrete and sealed storage ponds on the island; a total capacity of 13000 metres of water. From these ponds, a pipe network provides a house-to-house connection and water supply. The winter demand is adequately met by the first three local sources of water supply.

The location of the Dodecannese Islands of Greece

Supplement of the water supply becomes necessary from April to November when the minimum daily demand is about 800 m^3 of water. Of this quantity, in the summer, only some 40 m^3 per day are available from the wells. It should be noted here that the demand is based on an estimated 60 litres per capita per day during the winter, 80 in spring and autumn and 120 litres during summer.

Fig.1 shows the monthly fluctuation of the population on the island, based on 1985 data.

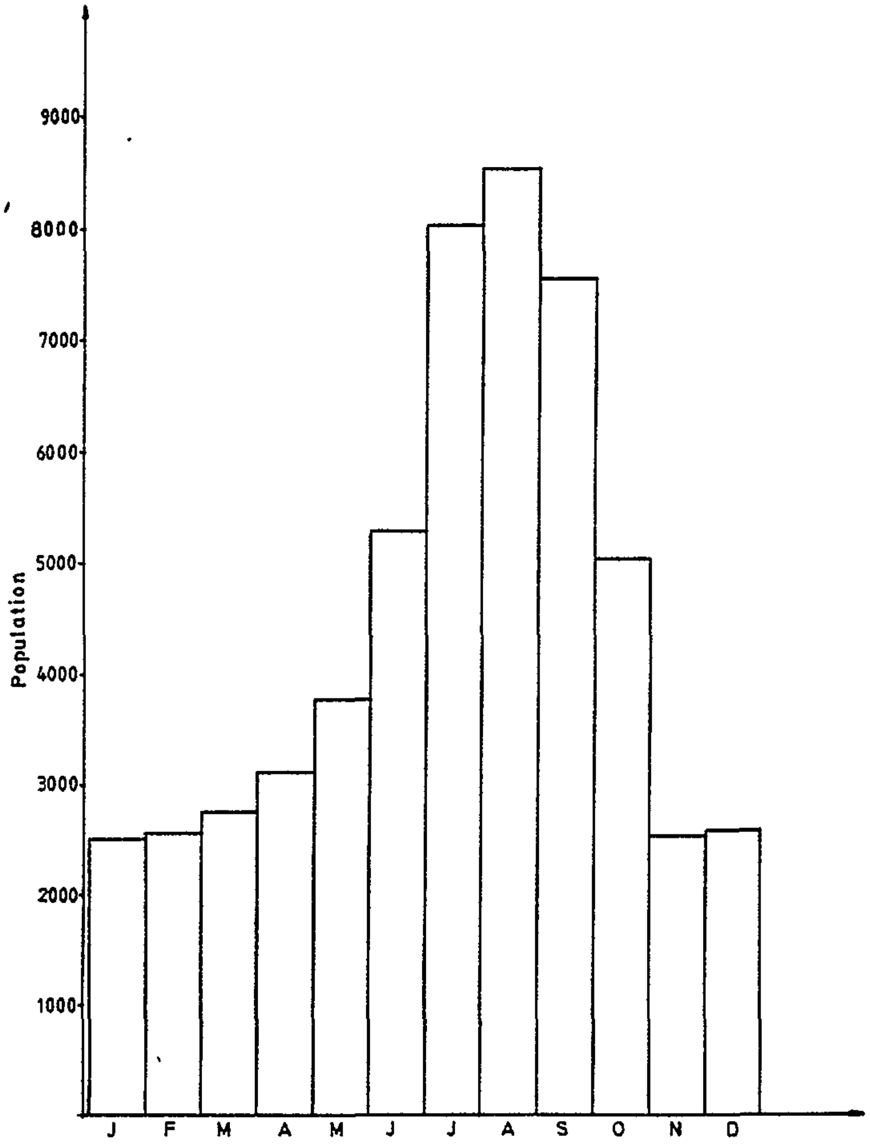

Fig.1 Monthly fluctuation of Patmos Island population (1985)

In Fig.2, where line a shows the monthly fluctuation of the water supply demand in 1985 and line b shows the monthly fluctuation of the available water resources of the island, it becomes obvious that the increase of population during the tourist season does not result in an analogous increase in water demand, but rather a multifold increase. This is due to the summer reduction of the local water resources and the increase at the same time of the per capita water consumption due to the summer high temperatures.

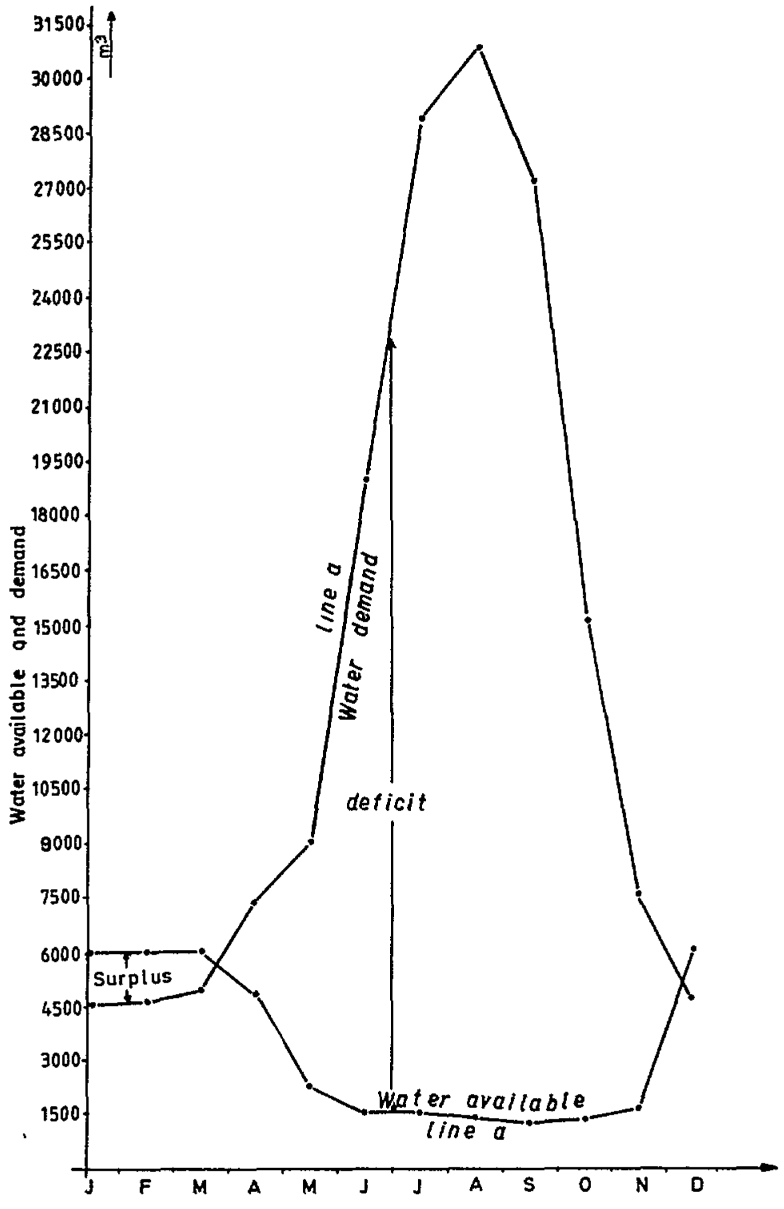

Fig. 2

line a: Monthly Fluctuation of the Water Supply Demand of Patmos Island (1985).

line b: Monthly Fluctuation of Water Resourses Available in the Island (1985).

The available surplus right after the winter season are stored in the public and private cisterns and are utilised in the early summer reducing thus somewhat, the quantities required for import by tankers.

It is obvious that the problem becomes very acute during the period May to October although on many occasions this period is extended until December, especially, if the winter rains are belated.

In Fig.2, the surplus or deficit at any moment is the difference between the two lines whilst the total water deficit can easily be worked out as the area between the two lines.

2. The Island of Symi

General

Symi island is 24 km NW of Rhodes and 13 km from the Turkish coast. It has an area of 58 km^2. It is a mountainous island with peak elevation of 616 m. The Eastern and Southern part is covered by vegetation and the North and West is barren and rocky.

Some 90 per cent of it consists of carbonate rocks, some flysch and schists. There are some minor springs not rendered for use. The population is about 2500 concentrated in one town. In the summer, the population increases to 5-6,000 due to tourism, with some 1000 daily visitors mainly from Rhodes. The famous monastery of Panormitis, besides the island's natural beauty, is the main attraction.

Water supply conditions

The water supply sources of the island are:

(a) The "Vrysi" spring which provides water for storage in 10 sealed ponds of total capacity of 13,500 m^3 and which dries out between April and October;

(b) Rainwater which is collected in private cisterns of total estimated capacity of 10,000 m^3, and

(c) Imported water via tankers from other islands.

The winter demand is met from the first two local sources. Import of water is necessary between April and December when all the local water resources are practically nil and the minimum daily water demand is 500-600 m^3.

Fig.3 shows the monthly fluctuation of the population (as it was in 1985) and Fig.4 shows the monthly fluctuation of the water demand and availability from local sources as it was in 1985. The same comments made for Fig.2 in the case of the island of Patmos also apply here in Fig.4 in the case of Symi island.

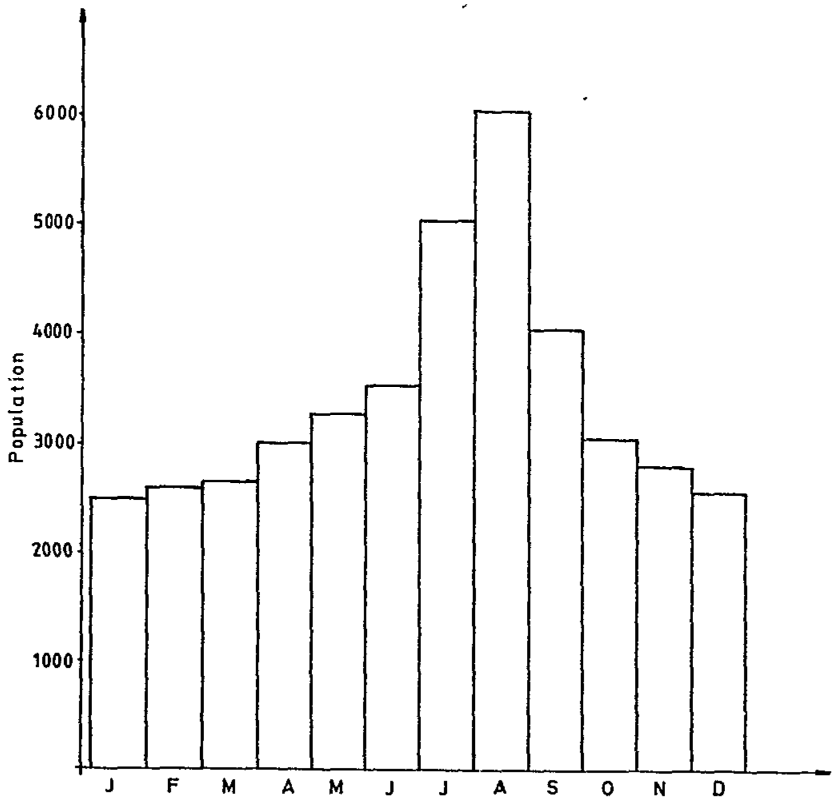

Fig. 3

Monthly Fluctuation of Symi Island Population (1985)

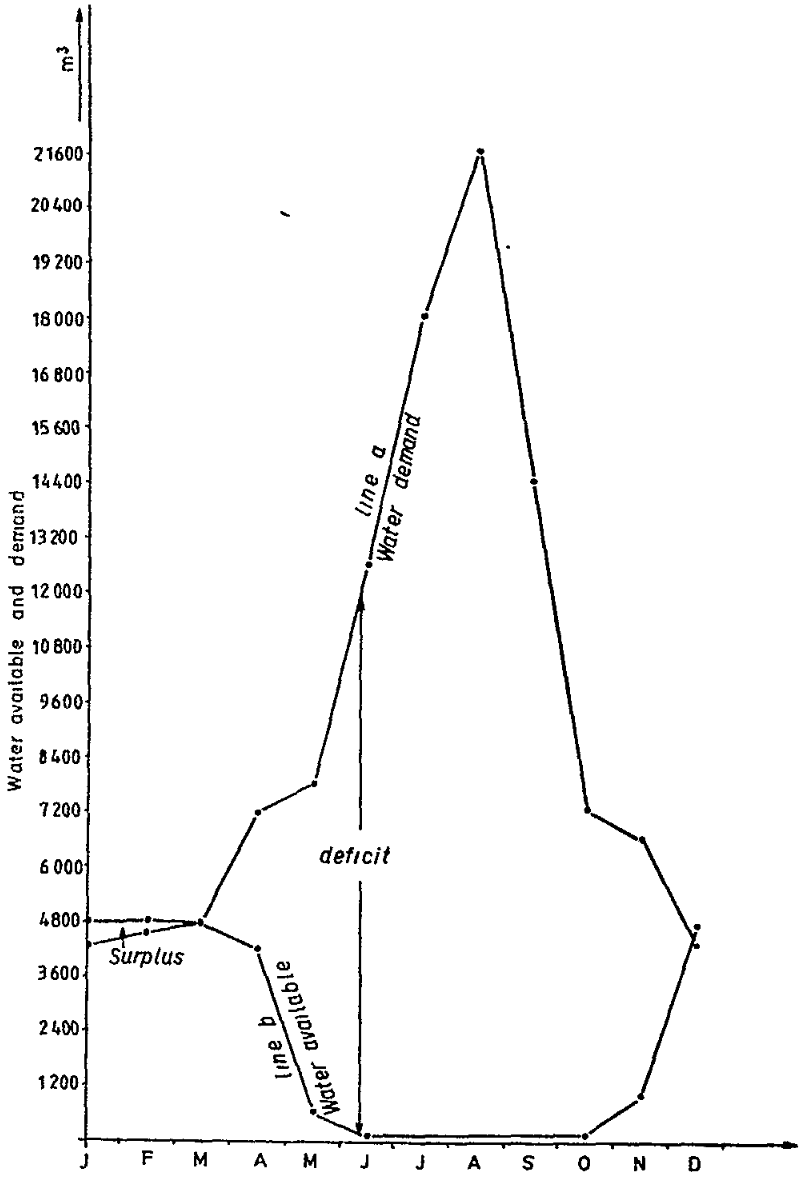

Fig. 4

line a: Monthly Fluctuation of the Water Supply Demand of Symi Island (1985)

line b: Monthly Fluctuation of Water Resourses Available in the Island (1985).

3. The Island of Nisyros

General

It is South of Kos at 14,8 km and North of Telos at 18 km. It has an area of 42 km^2 and its periphery is 25 km. Its coast is precipitous and the slopes are very steep. It is a volcanic island of conical shape, 7,2 km long and 8,4 km wide. In the central part there is a large caldera with 5 craters. The volcano is at a fumarolic stage. It is rocky and mountainous with terraces, covered with bushes and low shrub. Its highest peak at Profitis Elias is 698 m, which is in the centre of the island at the North-West of the caldera.

The whole island consists of volcanic rocks with two minor alluvial plains in the North. It has four villages, Mandraki (673 inhabitants), Emporio (45), Palli (180) and Nikia (80). Mandraki is a municipality and it is the capital of the island.

The white, splended, typical crater, the peaceful countryside, the dry and healthy climate and the thermal spa (at Palli et Loutra) make the island a very pleasant one.

In the summer, the total population exceeds the 2,500 inhabitants. Furthermore, some 400 daily visitors mainly from Kos, visit the island and the volcano.

The economy of the island is based on minor animal husbandry and the quarrying and export of pumice from the nearby small island of Yialli and more recently, on tourism.

Water supply conditions

The island, although quite green, does not have any other local water resources except from rain-harvesting in winter and storing in public and private cisterns. A very small spring, in the form of an open well, in the eastern part of the island, has a very low yield (2 m^3 per day), which is used for watering animals. Saline hot springs issue in the North and South. Some wells scattered in the plains yield brackish water, which is used for irrigation purposes.

Every house has its own cistern underground which stores rainwater collected from the roof, which is purposely designed for this. There are 12 public concrete and sealed ponds of total capacity of 7,500 m^3. Water is generally stored in the winter season in these ponds as well, which is used early in the summer. A house-to-house supply is provided through a pipe-network.

During the dry period of May to November, the required quantity of water is imported generally from Rhodes and occasionally from Kos by tankers, at a rate of 200 to 250 m^3 per day.

Fig.5 shows the monthly fluctuation of the population of the island (1985), and Fig.6 shows that of the demand and supply.

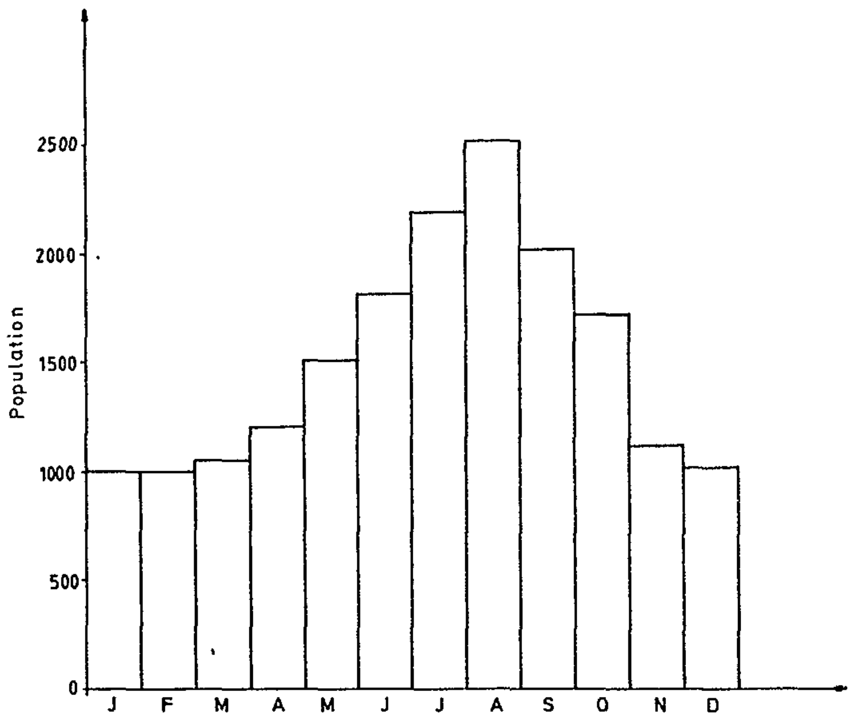

Fig. 5

Monthly Fluctuation of Nisyros Island Population (1985)

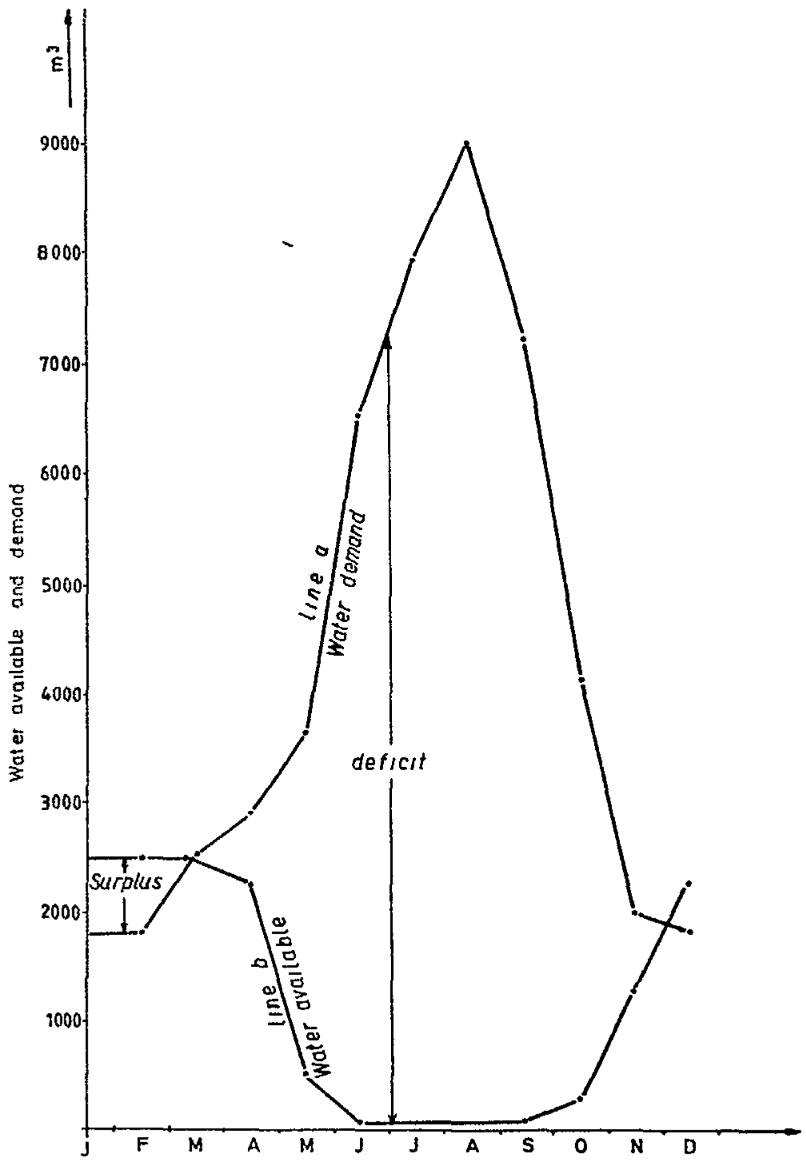

Fig. 6

line a: Monthly Fluctuation of the Water Supply Demand of Nisyros Island (1985)

line b: Monthly Fluctuation of the Water Resourses Available in the Island (1985)

4. The Islands of Telos, Chalki and Megisti

For these islands, due to the small population and the relatively small increase of the population during the tourist season in absolute numbers rather than percentage wise, their characteristics will be referred to very briefly.

Telos is situated South of Nisyros and South-West of Rhodes and Chalki, at a distance of 20 km from the Turkish coast. It has an area of 64 km^2. The population is gathered in two villages, the Megalo Chorio and Livadia. It consists mainly of Mesozoic limestones, flysch and schists. Locally, younger formations of volcanic toffa and alluvium are present.

A water supply problem exists only for the community of Livadia of 120 permanent residents and 400 in total, in the summer, when the yield of a local spring reduces considerably between July and until the first rains of November-December. Three communal ponds with 1,200 m^3 storage capacity serve all the houses with a pipe network. The required daily quantity of water supply in the summer is 40 m^3, although locally this is estimated to be about 100, because part of this water is used for irrigation of gardens of fruit trees and vegetables. The supplementary water required is imported in the summer with tankers from Rhodes.

Chalki is very near to the Western coast of Rhodes and has an area of 29 km^2. It consists of limestone rocks and some flysch. It has 325 permanent residents, whilst the population in the summer increases to 700. Its water supply is met from a borehole of 120 to 200 m^3 capacity per day, through a service tank of 100 m^3 capacity, from 2 public ponds, storing rainwater of 750 m^3 capacity and from private cisterns storing rainwater. Between May and October, water is imported with tankers from Rhodes.

In case of this island, theoretically, water conserved through the winter could suffice for meeting the summer demand and it would appear that import of water might not be necessary. Nevertheless, the water wastage (absence of water meters) and the seepage and losses from the old pipe network create a deficit during the summer of the order of 6,000 m^3.

Megisti (Kastellorizo) is very close to the South-Western coast of Asia Minor and has an aereal extent of only 8,9 km^2, and population of 250 becoming about 400 in the summer. It consists of limestone rocks.

The water supply is met from water collected from rain and stored in private cisterns of a typical capacity of 15 to 30 m^3 and from 5 to 6 m^3 per day produced by the desalination plant which operates on the island. In April and September, the supplementary water required is imported from Rhodes by tankers which is then distributed directly to the private cisterns.

It should be noted that the 100 litres has been assumed, as the daily mean consumption rate per capita in estimating the minimum daily water demand on every island. Normally though, the actual consumption in many cases is less adjusted to the water potential available.

3. CONDITIONS AND MOTIVES FOR USING TANKERS AS A WATER SUPPLY SOLUTION

It is obvious that, although the possibilities for securing local water are not exhausted and the hydrogeological investigation is still going on on some of these islands, most of them by themselves, are not able to cover all of their water supply demands during the summer-autumn season. Therefore, there is need to cover the deficit from other sources. Nowadays, the most interesting solution from an economic and technical viewpoint, is that of transported water from other areas by tankers.

This solution renders itself for the following reasons:

(a) The availability and commissioning of small tankers in the area is fairly easy. In addition to private boats, the Greek Navy readily offers its own boats and ships;

(b) The islands have the potential to employ the tankers on short notice and for undetermined periods during the critical period of summer, mainly July-August, according to their daily needs of water and the total available storage capacity of their ponds;

(c) Frequently the local water resources used in the summer are of inferior quality (summer regime), due to overpumping. Thus, blending it with imported water or completely replacing it with imported water of definitely better quality, results in an overall improved quality of water;

(d) The available harbour and other installations coincide with this operation;

(e) The cost is relatively low and the transportation distance to the consumption areas is generally small; and finally,

(f) Transportation of water by tankers is more compatible with economic, technical and other available facilities than with desalination of seawater or transportation by submarine pipe or surface water usage by dam construction, where possible.

4. DESCRIPTION OF THE BASIC FEATURES OF WATER SUPPLY BY TANKERS: TECHNICAL AND ECONOMIC

In winter, the local authorities of the islands mentioned earlier, apply to the Prefecture and provide their estimates of the required quantities of water to be imported by tankers. These estimates are not strictly followed since the programme prepared by the Prefecture is generally quite flexible and adjustable to any possible underestimate, etc.

At the end of the winter season, the Prefecture undertakes the commissioning of tankers beyond the fixed services of the Navy tankers which during 1985, transported 20 per cent of the total quantity required (31,400 m^3). The Navy Tanker has a capacity of 600 m^3 and obtains its supply from the nearest available source at the moment that the order is placed. The overall cost for the Navy Tanker was US $ 2.41 per m^3 of water. Navy Tankers were also used during the year 1986.

For the commissioning of private tankers, the Prefecture calls for Tenders. In 1985, two private tankers were supplying water to the islands at US $ 2.67 per m^3. These costs, as mentioned earlier, were borne by the Prefecture up until 1985, whilst since 1986, a charge of US $ 0.22 to 0.37 per m^3 will be levied on each island.

The private tankers also have a capacity of 600 m^3. They obtain water from Rhodes for all of the islands, except in the case of Patmos and Nisyros, which are very close to the island of Kos. Recently though, even these islands obtain water from Rhodes since Kos no longer has a large surplus. In 1985, the private tankers transported some 101,000 m^3 or 80 per cent of the total required water supply.

The water is provided free by Rhodes and Kos, thus the cost referred to the private tankers refers to transfer costs only. This is not the case with the Navy Tanker which sometimes obtains water from sources other than Rhodes and Kos, in which case the water must be purchased. The approximated quantity of water transported monthly in 1985 to each of the islands appears in Table I.

It should be noted that the tourist influx and the population, in general, increases from year to year, consequently increasing the water demand. Just to demonstrate this, in the period of 1st April to 17th of July 1986, the private tankers transported a total of 81,000 m^3 to the same islands mentioned in Table I.

The tankers discharge the water into the ponds near the coast at a point where the boat can easily approach. The time required for discharge is about 9 hours, which increases to 11 hours if the water is discharged directly to the pipe network, as it is in Patmos.

The travel time of the tankers from Rhodes and Kos appears in Table II.

The water tanks of the tankers as well as the ponds of the islands, are washed regularly. In addition, the ponds are chlorinated for the maintenance of the safest possible quality for the inhabitants of the islands.

The tankers are relatively small boats of small water carrying capacity, as anything larger would have been uneconomic and the approach to the generally small harbours would have been difficult. Of course this creates problems both in their navigation and entrance into the harbour under difficult weather conditions. However, this occurs very infrequently in summer and when it does, it is usually of short duration.

5. WATER QUALITY PROBLEMS

The transported water is the same that is used for consumption by the inhabitants of the islands, therefore it should be of suitable quality and regularly monitored. Of course, the quality is reduced to a certain extent during its transport and its storing period in the ponds of the islands. The cleaning of the ponds is carried out every year and more frequently when the conditions allow for it. Systematic efforts are placed upon all phases of transportation operation (from the taking out of the water up to the consumption of it), in order that the safe water quality is secured.

Table I

Monthly quantities of water transported in 1985 by tankers to each island (all in m^3)

Island	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
Patmos	-	-	-	3,000	4,200	6,000	4,200	8,400	7,800	5,400	3,600	1,800	44,400
Symi	-	-	-	3,600	6,000	7,800	9,600	10,200	7,800	6,000	4,200	3,000	58,200
Nisyros	-	-	-	-	2,400	3,600	4,800	4,800	3,600	1,800	1,800	-	22,800
Tilos	-	-	-	-	-	-	1,200	1,800	600	-	-	-	3,600
Chalki	-	-	-	-	600	1,200	1,200	1,800	600	600	-	-	6,000
Megisti	-	-	-	-	600	600	600	600	-	-	-	-	2,400
TOTAL	-	-	-	6,600	13,800	19,200	21,600	27,600	20,400	13,800	9,600	4,800	137,400

Table II

Travel time of tankers from Rhodes and Kos to the Various Islands (in hours)

	Destination					
Origin	Patmos	Symi	Nisyros	Telos	Chalki	Megisti
Rhodes	12	2	8	4	4	10
Kos	5		3			

6. CRITICAL ANALYSIS OF THE OPERATION

The alternative of meeting the islands' increased demand for water during the summer period, where the population increases multifold, through the importation of water by tankers, has been accepted as the only solution and thus, it offers the following advantages:

(a) The comparatively low cost of water transport compared to the other available alternatives (like water desalination, installation of submarine pipe, etc.).

(b) The potential for storing the required quantity of water when there is a forecast for increased requirements.

(c) The potential of maintaining safety reserves.

At the same time there are disadvantages like:

(a) Large storage facilities (ponds), which are required for the peak months. They are uneconomic since they are used only for a very short period every year.

(b) The uncertainty and insecurity of consumers regarding the timely arrival of the tanker (mechanical failures, weather conditions, large number of trips and requests by many islands for water).

(c) The rising trend in the population of all the islands, mostly on Rhodes and Kos, may in the end result in the reduction of available surplus (already having occurred on Kos), so that there will be no potential for supply and export from these islands. By the way, it should be mentioned that recent efforts have been made to increase the available water resources of Rhodes and Kos but, unless rational management is effected, the reduced surplus on these two islands and the continuously increasing water demands of the deficient islands will result in a very acute and difficult problem. In this case, water will have to be transported from located areas further away.

(d) The difficulties in the "in time" delivery of the water during the peak season, July-August, which is a period of great consumption and great increase of population for all the islands. The main effect of this is a bare minimum or even lower water consumption (less than 100 litres per capita per day).

In general, there is agony and stress on the water deficient islands for the securing of water in the summer. The general consensus and wish is that they are able to cover their demands from their own local resources.

During the last years, the responsible authorities have made intensive investigations towards this direction with a final target, the demand and exploitation of all the local water sources, surface and/or subsurface on each island, so that the required quantities of transported fresh water can be diminished.

7. MEASURES AND PROCEDURES FOR AMELIORATING THE PRESENT SOLUTION

Improvement of the present solution could be accomplished by:

(a) Enlargement of the storage capacity and the commissioning of a greater number of tankers.

(b) Regular commissioning of tankers beginning in April for increasing the water reserves, which are important in order to meet the peak demand of July and August in conjunction of course, with (a) mentioned earlier.

(c) The acquisition of a tanker by each island, which of course would mean an important investment and economic load for each island.

(d) The maintaining of considerable (rather sufficient) safety reserves.

(e) Implementing a systematic quality control of the water accepted by tankers and provided to the consumers.

(f) The correct and 'in time' forecast of water demands, which would result in the more rational programming of the tankers' trips.

(g) Improvement of the taking out and delivery water installations.

As mentioned earlier, the responsible authorities have shown, during the last years intensive activity for researching new local water sources on many islands such as Patmos, where the drilled boreholes by IGME gave a yield of about 250 m^3 per day; it is expected that their exploitation by 1987, will cover part of the water demand, especially the summer's.

On Sumi and Nisyros, the groundwater potential is being investigated with 4 and 12 alternative borehole sites respectively by IGME in 1986.

The prefecture is already completing its drilling programme by September 1986 and has already provided the solution to the water problems of Telos. The same is true for Chalki after the commissioning of boreholes drilled by the Prefecture.

Finally at Megisti, a new seawater desalination unit is expected to be installed so that this island becomes self-sufficient.

8. CONCLUSIONS AND RECOMMENDATIONS

It appears that the selection and/or preference to the alternative of using tankers and importation of water to meet the seasonal demands, should be preferred only when the potential of the local water resources has been completely studied, investigated and committed.

Unfortunately the small size, structure and hydrogeological conditions of the islands, in most cases, are not encouraging of a full scale investigation to secure fresh water resources to meet all of or part of the demand locally.

This results in the alternative of importing water from neighbouring islands or continental areas by tankers, especially in periods when there is a large seasonal fluctuation of the population. This solution is faster and more economic in comparison with others.

9. ACKNOWLEDGEMENTS

Appreciation and thanks are expressed to Dr P. Kolias, Civil Engineer (Ministry of Interior), Mr. I. Kolligris, Economist (Dodecannese Prefecture) and the Mayors and Community Leaders of the islands, for the necessary information that they provided for writing this paper.

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10. REFERENCES

Di Paola, G.M. (1974). "Volcanology and Petrology of Nisyros Island". Instituto Internationale de Vulcanologia, Catania, Sicily.

Dounas, A. (1970). "Report on the Hydrogeological Conditions of Patmos Island of Dodecannese". Institute of Geology and Subsurface Research, Athens, Greece.

Gersar (1985). "Mission de Reconnaissance dans les îles d'Astipalea, Nisyros et Tilos", Ministère de la Recherche et de la Technologie, Athène, Grèce.

Jacobides, J., T. Ramjak and J. Barbir (1984). "Report of the PAP/RAC Mission on Water Resources Development of Islands and Isolated Coastal Areas in Greece", Split, Yugoslavia.

Jacobides, J. and I.F. Fritz (1985). "Report on Water Supply of the Island of Nisyros", Phase I, PAP/PAC.

Kourmoulis, N. (1981). "Report on Hydrogeology Investigation and Improvement of Water Supply Conditions of Symi Island of Dodecannese". Institute of Geology and Mineral Exploration, Athens, Greece.

Kourmoulis, N. (1982). "Report on Hydrogeological Investigation and Improvement of Water Supply Conditions of Chalki Island of Dodecannese". Institute of Geology and Mineral Exploration, Athens, Greece.

Kourmoulis, N. (1984). "Report on the Results of Drilling Works in Symi Island". Institute of Geology and Mineral Exploration, Athens, Greece.

Papapetros, P. (1985). "Report on the Results of Drilling Works in Patmos Island". Institute of Geology and Mineral Exploration, Athens, Greece.

Strogilis, G.I. (1981). "Report on Hydrogeological Research of Patmos Island". Ministry of Coordination, Athens, Greece.

DESALINATION TECHNOLOGY ON MALTA

by

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ABSTRACT

Desalination of seawater on a large commercial scale to produce fresh water has been practiced on Malta for a long time. Multi-stage flash distillers were introduced in 1966 and reverse osmosis in 1982. There is thus, appreciable experience of both processes. Some of this experience is presented in this paper.

Desalination of seawater is costly, both capitalwise and in its consumption of energy. Therefore, before being used, all other possible cheaper sources of water must be investigated. This includes rainwater harvesting, aquifer exploitation, water conservation and reuse. If this is not done, desalination will not be assisting in the solution of the problem, but rather hiding the appropriate solution.

The paper also includes a brief account of the ground water sources in Malta and the degree of their exploitation to justify involvement with desalination.

1. *INTRODUCTION*

It is appropriate that this Seminar on water problems on Mediterranean Islands be held here in Valletta and that Malta contributes its experience in the application of desalination technology as a means of augmenting its natural water resources.

Malta has a long standing association with desalination. It was over a hundred (100) years ago, in 1881, to be exact, that a small primitive distiller was constructed in Sliema, at Tigne. In the National Library, there are newspapers of that time commenting on the event. One paper comments on its benefits to the people of Tigne area and its effect on human health, while another comments on the expense incurred in its construction which the paper says could have been avoided since alternative means of supply to the area were available. Basically, similar considerations applied to modern situations are discussed in technical meetings of this type to this day!

Needless to say, such a long history of association of desalination of water is an indication of the problems and difficulties that, over the years, have faced the Maltese Islands in reconciling the ever-increasing demand for water with the available supplies. Over the years, exploitation of naturally occurring water in the aquifers, desalination of sea and brackish water by Reverse Osmosis and Multistage Flash Distillation and Sewage Treatment for agricultural use have all been employed.

In a spirit of cooperation, confident that a presentation of our experience in desalination will be of benefit to all, this paper will attempt to provide a detailed and critical analysis of our experience in the field of desalination and will attempt to put in perspective the role of desalination technology in mitigating somewhat the water supply problems in Malta.

Desalination of seawater on a large scale is expensive and is not to be embarked upon lightly. All other sources and methods of preservation and leakage control must be exploited to the full, before desalination is considered.

Unless this is done, it may not be correct to state that any desalination has "solved" the water supply problem. It may only be hiding the correct solution.

In a paper of this type, one can discuss various aspects of desalination - the theoretical approach, the historical and the practical. The paper would then be very lengthy. I had to be selective and I therefore included these aspects which I believe are of most interest to this Seminar. Mainly, I have included a summary of our experience on distillation (though, in view of later development, this may be out of date) and also some of our experience with reverse osmosis. This I believe is most useful.

2. PHYSICAL CHARACTERISTICS OF THE ISLAND OF MALTA RELEVANT TO NATURAL WATER RESOURCES

General

Malta is situated roughtly in the centre of the Mediterranean Sea, 90 km to the south of Sicily and 290 km from the North African mainland. Its area is about 250 km^3. With a population of about 300,000 inhabitants, it is the second most densely populated country in Europe after Gibraltar.

The climate is typically Mediterranean with a mild wet winter and long dry summer - a wet winter is invariably followed by a long dry summer. In view of the importance of rainfall to the water balance of the country, records have been kept systematically over a hundred years. The annual average is about 470 mm. The bulk of the rainfall occurs mainly during the months of November, December and January.

Surface hydrology

There are no perennial surface streams in Malta. Water only flows along the bed of major valleys for a few days, after heavy downpours. About 3 per cent of the annual precipitation measured over many years by run-off recorders located at exit points of major drainage areas, finds its way into the sea.

It is unfortunate that the major drainage lines cross the entire width of the Island from their sources close to the western coast before entering the sea on the east. This gives the surface water maximum time to seep into the underground aquifers through fissures and permeable rock formations. A large number of dams have been constructed across these valleys to retard discharge and so serve to increase percolation to the aquifer and retard soil erosion.

Hydrogeology

Two main aquifers are found on the Maltese Islands:

(i) A Perched Aquifer situated in the porous upper Coralline Limestone which lies directly above the impermeable Blue Clay formation. No salt water intrusion in the aquifer south of the Victoria Line is possible since it is everywhere located well above sea level. To the North, the aquifer is in many places in contact with seawater, and intrusion is a problem. Private extraction for farming exploits this aquifer almost to the full, leaving only a small fraction for the public supply which comes largely.

(ii) The Mean Sea Level Aquifer is more important and accounts for about 75 per cent of the total freshwater supply. The aquifer lies in the pores and cracks of the globigerina and the lower coralline limestone situated in the region of the mean sea level. This freshwater body rests on a saturated zone but owes its existance to the fact that every winter, the local rainfall adds more freshwater to the underground store that can be dissipated by direct discharge around the coast.

There is no sharply defined plan of separation between the superficial freshwater and the saline water which is underneath. The equilibrium of this "lens" is in a state of flux depending on fluctuations in rainfall, tides and other factors. Large areas on the central part of the Island have a water table of 2-3,5 m above mean sea level under static conditions.

Recharge to the aquifer is predominantly through fissures in the overlying globigerina limestone. Permeability is fissure dependent. This aquifer is exploited mostly by a system of underground galleries and by a number of boreholes. Seawater intrusion into this mean sea level aquifer presents a problem since rock permeability is mainly through fissures.

3. WHY DESALINATION?

The demand and supply of first class potable water over the last years is shown on the Figure 1. It shows an average yearly increase in demand of about 2,500 m^3/day.

- The graph also shows the amount of ground water extraction, and production by seawater desalination (i.e. distillation and reverse osmosis) which indicates the deficit in demand that had to be made good by desalination.

The graph of water production for 1984 (Figure 2) is also indicative in the sense that there are no remarkable season peaks in demand. This is because of some unsatisfied demand throughout the peak season and may also be affected by an unknown amount of unaccounted for water and unauthorised use.

These graphs illustrate that the solution of desalination was not turned to lightly. Salinity curves, for ground water, also show that the extraction of ground water has been practiced to maximum tolerable limits. In fact, the safe yield as dictated by the yearly water balance has been exceeded by continuous overpumping in certain areas and gradual deterioration in groundwater quality has resulted. At present only 60 per cent of groundwater is produced from metastable sources and the balance of 10 per cent from unstable sources where salinity is on the increase; blending with better quality waters is done in reservoirs to improve the quality.

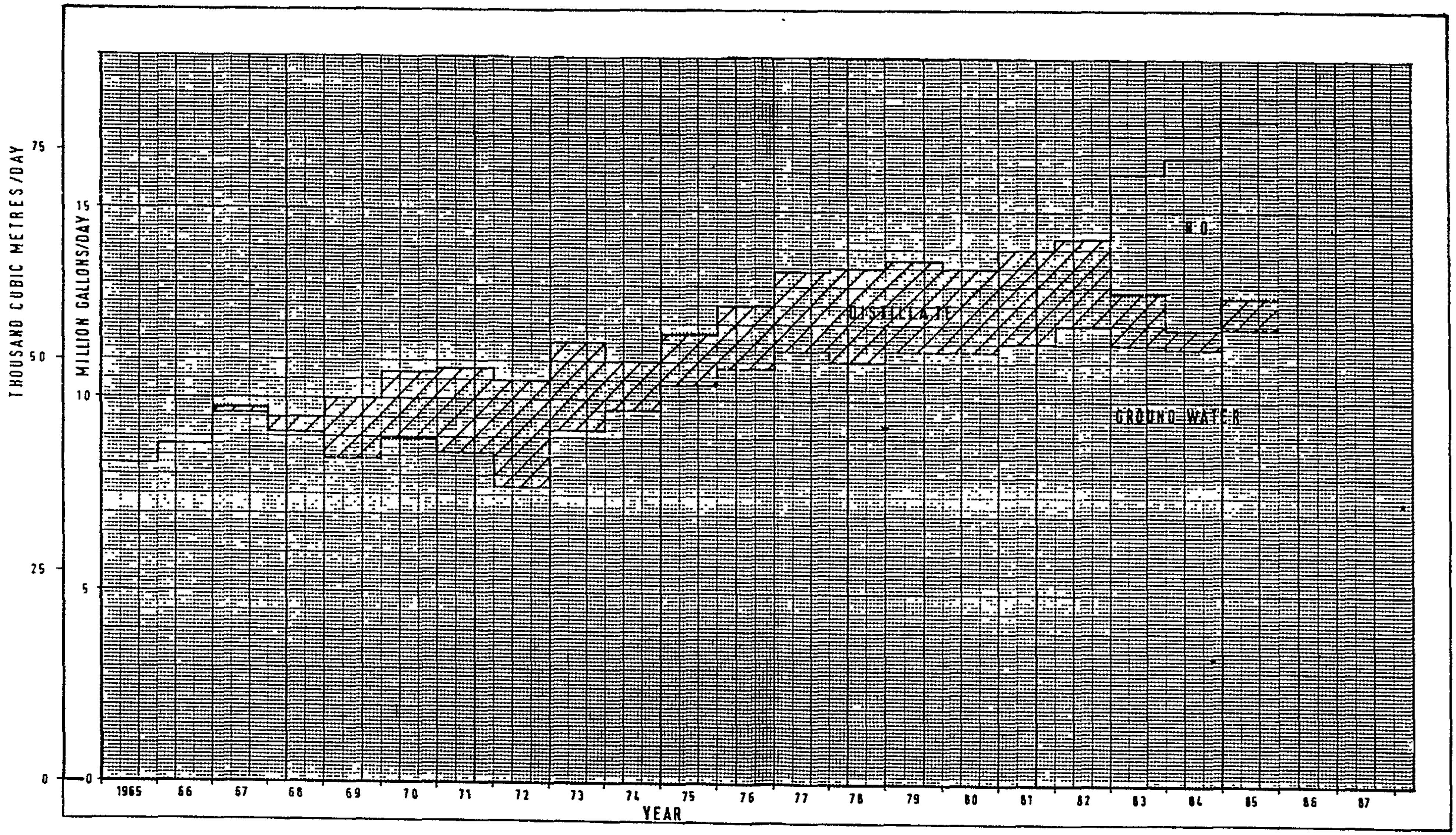

Fig. 1 Malta - Average daily water production

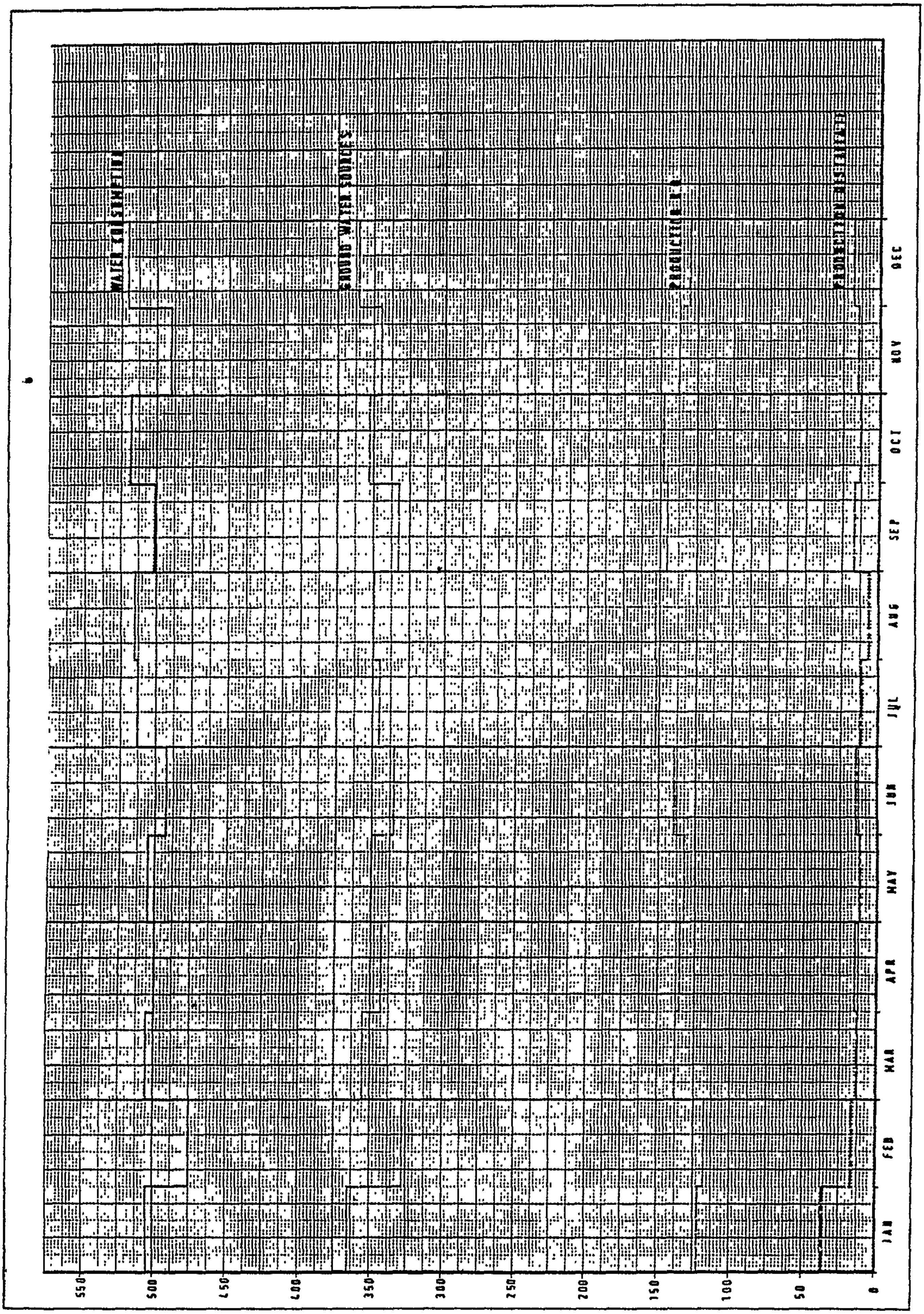

Fig. 2. Malta 1984 - Water production and consumption

This unfavourable condition has been receiving due consideration and it is the intention to limit extraction to give the aquifer a chance to recover. It is also planned and, in fact, preliminary arrangements are being made to embark upon a project of study of the aquifers by mathematical modelling. This is now widely practiced and is a very useful tool for evaluating the possibilities and limitations of groundwater use.

In addition, the ongoing programmes of leaking detection are being intensified and a programme of network analysis on the distribution system is imminent.

To complete the picture, the Sewage Treatment Plant can also be mentioned. This indirectly reduces first class potable water requirements by providing water suitable for agriculture. It is also planned to extend this supply to industry after further treatment.

4. DESALINATION IN MALTA'S WATER SUPPLY SYSTEM

Malta's involvement with modern desalination technology desalination over the last twenty (20) years is conveniently divided into two (2) phases: that of Multi-Stage Flash Distillers first installed in 1966, and that of Reverse Osmosis in 1982.

Multi-Stage Flash Distillation - 1966/69

In 1966, multi-stage flash distillation was the only viable commercial seawater desalination process, though research in other desalination processes was going on. Freezing methods were receiving a lot of attention, but this was soon discontinued. Reverse Osmosis membranes were developed for brackish water and a breakthrough was being expected in membrane technology to treat seawater. The process showed promise because of its inherent simplicity and low energy consumption. LTV boiling methods were also being studied because of their potential to attain higher Gross Output Ratio. The first real multi-flash plant was built in 1960 in Kuwait and the first unit for Malta was built in 1966.

This is not the place to explain the thermodynamic and flowsheet of multi-stage flash distillation. This has been done several times in various papers but a distinction between the economics of single and dual purpose operation must be made.

Generally speaking, a flash plant is only commercially interesting if it is tied to a source of cheap low pressure steam. In the case of Malta both then, in 1966, and even now, this meant operating in conjunction with the power station, with the distillers getting most of their heating steam at low pressure from power turbines. (The plant can also be engineered in such a way that a steam turbine driving the large recirculation pumps is of the back-pressure type and its exhaust is used to assist heating of the brine.

At this stage, it is pertinent to point out that in the case of such dual-purpose operation (i.e. combined power-generation and water production), the passout heating steam is far from being "waste" heat. Exhausting the steam at 1,67 atmosphere (atm) means losing a third of the electricity - generating capability of the original high-pressure steam (at 45 atm).

However, if the distillation operation were done in a single-purpose plant, (water production only) specific fuel consumption would be about 60 per cent higher.

In 1964, a power station was being built in Malta and the consultants recommended a dual-purpose station. In 1966/67, the first flash plant was installed. It was a phosphate dosed one million gallon per day unit. The main distinguising features of this plant were its tube bundle configuration (being in the form of a "U") and also its stage geometry.

The plant had its share of teething troubles; some particularly heavy scale deposits and the frequent breakdown of its main booster pump impeller are well remembered. The U-tube bundles were not found advantageous in practice though they may have simplified construction and erection. The bends in the tubes, especially the inner small radius ones, seemed to encourage stoppage of rust flakes and other debris, and hence favoured faster scaling, not least by reducing tube velocities.

That distiller, at its design stage had not benefited from research work in stage geometry which was later carried out. As a result it was large and incorporated ample design margins, particularly in stage geometry.

In 1967/69, three other distillers were built. They were each rated at one million gallons per day, if phosphate dosed, and at 1,17 million gallons per day when converted to acid scale-control treatment.

Unlike the previous one, these distillers had little margin in their design. Most instrumentation including that associated with acid injection was not found sufficiently reliable. Its vacuum equipment was also found troublesome.

Materials of construction

These plants, now about twenty (20) years old, are our only direct experience of specification, construction and operation of flash distillers. This is not very up-to-date and would be misleading if presented without the comment that more modern plants built with better materials of construction offer better performance and higher availability. For completeness sake, a table of the materials of construction of the major components (with some comments) is included.

By way of amplification, it must be said that when in 1973, fuel prices increased and flash desalination plants became, overnight, very expensive to run, the distillers spent much time idle and on standby, sometimes with a "vacuum retaining" plant hooked on.

Abnormal rusting and corrosion occurred under these conditions and the absence of the filter in the brine circuit meant that much of this rust scale found its way into the brine circuit and heat recovery section tubes. Maintenance was heavy and the drop in plant performance after overhauls was higher than expected. For this reason also, no figures of production and availability are presented because they are artificially depressed.

The idea of balancing the desalination plant capacity between reverse osmosis and modern dual-purpose flash desalination is now being studied since a new power station is in the offing. Also assisted by the Council of Europe, we are at present undertaking a survey of these old desalination plants to consider the feasibility of refurbishing them. This should prove a useful exercise.

Table I

Summary of data on materials of construction
All Distillers - Type - Horizontal Grosstube Multi-flash

	Number 2	Numbers 1, 3 and 4
Rating	1,000,000 imp gls/day phosphate dosing	1,000,000 imp gls/day - phosphate dosed 1,170,000 imp gls/day - H_2SO_4 dosed
Commissioned	1966/67	1969
Exhaust steam heater		
Shell	Mild steel	Mild Steel BS 15 Grade I
Tube plate	Aluminium bronze	Naval brass
Tube	90/10 CuNi	Aluminium brass
W box protection	Monel clad	Neoprene
Distiller stages		
Shell material	Mild steel	M.S. BS 15 Gr I
Shell protection	Corrosion allowance on plate thickness	Corrosion allowance on plate thickness
Tube plate material	Naval brass	Naval brass
Waterbox protection	Neoprene	Lined with 90/10 CuNi sheet (4" pitch spot welded)
Tube material 1,2,Rej	Aluminium brass	90/10 CuNi
Tube material other	Aluminium brass	Aluminium brass
Demister material	4" thick close double monel wire-mesh pads	- as for No.2 -
Piping		
Feed water piping	rubber lined	rubber lined
Brine piping	rubber lined	epoxy lined
Pumps		
Brine recirculation pumps		
Casing	Cast iron	3° Nickel iron
Impeller	Ni-Resist C. 1.	Aluminium bronze
Shaft	Stainless steel	Stainless steel
Condensate pumps		
Casing	Bronze	Cast iron
Impeller	Bronze	Bronze
Shaft	Stainless steel	Stainless steel

Table I (continued)

Seawater feed pumps

Casing	Ni-resist C.l.	Austenitic C.l.
Impeller	Ni-resist C.l.	18/10/3 Stainless steel
Shaft	Stainless steel	E.N. 58J

Distillate pump

Casing	Bronze	Cast iron
Impeller	Bronze	Bronze
Shaft	Stainless steel	Stainless steel

REMARKS

1. Heater and Shell W Box protection

Monel and 90/10 Cupronickle lining (spotwelded at 4 inch pitch) extremely suitable. Neoprene lining (site applied) requires a lot of maintenance especially at the higher temperature end and where effected by eddies. Neoprene not suitable above 190/195 ^{o}F.

2. Mild steel shell

Good service for 18 to 20 years, except for corrosion in distillate catch-plates and troughs. Probably due to interruptions in service and long shut-down periods, rust flakes from walls, etc. fall off the stage walls, roof, etc. and when caught in the brine circuit, are pushed into tubes. Filter in brine circuit recommended.

3. Aluminium brass tubes

Aluminium brass tubes are less satisfactory in heat rejection section, though failures in Cu Ni also occurred. Seawater for cooling section was not satisfactorily filtered.

4. Demister material

Monel was found suitable. When stainless steel (EN57) was tried, it was not successful.

5. Piping

Rubber lining satisfactory at suitable temperatures, but needs yearly attention and maintenance. Epony lining less suitable.

6. Brine recirculation pumps

Ni-resist C.I. was not to standard and there were very frequent replacements of impellers. Some casings changed after approximately 12 years but see (2) above.

7. Other pumps

As listed above generally satisfactory.

We are also aiming to keep abreast of current developments in thermal plant technology, both classical and variants such as low temperature evaporation and vapour compression, because distillation has after all been found a reliable, rugged process which all considered, has served us well.

Reverse osmosis

In 1981, it was decided that the desalination facilities in Malta were to be increased. At the outset, a difficult decision presented itself in the choice of process - the new unproven reverse osmosis or the long established multi-stage flash distiller.

Feasibility studies aimed at identifying and, where possible, quantifying the advantages and drawbacks of each system were undertaken. It was concluded that in the then-specific local circumstances, employment of the reverse osmosis process was recommended, as the advantages it offered were attractive enough to counterbalance its innovative status. However, to ensure up to date technical and market data for final analysis, a tender for the supply of multi-stage flash distillation on reverse osmosis plants was issued. From data received in the offers and subsequent negotiations, a detailed evaluation could be made and a final decision taken.

Fuel consumption

It was calculated that with energy recovery, the equivalent specific fuel consumption of the reverse osmosis plant will be in the region of eleven (11) tons of fuel per m^3, given the electricity generating characteristics of the power plant in Malta. For multi-stage flash distillation, with the same power plant, this would be of the order of twenty-two (22) tons of fuel per m^3. This figure assumes that the distillers were run as dual purpose plants, otherwise their fuel consumption would rise by an estimated 60 per cent.

In Malta, it was not possible to take on new distilling plants and combine them with existing passout turbines. The only such machines in service had been installed in 1964 and were then seventeen (17) years old. They were relatively small (2 units x 12.5 MW and 1 unit x 30 MW) and were required to support the existing distillers. The turbines, being installed then, were preferred over electricity generation both from the economic and operational convenience point of view.

They were of the fully condensing type and were of a capacity more suited for the electricity load being carried by the Power Station.

On the other hand, there were some technical difficulties associated with the power supply to the reverse osmosis plants and some reinforcement of the electricity distribution system had to be considered. These difficulties included the electrical losses associated with transfer of bulk loads (over 6 MVA) over long distances and start-up of large motors at the reverse osmosis site.

Capital cost

It was expected that the market capital costs of large size reverse osmosis installations be lower than those for multi-stage flash, more so in view of the system at that time of competitive bidding and the interest of various manufacturers to be associated with a large landbased reverse osmosis plant. Subsequent tender evaluation revealed that the ratio of cost of the reverse osmosis process plant to single-purpose multi-stage flash was 2:3. Of course, the capital charges in reverse in reverse osmosis membranes are required throughout the plant's life.

Speed of erection

The new plant, whether reverse osmosis or multi-stage flash, was required in order to start production of water as soon as possible after the award of contract.

The reverse osmosis offered promised completion by twelve (12) months. The successful tenderer, however, completed it in less time despite the completely undeveloped site which was earmarked for the project. The multi-stage flash bids specified a completion time of about twenty-two (22) months. This was on the understanding that the plant was to be built on a semi-developed site adjacent to the power station and was to benefit from the already existing infrastructure such as cooling water and other common systems.

Location

In Malta, a multi-stage flash plant could realistically be installed only adjacent to the power station, mainly for economic reasons. This location is far from the existing areas of high water consumption and therefore, major pipeline construction, mostly in busy roads and areas, would have been required.

On the other hand, while the reverse osmosis plant site could have been chosen anywhere along the coastline, there was the electricity supply to be considered. Economic analysis on possible sitings were carried out and these were then taken into consideration in the final choice of site.

Technology

Flash plant had been operated in Malta for twelve (12) years with reasonable success. Local staff were familiar with this technology which, from the operation point of view was not much different from basic power generation technology. Reports from elsewhere, notably Saudi Arabia, Bahrain and other Middle East countries testified to the improvements being made on this type of technology and the very high rates of reliability which were being achieved. It was apparent that the materials of construction now being employed were giving much better results.

On the other hand, the operation of large seawater reverse osmosis plants were new to the Maltese Islands, with little experience existing in the rest of the world. There was only one such large reverse osmosis plant working in the United States. It had been operating for only a year and did not incorporate such important aspects as Energy Recovery from the reject brine stream. There was neither readily available comprehensive and reliable information nor any operating history of the membrane over the span approaching its guaranteed life-time.

It was therefore considered prudent to safeguard ourselves by entering into an Operations and Maintenance Agreement with the plant supplier for the initial five (5) years of its life.

This Agreement guaranteed to the supplier/operator a payment made up of two (2) parts - a fixed monthly payment and another payment per cubic metre of water produced. In return, the operator guaranteed the level of production (tied up with age of plant and seawater temperature) and water quality.

All maintenance expenses, above those incorporated in the agreed payment, were to be made to the operator's account. This also included membrane replacements over and above their original maker's warranty.

Besides these basic clauses, the Agreement also regulated the operator's duties and tasks, the services to be made available to him, training of local staff and other administrative matters such as insurance and price variation terms.

It is to be recorded that this Agreement worked very well in practice and turned out to be a good coverage to the Government against membrane (or plant) mal-performance.

Thus, when all these matters were taken into account, it was decided to opt for a reverse osmosis plant and a complex for producing 20,000 m^3/day. The site chosen was Ghar Lapsi, on limits of Siggiewi at the south-west of the Island. The contract was awarded in March 1982 and the first production of water was in late December 1982.

Operating Experience

Reference (1) gives technical details on the plant, thus they need not be repeated here.

Without exaggerating them, it may be beneficial to point out the difficulties and problems met. This will serve as a case study and of course, need not necessarily be applicable elsewhere.

The first difficulty met concerned the boreholes. At the initial planning stage, it was assumed that four boreholes were sufficient to run the plant and still have some spare margin. Site investigation and borehole drilling soon showed that this was too optimistic and by the end, the plant had fourteen wells discharging into a breaktank and an extra four were dug for standby purposes. Some wells were abandoned because of collapse, though most drilling was done in compact limestone.

Initially, the wells produced water with high Silt Density Index (SDI) and it took weeks and, in some cases, months for the high sand content in the water to clear. The wells finally stabilised and since, feed water has consistently been of good quality. It is good to point out that this state of affairs occurs, even though the area is highly fissured and drawdown from the wells is nil in most cases.

The membranes had their problems too. Salt passage was initially higher than specification in about 20 per cent of them. These were replaced under warranty.

After a few months operation, salt passage through the membranes started to increase. Long and thorough investigations were carried out by the membrane and plant supplier to try to control this phenomena. At one stage, the problem was blamed on biological activity in the feed water, specifically on algae-type marine creatures identified as diatoms. A high diatom content was found in the cartridge filters when these were examined. Since these creatures require sunlight for growth, the feed water system was painted and otherwise rendered opaque to sunlight. Some improvement in salt rejection was recorded by a programme of chemical cleaning and post-treatments.

Decrease in permeator flow was another troublesome phenomenon met in the first months of operation. Some of this was traced as being due not to membrane fibre deterioration but due to core movement inside the shell and subsequent internal damage. At present, microbiological fouling is also being blamed for some of the decline. Permeator design modifications have been carried out which hopefully are eliminating the first two causes while some of the flux decline has been recovered by suitable repairs. Guaranteed design flow has been restored through permeator additions.

At an early stage of plant life, a third problem with the permeators was met. A number of permeator shells split in service. This was traced to water hammer in the system and not through any inherent faults in the shells. Better operation procedures designed to eliminate air from the system were instituted and this problem was soon solved and is no longer cause for concern.

Apart from the more serious difficulties already mentioned, there were some less serious problems with some of the smaller auxiliaries. While the large turbopumps gave excellent service, there was some excessive pitting corrosion in the impellers of the well and boost pumps. This has not yet been explained. Again localised pitting corrosion in the 316 L stainless steel mainfolds and permeator fittings was the cause of their replacement after about two (2) years life. Alternative connection methods have reduced this corrosion.

Having said all this, it is fair to record that the Lapsi Reverse Osmosis Plant has now reached its fourth year of service and its performance has generally been satisfactory through the technical and financial efforts of the plant and membrane suppliers, the plant generally met and in some cases exceeded the guarantee levels of production. Thus, expansion at the original Lapsi Plant and the construction of a new plant at Tigne, on the limits of Sliema, utilising basically similar components were undertaken with confidence. The new plant has only been in service for four (4) months and performance is satisfactory.

5. REVERSE OSMOSIS - WATER COST

At this stage, it may be useful to comment on the cost of water of the Lapsi Plant to the Malta Government.

Reference (2) gave some figures and these are now given from the point of view of the Government of Malta. It is considered helpful to add some explanation as to the method of working and parameters used, otherwise the exercise would be meaningless and of no help in predicting costs in other situations or as use for comparative purposes. This has to be done since standard methods of cost calculation for the various plant/processes do not exist.

Capital cost

The capital cost of the complete process plant was approximately seven million Malta Liras (Lm 7,000,000). This included membranes, plant, pipelines, electrification works and others.

By selective amortisation (plant - 20 years life membrane - 6 years life and civil works - 50 years, and an average interest rate over the life of the plant of 5 per cent) an annual charge on capital of about eighty-five Maltese cents (85c) per one thousand (1,000) gallons (19 cents/m^3) is arrived at.

The method employed is summarised in the formula:

$$p = \frac{P_r (1 + r)^n}{(1 + r)^n - 1}$$

Where "r" is interest rate
"n" is component life (in years)
"P" is the initial capital cost
"p" is the annual charge

Energy consumption

All inclusive energy consumption (i.e. including wellfield) has been 27 kw hrs/1,000 imperial gallons (6.1 kw hrs/m^3). Since the real cost to the country where the electricity is generated varies, mainly according to the type and cost of the fuel being used, at any particular time it is impossible to predict an average cost over plant life. A cost of three cents five mills (3c5) per kw hr is taken as average for the last years, so energy component of water cost has averaged ninety-four cents per one thousand gallons (94c/1,000 gls), twenty-one cents three mills per m^3 (21.3c/m^3).

Other

Operation, maintenance and other minor costs are of the order of fourty-five cents per one thousand gallons (45c/1,000 gls), ten cents per m^3 (10c/m^3) (about 50 per cent of the capital charges). These include chemicals consumed, spares, and others.

Total water cost to the Malta Government from Lapsi Seawater Reverse Osmosis Plant is thus of the order of two Malta Liras, twenty-five cents per one thousand imperial gallons (Lm 2.25c/1,000 imp gls), fifty cents per m^3 (50c/m^3).

Note:

at time of award of contract - Lm 1 (100 cents) = 2.4720 US$
at present - Lm 1 (100 cents) = 2.6453 US$

6. BRACKISH WATER REVERSE OSMOSIS

In Malta, there is also a brackish water reverse osmosis plant which treats highly brackish water (13,000 to 17,000 ppm) to potable standards. This plant is attractive mainly because of its energy consumption relative to the seawater reverse osmosis plant, since energy consumption of the reverse osmosis process is related to feed water salinity. The plant flowsheet is described in Reference (1). Some points are mentioned here and commented upon.

The plant exploits, as feed water, the coastal discharge at one of the more significant drainage areas on the Island, at Marsa. This brackish water occurs when water from the freshwater lens, slowly but steadily migrating laterally towards the coast, mixes with seawater that infiltrates through the pores and fissures in the rocks. It becomes more and more brackish until it discharges to the sea at one of the coast drainage points.

Marsa Reverse Osmosis Plant treats feedwater with Total Dissolved Solids (TDS) ranging from below 11,000 to 17,000 ppm depending on the season and rainfall. The plant uses seawater type membranes and runs at over 70 per cent recovery. It is therefore designed in a three-pass configuration.

In winter time, Marsa reverse osmosis is plagued with feedwater problems. SDI rises to above 3 and is highly unsteady. This phenomenon has been under investigation for some time and only lately, has it been better understood. Two separate causes have been identified that contribute to this stage of instability. Both are rain-related. One is ordinary sand and silt which is drawn up with the well water in view of the terrain immediately surrounding the boreholes. It has been observed that even slight but sudden fluctuations of the level of the water table caused by variations in pumping or tidal effects adversely affect the SDI. Treatment for this type of interference is large and expensive and it has been judged only feasible to install it for use during a short period of the year.

The second mechanism that has been identified as being co-responsible for SDI level is bacteriological activity in the system. Minute traces of iron are present in the feed water. Certain types of bacteria that feed on this metal are multiplying and causing the iron to precipitate in the system. It is thought that by suitable dosing of complexing agents and bactericides, this can be controlled. Work is proceeding along these lines.

It is hoped that once this problem is cleared, the availability of Marsa reverse osmosis will increase. It must be said that the Marsa harbour is a highly industrialised area, most of the feedwater wells are in a shipbuilding yard, and thus feed water quality must be closely observed in order to ensure membrane safety against possible contaminates in the feed water.

7. CONCLUSION

It is hoped that the account of desalination experiences in Malta will be found useful to others involved in or considering desalination. This paper out of necessity has had to be brief and selective in the aspects it has tackled.

8. ACKNOWLEDGEMENTS

I wish to thank the Honourable Prime Minister and the Parliamentary Secretary (Water) for permission to use information included in the paper, but otherwise all opinions are my own. Dr Godwin Debono of the Water Works Department has assisted with hydrogeological matters.

9. REFERENCES

1. Andrews & Bergman, The Malta Seawater R.O. Facility.

2. Andrews & Bergman, Update on first two year operation.

3. UNDIC Seminar, Supplying the Maltese Islands with water, Bermuda, December 1985.

4. Polymetrics Inc., Unpublished reports on Ghar Lapsi R.O. plant operation.

REUTILISATION AGRICOLE DES EAUX USEES A L'ILE DE MAJORQUE (ESPAGNE)

par

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R E S U M E

L'île de Majorque a une extension de 3.626 km^2. Sa population stable est de presque 600.00 habitants. On cultive 205.000 ha, dont 19.200 sont irriguées et produisent principalement des pommes de terre, cultures maraîchères et fourrages. Le tourisme est très important; les séjours enregistrés durant 1984 montèrent à plus de 54 millions. Cette population touristique s'établit surtout sur la côte et se concentre sur les mois de juin à septembre.

Les demandes d'eau ont été évaluées en les chiffres suivants (millions de m^3/an):

Population stable: 60; Tourisme: 20; Agriculture: 210

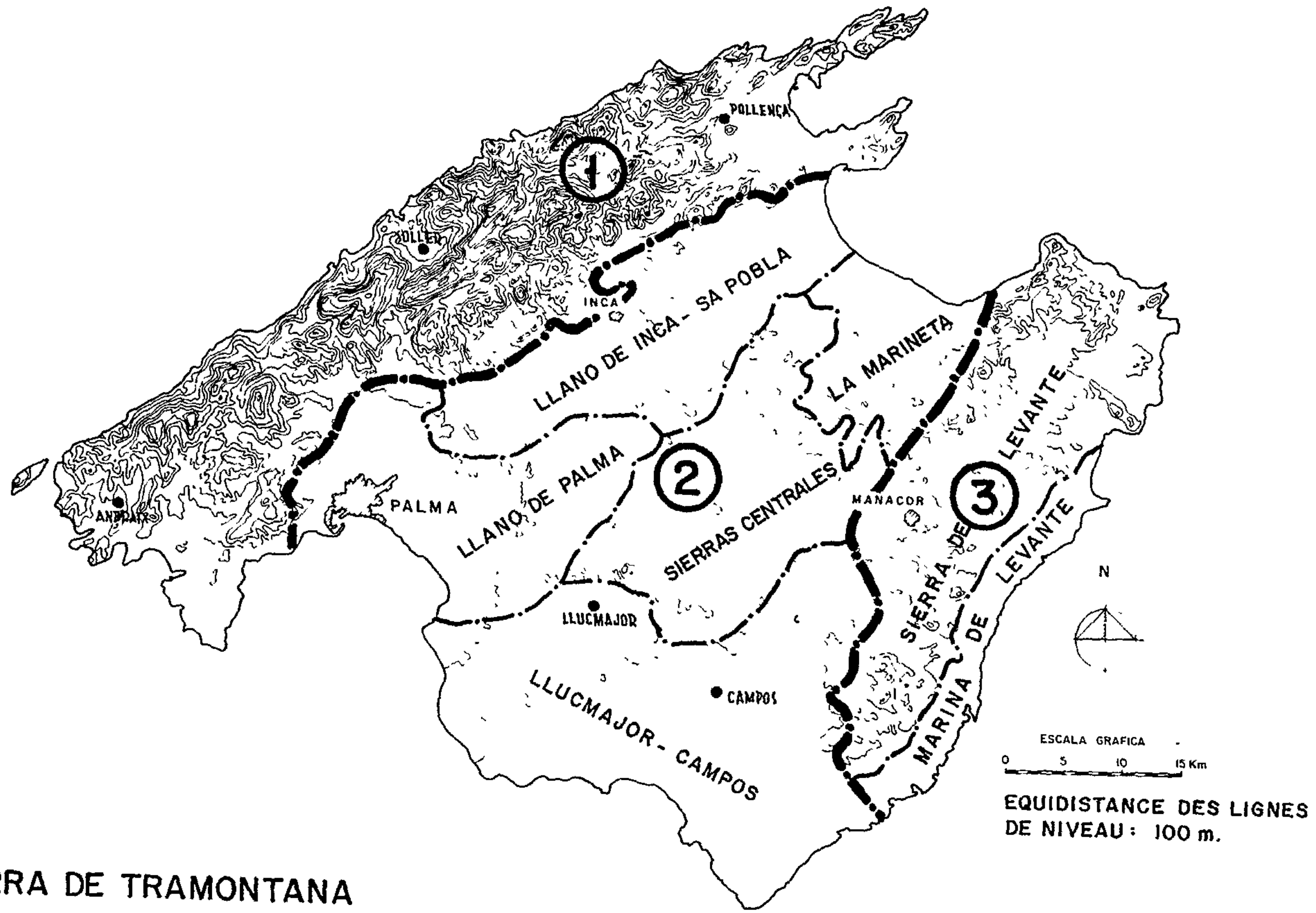
A Marjorque il n'y a pratiquement pas d'eaux superficielles. Les ressources souterraines sont exploitées au 85% environ et l'on enregistre, dans plusieurs zones, des baisses permanentes du niveau piézométrique et quelques processus de pénétration d'eau de mer dans les nappes aquifères. Il en ressort l'intérêt d'intégrer l'usage des eaux résiduaires urbaines dans le cadre de l'économie hydraulique globale de l'île de Majorque.

Actuellement, 416 ha distribuées sur sept zones, sont déjà irriguées avec des eaux résiduaires épurées avec de bons résultats et sans avoir constaté d'effets nocifs sur la santé des agriculteurs et non plus sur les nappes aquifères. La zone du Pla de Sant Jordi est la plus importante; on irrigue là environ 200 ha avec les eaux épurées en provenance de la station Palma I. Grâce à cela, non seulement on a sauvé l'agriculture de cette zone, vouée à l'abandon à cause de la salinisation croissante des eaux de puits, mais de plus on a amélioré son rendement. Il s'agit primordialement de cultures de luzerne et d'autres fourrages qui nourrissent du bétail bovin laitier.

On est en train d'encourager la réutilisation agricole des eaux usées. Par exemple, les eaux résiduaires épurées provenant de la nouvelle station Palma II seront profitées pour améliorer l'irrigation sur d'autres 1.300 ha du Pla de Sant Jordi et on envisage de les envoyer aussi à la Zone de Campos, à quelques 40 km de distance. Au même temps, on devra faire des études, retrospectives et prospectives, et démarrer des programmes de surveillance et de contrôle.

1. INTRODUCTION

L'île de Majorque est la plus grande de l'Archipel des Baléares. Sa surface est de 3.626 km^3, son sommet le plus élevé atteint 1.445 m et la longueur de ses côtes est de 554 km (Fig.1).



① SIERRA DE TRAMONTANA

② LLANOS Y SIERRAS CENTRALES

③ SIERRA Y MARINA DE LEVANTE

Fig. 1
MORPHOLOGIE

Le climat de l'île est typiquement méditerranéen, avec des hivers doux et des étés longs. Les pluies (Fig.2) ont lieu surtout en automne et au printemps; leur valeur moyenne annuelle est de 630 mm, mais on constate d'importantes variations selon les différentes zones de l'île, des 400 mm de la région plate du sud-est jusqu'aux 1.600 mm des hauts sommets du nord-ouest.

Dans ce rapport, on donne une notice sur la situation actuelle des éléments qui produisent les demandes d'eau (population stable, tourisme et agriculture), sur les ressources en eau et sur le bilan hydraulique de l'île.

Tenant compte du pourcentage d'exploitation des ressources en eau déjà atteint, il devient clair l'intérêt de l'usage agricole des eaux résiduaires épurées. Puisque, de plus: le caractère saisonnier de la consommation urbaine coincide avec celui de la demande agricole, les volumes d'eaux résiduaires récupérables représentent du 20 au 25% de la demande agricole actuelle et il s'agit d'eaux urbaines qui ne présentent pas en un degré appréciable de contenus d'origine industrielle.

Il existe déjà actuellement certaines réalisations intéressantes, telles que celles du Plan de Sant Jordi, Palma Nova-Santa Ponça, Felanitx, Ses Salines, S'Arenal, Inca et Pollença, qui sont référées dans ce rapport, et l'on espère améliorer et étendre à d'autres zones la réutilisation en agriculture des eaux urbaines épurées.

2. LA SITUATION HYDRAULIQUE

2.1 Géomorphologie et Hydrologie

Dans l'île de Majorque on peut distinguer, de façon schématique, trois grandes unités géomorphologiques (Fig.1), qui ont des conditions hydrologiques bien definies:

(a) La "Sierra de Tramontana" (Chaîne du Nort)

Chaîne montagneuse importante, de direction sud-ouest nord-est, qui conditionne complètement la côte nord-ouest de l'île et un peu dans d'un quart de sa surface (elle occupe environ 1.100 km^2). Elle constitue une région abrupte, aux accès difficiles, avec quelques vallées intérieures abritées et accueillantes. Sa population est de 65.000 habitants environ.

La "Sierra de Tramontana" est formée de terrains secondaires et tertiaires (calcaires, calcaires dolomitiques, dolomies, marnes et argiles) avec quelques remplissages quaternaires (conglomérats et limons). La structure géologique de ces matériaux est très complexe; leur alignement général est sud-ouest nord-est, avec des pendages de préférence vers le sud-est, des forts plissements et même des chevauchements, outre d'importantes failles aussi bien longitudinales que transversales.

Tout cela donne lieu à de nombreuses nappes aquifères, de nature essentiellement calcaire et en général assez indépendantes les unes des autres. Ces nappes se déchargent par des sources (surtout sur le versant nord-ouest), par flux souterrain dans la mer et par flux souterrain vers les "plaines centrales".

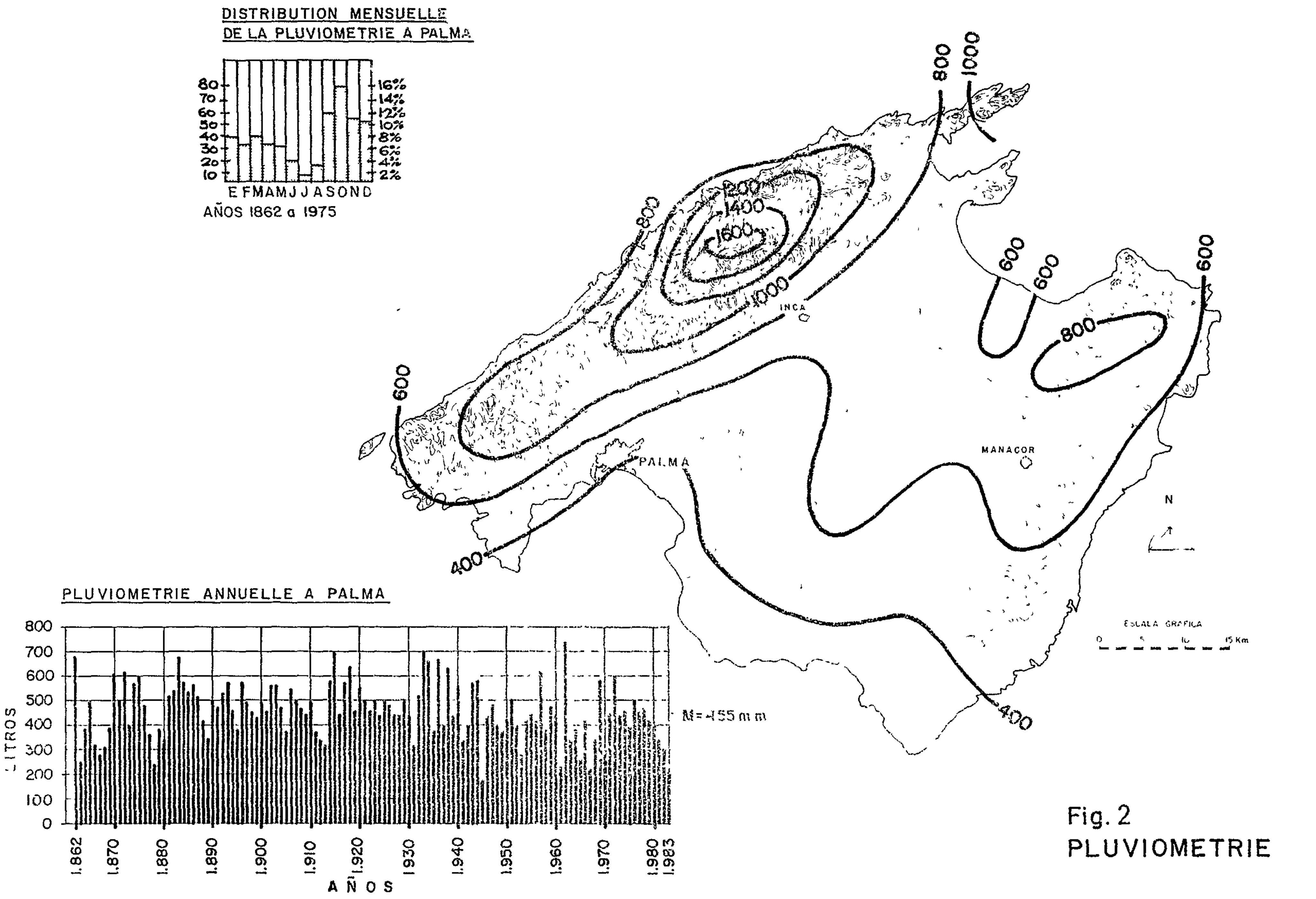


Fig. 2
PLUVIOMETRIE

(b) La "Sierra de Levante" (Chaîne du Levant)

Chaîne montagneuse semblable à celle du Nord, mais avec des structures moins développées et une topographie plus douce. Son alignement général est aussi sud-ouest nord-est et, adossée à son flanc oriental, il y a une plateforme miopliocène où prédominent les matériaux calcarénitiques et récifaux ("Marina de Levante").

Les sommets les plus élevés de cette chaîne ont 500 m d'altitude environ. La surface de l'ensemble, chaîne et "marine", atteint autour de 700 km^2 avec une population de 60.000 habitants environ.

Dans la "Sierra de Levante" on retrouve les caractéristiques de compartimentage en unités aquifères indépendantes ou presque indépendantes typiques de la "Sierra de Tramontana". La plateforme miopliocène adossée ("Marina de Levante") constitue une unité plus ou moins homogène avec une disposition allongée et parallèle à la ligne de côte.

(c) Les "Llanos y Sierras centrales" (Plaines et chaînes centrales)

Entre la "Sierra de Tramontana" et la "Sierra de Levante" s'étendent des terres basses et essentiellement plates. Sauf un secteur de petites montagnes dont les sommets ne dépassent pas les 300 m d'altitude, le reste a un relief doux et des hauteurs de 150 m tout au plus. Sa surface totale est de 1.800 km^2 environ (à peu près la moitié de l'île) et sa population atteint autour de 450.000 habitants. Il faut signaler trois secteurs spécialement importants: la Plaine d'Inca-Sa Pobla, au nord; la Plaine de Palma, à l'ouest; et la Zone de Campos, au sud.

Les plaines centrales sont formées par plusieurs cuvettes de subsidence remplies de matériaux postalpins (tertiaires et quaternaires), surtout de conglomérats, marnes, calcarénites, calcaires récifaux, limons, argiles et graviers. Certains affleurements de calcaires dolomitiques et marneux du socle secondaire donnent lieu aux nommées "Sierras Centrales".

C'est dans les cuvettes des plaines centrales où se trouvent les nappes aquifères les plus importantes de l'île de Majorque.

2.2 Population stable

La population stable de l'île était, en mars 1984, de 572.232 habitants, dont 311.197 correspondaient à la commune de Palma. Le reste se distribuait parmi 52 communes, dont 10 avaient moins de 1.000 habitants, 23 en avaient entre 1.000 et 5.000, 11 entre 5.000 et 10.000, 6 entre 10.000 et 2 entre 20.000 et 30.000 (Fig.3).

Nous avons donc une importante concentration de la population à Palma et ses alentours, avec d'autres pôles secondaires à Manacor et Inca.

2.3 Tourisme

L'activité touristique constitue actuellement le moteur principal de l'économie de Majorque.

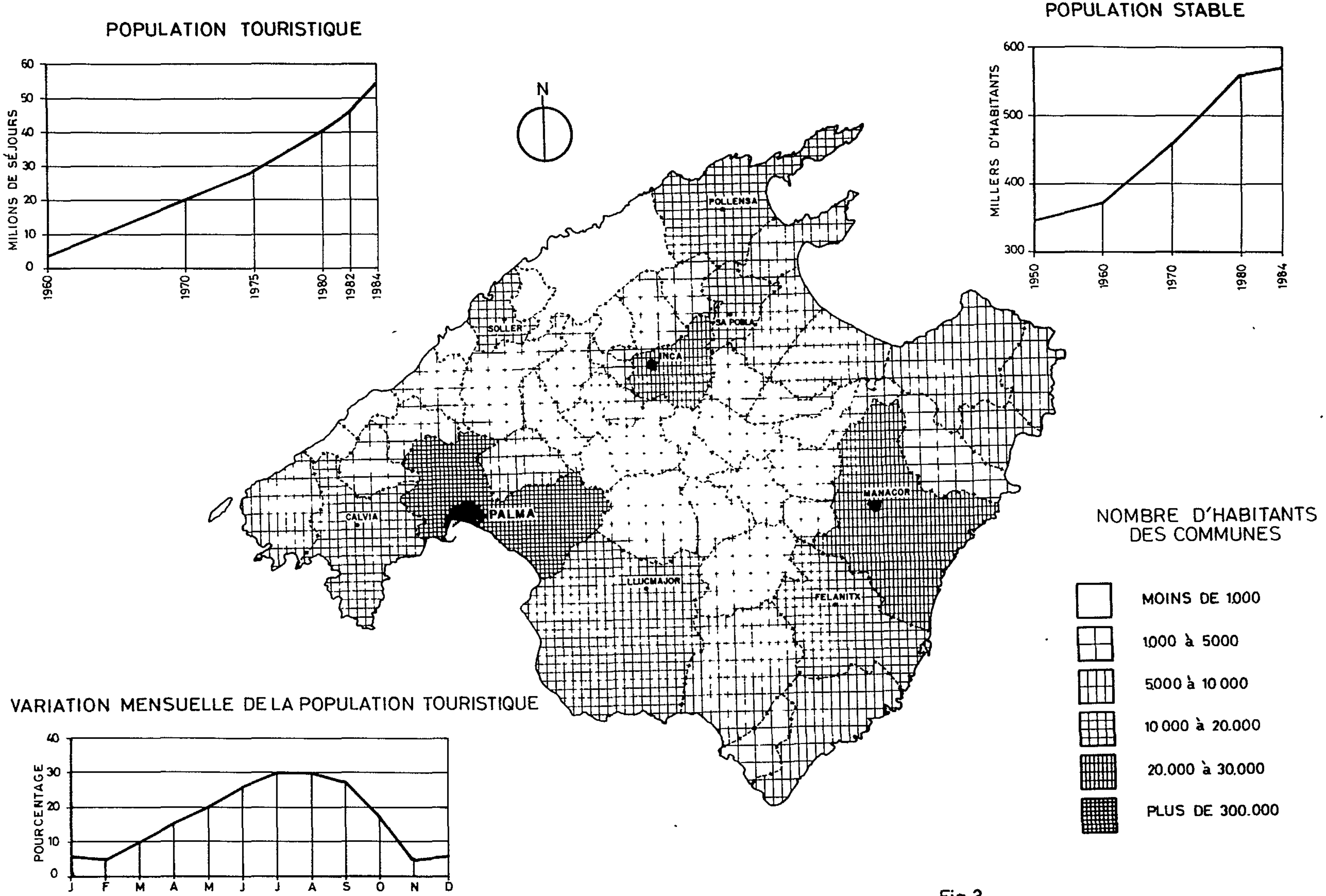


Fig 3
POPULATION STABLE ET TOURISTIQUE

Bien que la vocation touristique de Majorque soit ancienne, c'est pendant les années 60 que commence le processus d'expansion qui se déroule encore aujourd'hui (Fig.3).

L'évolution du nombre de voyageurs logés à l'hôtel fut la suivante (en milliers):

Année	Voyageurs	Année	Voyageurs
1960	446	1981	3.065
1965	960	1982	3.489
1970	1.852	1983	3.568
1975	2.765	1984	3.807
1980	2.781		

Actuellement, (les chiffres sont pour 1984), les séjours touristiques enregistrés sont les suivants:

A l'hôtel	40.509.927
En appartements, chalets et autres logements	13.561.216
Total:	54.071.143

Le séjour moyen à l'hôtel est à peu près de 10 jours et dans des appartements, chalets et autres logements, de presque 18 jours.

Au sujet de cette population touristique, il faut remarquer son caractère fortement saisonnier et sa distribution sélective. Ces deux questions ont une grosse importance par rapport à la localisation, dans le temps et dans l'espace, des demandes d'eau que cette population engendre et des rejets d'eaux résiduaires qu'elle produit.

Le caractère saisonnier de la population touristique se traduit par les pourcentages mensuels suivants:

janv.	fév.	mars	avr.	mai	juin	juil.	août	sept.	oct.	nov.	dec.
3	2,5	5	8	10	13	15	15	14	9	2,5	3

Quant à sa distribution géographique, on peut affirmer que la population touristique se concentre sur la côte. Voici les pourcentages de cette distribution par secteurs:

Côte de Palma	Côte de Tramontana	Baies de Pollença et Alcudia	Côte de Levante
63	1	13	23

2.4 Agriculture

Des 205.000 ha cultivées actuellement à Majorque, on n'en irrigue que 19.200, parmi lesquelles 5.000 environ obtiennent deux récoltes par an.

Les principales cultures sont la pomme de terre, les cultures maraîchères et les fourrages. Dans certaines zones dont les eaux se sont salinisées à la suite de la sur exploiration de leurs nappes aquifères (comme la Plaine de

Palma et la zone de Campos), les possibilités agricoles se sont réduites presqu'exclusivement à la culture de la luzerne, qui est en rapport avec l'établissement de l'élevage dans ces zones, un élevage surtout centré sur l'exploitation de la vache laitière.

Les techniques d'irrigation les plus pratiquées sont l'épandage par sillon et l'aspersion.

La dose moyenne per hectare irriguée, dans les zones qui possèdent des eaux de bonne qualité, est de 7.000 m^3/an environ, et elle atteint de 10.000 à 14.000 m^3/ha an dans les secteurs où l'on arrose avec des eaux saumâtres.

2.5 Demandes d'eau - ressources en eau

La population stable, le tourisme et l'agriculture que l'on vient de décrire, donnent lieu à des demandes d'eau évaluées selon les chiffres suivants (en milions de mètres cube per an):

Population stable	Tourisme	Agriculture	Total
60	20	210	290

Pour satisfaire ces demandes, Majorque ne dispose pratiquement que de ressources en eaux souterraines. Il n'existe pas de cours importants d'eau superficielle. Il n'y a d'eau en permanence ou presque en permanence que dans certains lits avant leur embouchure; cependant, ces eaux ne sont pas à vrai dire "superficielles", mais souterraines affleurant au dehors à la suite du drainage des nappes aquifères produit par le lit même. Les seules véritables eaux superficielles sont celles que retiennent les barrages du Gorg Blau et de Cuber, situés tous les deux dans la "*Sierra de Tramontana*", avec un total de 5 à 10 millions de m^3/an qui sont destinés à l'approvisionnement de la zone urbaine de Palma. A part l'usage de ces eaux, qui ne couvrent que 25% des besoins du secteur de Palma et moins de 5% de ceux de l'île, le reste des eaux utilisées à Majorque sont des eaux souterraines et leur utilisation se fait presqu'entièrement au moyen de puits (sauf quelques sources).

La quantification des ressources en eaux souterraines qui sont exploitables et de celles qui sont déjà en exploitation, dans chacune des trois grandes unités géomorphologiques décrites brièvement à l'épigraphe 2.1 sur la Fig.1, se reflète dans le Tableau I.

Tableau I

Infiltration et ressources en eau (10^6 m^3/an)

	Sierra de Tramontana	Llanos y Sierras Sierras Centrales	Sierra y Marina de Levante	Total
INFILTRATION				
-des précipitations	125	160	60	345
-des ruisellements d'eaux de surface	-	35	-	35
RESSOURCES				
-Profitables:superf.	25	-	-	25
- :souter.	55	165	25	245
-Déjà profitées:sup.	10	-	-	10
- " " :sou.	45	150	20	215

D'autre part, la Fig.4 présente une schématisation de leurs bilans hydrauliques respectifs, ainsi que celui de l'ensemble de l'île. Remarquons que les chiffres du Tableau I représentent des "ressources nettes", tandis que sur la Fig.4 ils correspondent aux "demandes satisfaites", c'est-à-dire à des extractions réelles des nappes aquifères; c'est pour cette raison que l'on donne sur cette Fig.4 la valeur de la réinfiltration des excédents d'irrigation et des fuites d'eau dans les réseaux de distribution.

Nous pouvons constater que:

(a) Le bilan hydraulique global dans la Chaîne du Nord ("Sierra de Tramontana") est fortement positif. Cependant, ses conditions géologiques et topographiques rendent très difficile l'utilisation des ressources en eau, ce qui fait qu'il ne semble guère possible d'accroître leur exploitation en plus de 10 millions de m^3/an environ. Dans la région sud-occidentale, on observe quelques processus de pénétration d'eau de mer (Fig.5).

(b) Pour les Plaines et Chaînes centrales ("Llanos y Sierras Centrales"), le bilan est également positif dans l'ensemble, mais il y a des zones surexploitées où l'on enregistre de considérables pénétrations d'eau de mer (Fig.5). Ceci devient spécialement important dans le cas des nappes aquifères de la Plaine de Palma et de la Zone de Campos, tandis que la Plaine d'Inca-Sa Pobla est excédentaire.

(c) Pour la Chaîne et la Marine du Levant ("Sierra y Marina de Levante"), le bilan global est aussi positif, mais les ressources supplémentaires à exploiter ne sont que de l'ordre de 5 millions de m^3/an.

Quant aux eaux superficielles, on doit ajouter que la construction de nouveaux barrages de régulation ne peut se faire que dans la "Sierra de Tramontana". En plus des barrages du Gorg Blau et de Cûber, des recherches ont été effectuées au sujet de l'emplacement d'autres barrages dont la capacité totale de régulation s'estime en 10-20 millions de m^3/an.

Comme résumé de tout ce qu'on vient d'exposer, on peut dire que dans l'île de Majorque le rapport entre les ressources en eau déjà exploitées et celles qui peuvent l'être atteint déjà des valeurs très élevées: 85% environ pour l'ensemble du territoire insulaire et plus de 100% pour certaines zones.

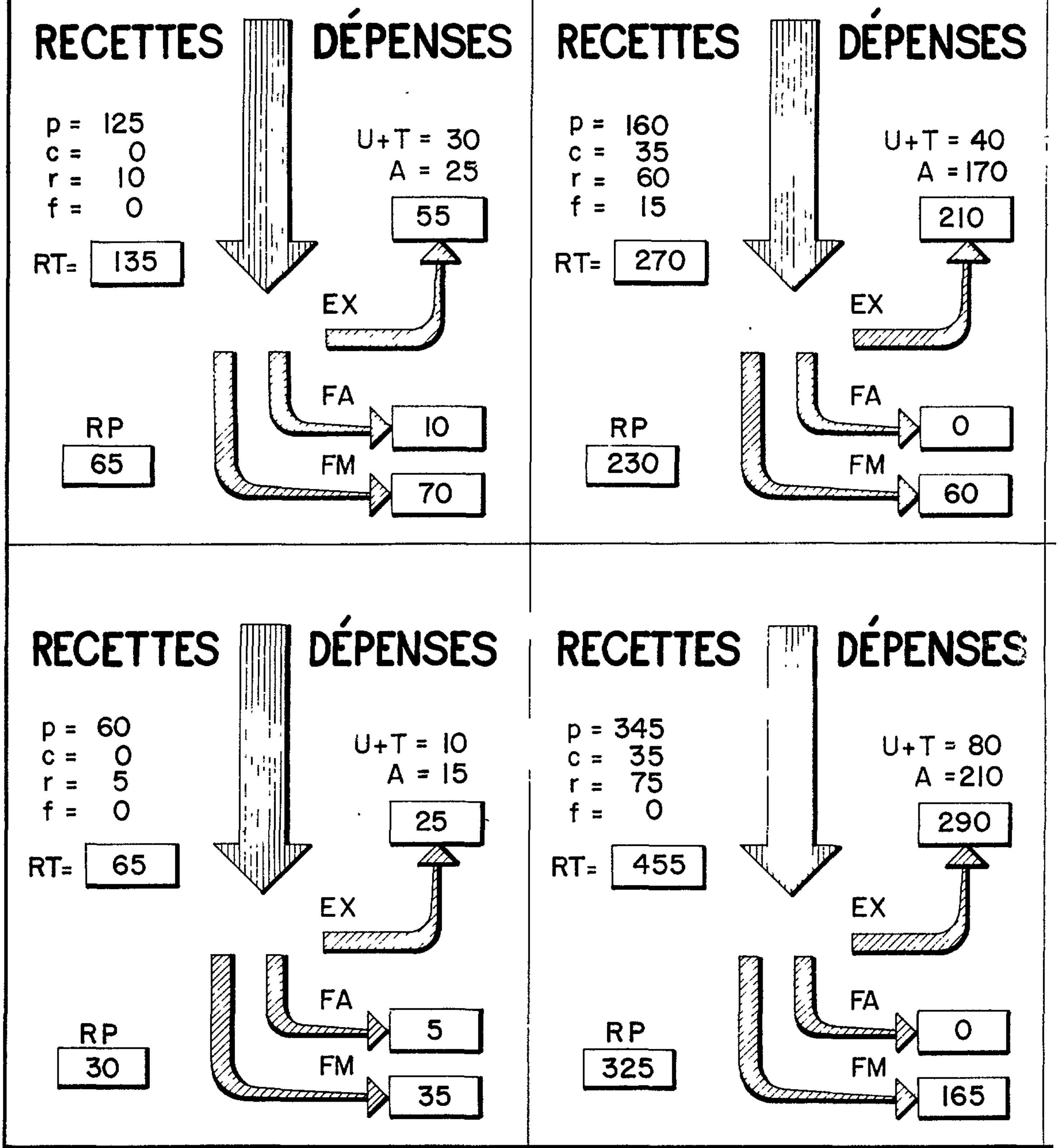
3. FACTEURS GENERAUX FAVORABLES A LA REUTILISATION AGRICOLE DES EAUX USEES

3.1 Le bilan hydraulique

Comme on l'a vu au chapître précédent, les ressources hydrauliques de l'île de Majorque sont déjà fortement exploitées.

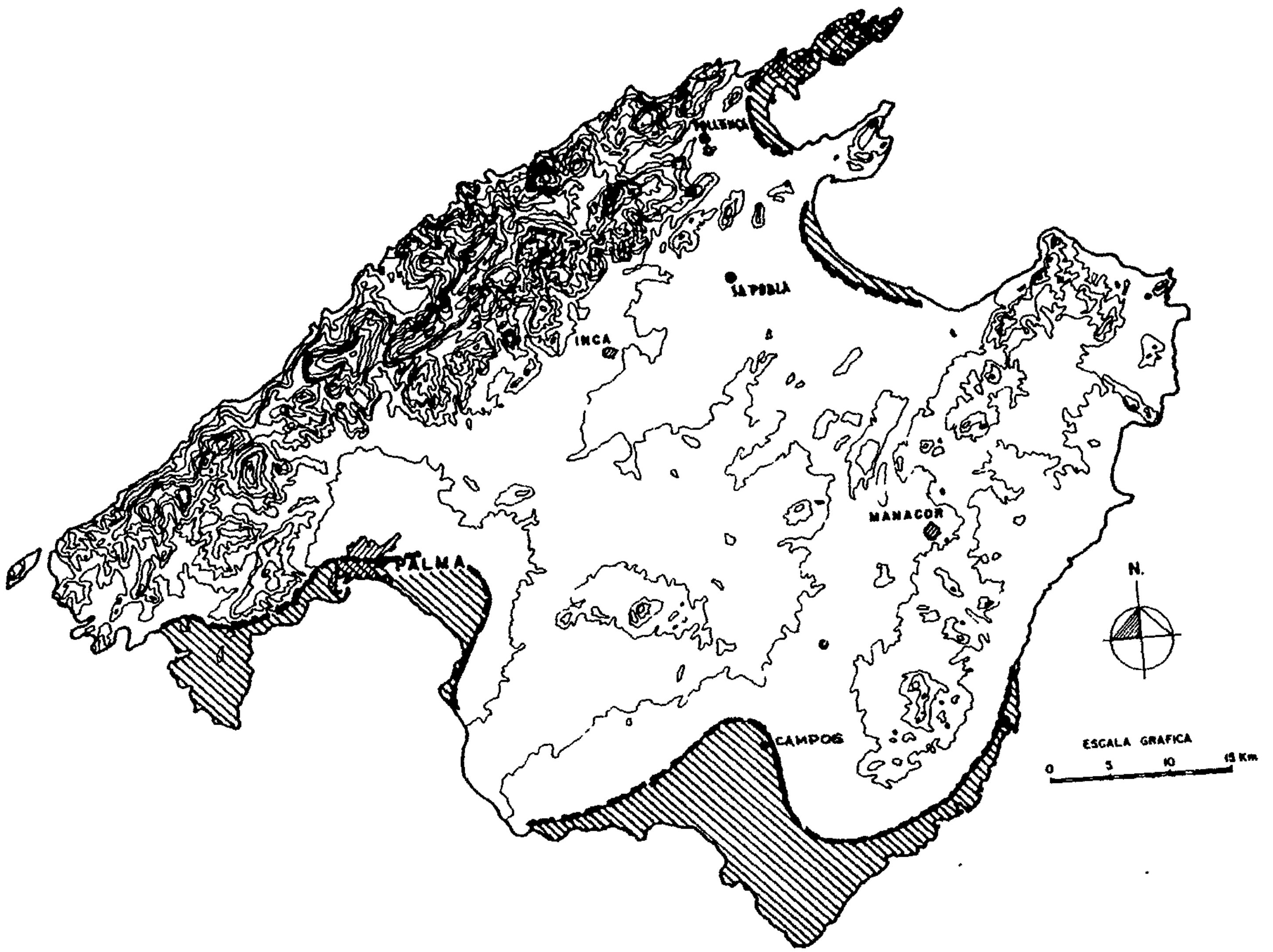
Ce fait entraîne:

(a) L'apparition de quelques processus de pénétration d'eau de mer, qui ont provoqué la salinisation de certaines nappes aquifères, en les rendant ainsi non aptes à l'usage de l'homme et réduisant leurs possibilités d'usage agricole (Fig.5, 6 et 7).



p = INFILTRATION DIRECTE DES PRECIPITATIONS
c = " DES RUISELLEMENTS SUPERFICIELS
r = " DES EXCÉDENTS D'IRRIGATION ET DES FUITES DES RESEAUX DE DISTRIBUTION
f = FLUX SOUTERRAIN PROVENANT DE NAPPES AQUIFÈRES VOISINES
FA = " " VERS DE NAPPES AQUIFÈRES VOISINES
FM = " " VERS LA MER
EX = EAUX EXTRAITES
U = " DEMANDÉES PAR LA POPULATION STABLE
T = " " " LE TOURISME
A = " " " L'AGRICULTURE
RT = RECETTE TOTAL
RP = " PROFITABLE

Fig. 4



ZONES OÙ L'INTRUSION D'EAU
DE MER EST IMPORTANT
$Cl^- > 1000$ mg./l.

Fig.5
INTRUSION MARINE

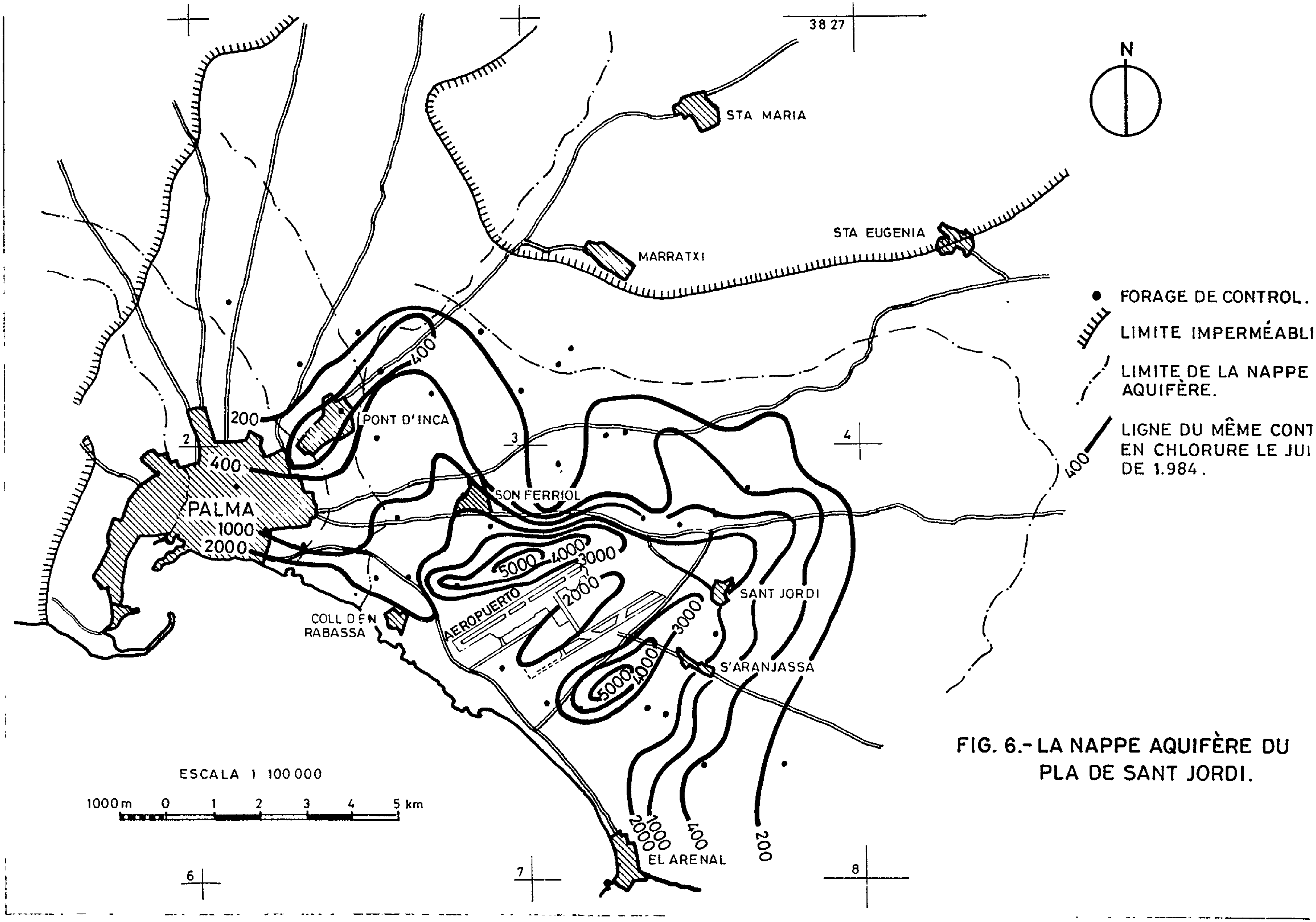


FIG. 6.- LA NAPPE AQUIFÈRE DU PLA DE SANT JORDI.

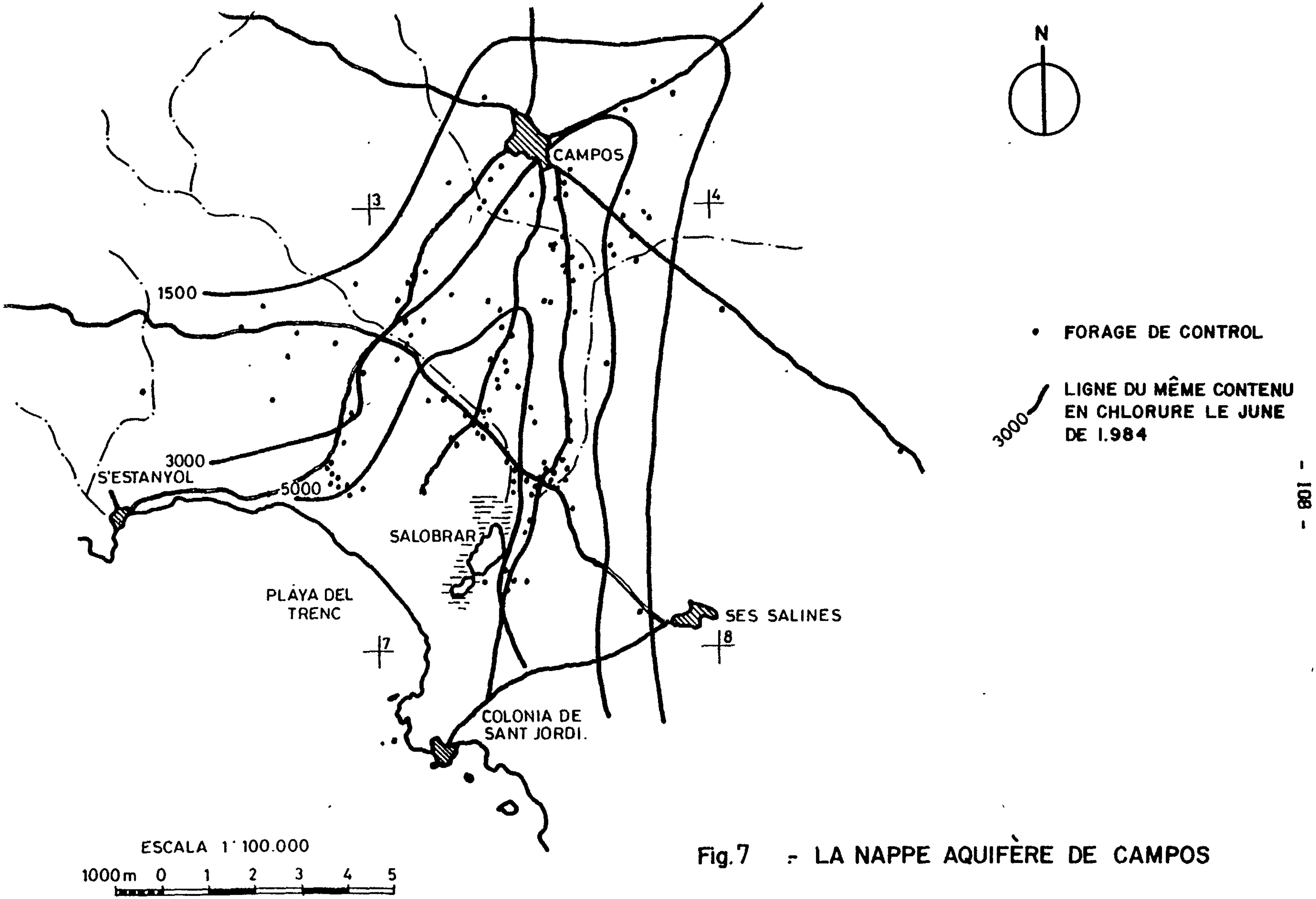


Fig. 7 - LA NAPPE AQUIFÈRE DE CAMPOS

(b) Le coût élevé des ressources additionelles, puisque leur mise en exploitation exige des travaux de plus en plus coûteux et leur extraction devient d'autant plus chère que la profondeur de pompage augmente.

Par conséquent, la réutilisation agricole des eaux urbaines usées doit être envisagée dans le cadre d'une économie hydrique globale. D'une part, son coût peut être compétitif par rapport à certains ressources additionelles de premier usage et, d'autre part, l'exigence et la surveillance quant aux risques de pollution des nappes aquifères pourront se réduire ou même devenir superflues quand ces nappes aient des eaux de mauvaise qualité.

3.2 Volumes récupérables

Il faut souligner les volumes d'eaux résiduaires utilisables pour l'approvisionnement agricole à Majorque:

Palma et ses alentours

Il existe aujourd'hui deux stations d'épuration à boues activées: Palma I (Sant Jordi) et Palma II (Son Puig), toutes les deux situées dans la zone de l'aéroport (Fig.8). Palma I traîte environ 20.000 m^3/jour pendant l'été et autour de 5.000 m^3/jour pendant l'hiver. Palma II a une capacité de 30.000 m^3/jour et on y effectue actuellement des travaux d'agrandissement qui augmenteront sa capacité à 90.000 m^3/jour.

Le volume d'eaux résiduaires traitées dans ces stations d'épuration est aujourd'hui de 3 et 10 millions de m^3/an, respectivement. Quand l'ampliation de Palma II commencera à marcher (été 1987), elle traitera de 30 à 35 millions de m^3/an.

D'autres communes

Indépendamment des stations d'épuration des hôtels et des petites agglomérations, on doit remarquer qu'il existe plusieurs localités qui disposent de stations d'épuration municipales dont les effluents ont ou peuvent avoir de l'intérêt pour l'agriculture:

Commune	millions m^3/an	Commune	milions m^3/an
Calviá:	3,5 - 4,5	Felanitx:	1,0 - 1,5
Manacor:	2,0 - 3,0	Capdepera:	0,5 - 1,0
Llucmajor:	2,0 - 2,5	Andraitx:	0,5 - 1,0
Inca:	1,5 - 2,0	Pollença:	0,5 - 1,0

Il s'agit donc d'un total de 10-15 milions de m^3/an.

Résumé

On doit souligner que les 40-50 millions de m^3/an d'eaux résiduaires urbaines qui pourraient être employés pour l'agriculture à Majorque représentent le 15-17% des ressources exploitables de l'île et le 20-25% de la demande agricole actuelle.

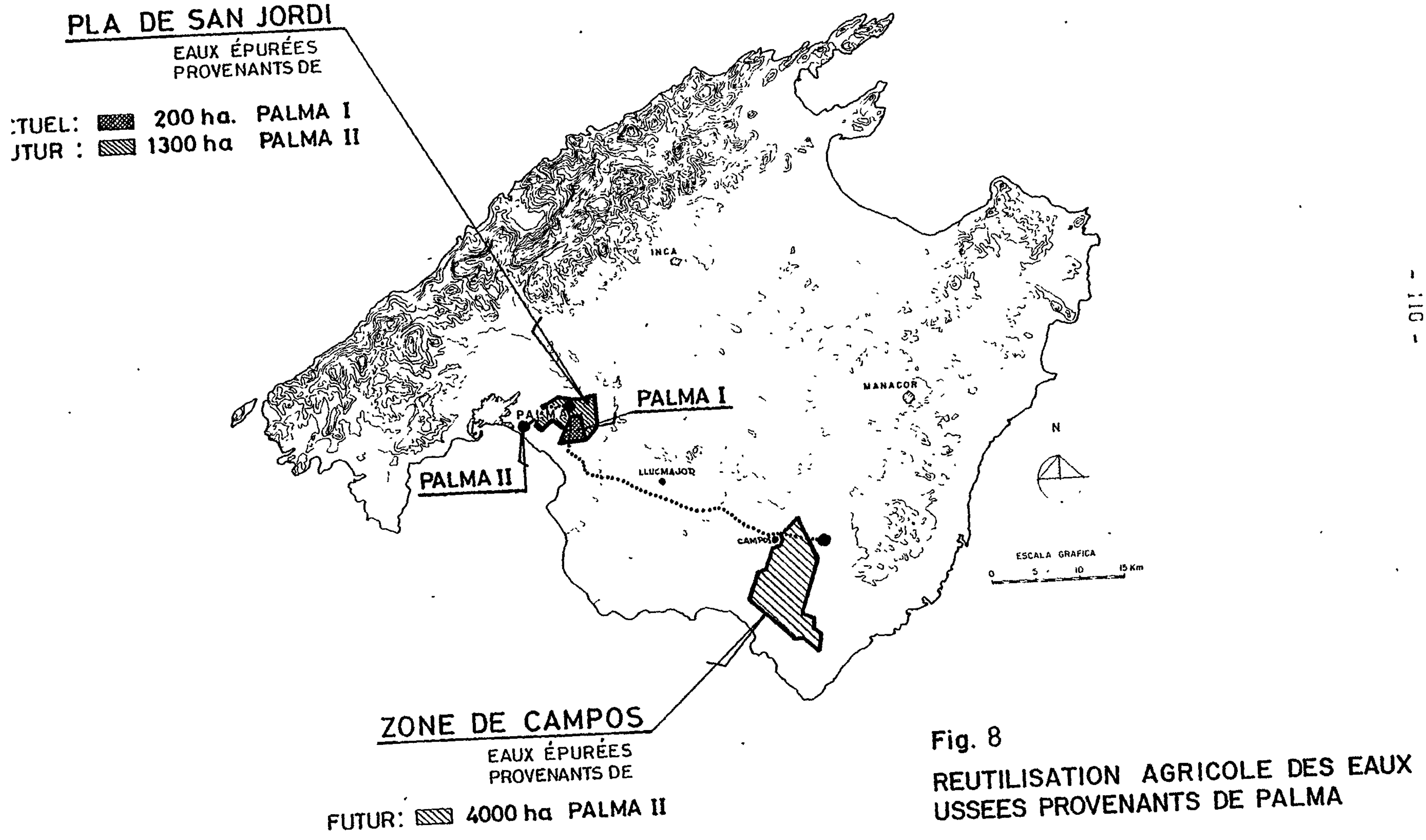


Fig. 8

REUTILISATION AGRICOLE DES EAUX USSEES PROVENANTS DE PALMA

3.3 La qualité des eaux residuaires

A Majorque, il n'existe pas d'activité industrielle importante, raison pour laquelle ses eaux résiduaires ne présentent pas de contenus remarquables en métaux lourds. Il s'agit dans tous les cas d'eaux typiquement urbaines.

Les plus grandes difficultés pour leur réutilisation en agriculture peuvent dériver des contenus en clorure sodique et en nitrates. Par exemple:

Selon IRYDA (1982), les valeurs moyennes (m) et la déviation typique (d), trouvés sur 30 échantillons, ont été les suivantes:

		Cond. Elec.	Solides Totaux	Cl^-	HCO_3	SO_4	Ca^{++}	Mg^{++}	Na^+
Palma I	m	3,85	2.740	863	480	200	77	48	490
	s	0,50	375	102	120	52	9	17	135
Palma II	m	3,72	2.500	854	575	237	71	27	502
	s	0,72	455	223	85	102	31	7	71

Et selon EMAYA (été 1985), on a trouvé ces valeurs moyennes:

	Cond. Elec.	Solides Totaux	Solides dissous	NH_4^+ (en N)	PO_4^{3-} (en P_2O_5)
Palma I s/.8 échantillons	6,66	4.330	4.290	42(32)	25(15)
Palma II s/.4 échantillons	7,53	5.150	5.110	34(27)	37(27)

Le besoin d'améliorer la qualité chimique (diminuer les clorures) des eaux résiduaires de Palma pour les destiner à l'usage agricole est un facteur de plus à l'appui de l'amélioration nécessaire de ses eaux d'approvisionnement.

4. REALISATIONS ET PROJETS

4.1 Stations d'épuration de Palma

Irrigation actuelle

La station d'épuration Palma I reçoit les eaux qui proviennent d'une frange littorale de 3 km environ de longueur, avec une population essentiellement touristique, une présence hôtelière importante et sans aucune implantation industrielle.

Quand en 1971 cette station d'épuration commença à marcher, les eaux traitées étaient versées dans le lit d'un cours d'eau publique. Mais, étant donné que sa pente était très peu prononcée et qu'il n'avait de débit proprement dit que les jours de pluie, on dut cesser de l'employer à cette fin et verser les eaux dans plusieurs puits d'absorption qui furent construits près de la station même. Mais il apparut aussitôt l'alternative possible de l'usage de ces eaux pour l'irrigation agricole, vu que la qualité chimique des eaux souterraines qu'on avait employées jusqu'alors pour l'irrigation des terrains du "Pla de Sant Jordi" (prochains à la station d'épuration) se détériorait progressivement.

Le "Pla de Sant Jordi" est un secteur qui possède de longue date une agriculture d'irrigation. Les eaux utilisées provenaient d'un grand nombre de puits creusés, d'où on les extrayait au moyen de pompes mues par des moulins à vent. Une fois extraite, l'eau se gardait dans un bassin situé auprès de chaque puits, et de là on la distribuait jusqu'aux parcelles de cultures par des rigoles.

Mais à partir des années 60, on installa des équipes de pompage mûs par des moteurs électriques et de plus on fora de nouveaux puits. L'extraction d'eau pour irriguer augmenta progressivement. D'autre part, les extractions pour l'approvisionnement urbain de Palma s'accrurent également, aussi bien dans les mêmes nappes aquifères du Pla de Sant Jordi que dans d'autres nappes voisines qui présentaient un écoulement souterrain vers les premières. Par conséquent, en diminuant sa recharge souterraine et en augmentant les extractions, le bilan hydraulique du Pla de Sant Jordi devint négatif et déclencha un processus de pénétration d'eau de mer. L'utilisation agricole des eaux épurées à la station de Palma I s offrit alors comme une alternative intéressante, qui de plus réglait le problème de l'élimination de ces eaux.

On construisit un petit réservoir de charge et un réseau de distribution. Celui-ci est en fibrociment; il est enterré dans des tranchées et possède un diamètre moyen de 150 mm et une longueur totale de presque 20 km. Le comptant de l'inversion réalisée (1973-1975) fut de presque 25 millions de pesetas.

La surface couverte par le réseau de distribution atteint presque les 300 ha, mais il n'y en a que 200 ha qui reçoivent leur irrigation effective depuis 1975.

La remise de l'eau à chaque propriété s'effectue en la versant dans l'ancien bassin (auprès de l'ancien puits) qu'elle possède. La répartition se réalise au moyen de la mise en marche manuelle des clés de distribution respectives par le personnel de surveillance, selon des services de jours et d'heures établis auparavant. Ce personnel vérifie et règle le débit d'accès dans chaque bassin.

Le système d'arrosage plus usé est l'aspersion.

Les terres sont formées par un quaternaire limoneux qui repose sur des formations pliocènes de conglomérats.

Les cultures qui s'y font sont essentiellement: la luzerne, le maïs à fourrage, la pâture du Soudan, le ray-grass italien et le trèfle d'Alexandrie. On consacre à la luzerne plus de 60% de la surface occupée; dans le reste on obtient deux récoltes annuelles en alternant les autres cultures.

Toutes ces cultures servent d'appui à un troupeau bovin laitier d'environ 600 têtes. Les propriétés ont, la plupart, une étendue de 5 à 6 ha avec 15 à 20 vaches. On obtient environ 5.000 l/an de lait par vache.

Quant aux résultats obtenus en cette expérience de plus de dix ans d'irrigation aux eaux résiduaires, on peut dire, d'après les renseignements fournis par la Communauté de Cultivateurs ayant droit d'arrosage, que:

(a) Les champs de luzerne permettent des coupes tous les 20-25 jours.

(b) On obtient autour de 15 tonnes/ha x an de luzerne.

(c) Le nombre de têtes de bétail par hectare a doublé (et en certains cas triplé), tout en passant de 1-1,5 à 2,5-3 tête/ha.

(d) Le fumier des vacheries, qui s'employait auparavant comme engrais dans les propriétés mêmes, se vend à présent aux agriculteurs d'autres zones. On ne se sert pas d'engrais azotés, on ajoute seulement quelques apports de phosphate et de potasse.

On n'a pas détecté d'effets négatifs sur la santé des agriculteurs ni sur les terres et les eaux souterraines. Il faut reconnaître que des études systématiques n'ont pas été faites sur ces sujets-là, exception faite de quelques contrôles de la salinité des eaux souterraines qui, dans l'ensemble, a subi une certaine amélioration dans le secteur irrigué. On doit observer que la détérioration de l'eau d'approvisionnement de Palma, qui s'est produite au cours de ces quatre dernières années, a coïncidé avec une période de sécheresse et on peut penser que ses possibles effets négatifs n'ont pas encore pu se manifester. En tout cas, il est évidemment nécessaire de réaliser des études aussi bien rétrospectives que prospectives, qui permettent une quantification des paramètres les plus significatifs.

Irrigation future

La station d'épuration Palma II reçoit les eaux de la ville de Palma et ses alentours. On amplie actuellement cette station et quand cette ampliation sera mise en service on disposera d'environ 30-35 millions de m^3/an d'eaux résiduaires épurées.

Sur cette base, il existe le projet de (Fig.8):

(a) Améliorer l'irrigation du Pla de Sant Jordi: nouveau réseau de distribution pour 1.300 ha avec système de service automatisé.

(b) Améliorer l'irrigation de la Zone de Campos: conduite de 40 km, reservoir de régulation et réseau de distribution pour 4.000 ha.

4.2 D'autres cas

En plus du Pla de Sant Jordi, il y a à Majorque d'autres zones où les eaux résiduaires sont déjà employées pour l'irrigation. Dans toutes ces zones, on se sert d'eaux qui procèdent de stations d'épuration municipales, du genre des boues activées. Il s'agit en général de cultures de luzerne et de maïs, qui emploient ces eaux pendant l'été. Il n'y a en aucun cas de systèmes d'accumulation saisonnière, et quand les eaux ne sont point utilisées pour l'arrosage, elles vont à la mer au moyen d'émissaires sous-marins ou bien on les verse dans quelque lit de cours d'eau dans lequel elles circulent et s'infiltrent dans le terrain au long du parcours.

Ainsi, on peut nommer les cas suivants (Fig.9):

(a) A Palma Nova-Santa Ponça: on arrose 52 ha de terrains de golf.

(b) A S'Arenal: on arrose 40 ha de fourrages.

(c) A Sea Salines: on arrose 56 ha de maïs fourrager.

(d) A Felanitx: on arrose 31 ha de cultures veriées.

(e) A Inca: on arrose 27 ha de cultures variées.

(f) A Pollença: on arrose 10 ha de cultures variées.

On peut affirmir que, dans l'ensemble, les agriculteurs ne montrent pas de réticence envers l'usage des eaux résiduaires épurées. L'Administration a encouragé la réalisation de l'irrigation du Pla de Sant Jordi, mais dans tous les autres cas, les entreprises correspondent à l'initiative privée, sans appui et pratiquement sans contrôle des organismes officiels, exception faite, tout au plus, de la concession et l'enregistrement des prises d'eau.

Toutefois, on peut affirmer que les services de la nouvelle Administration hydraulique régionale, (lesquels fonctionnent dès juin 1985) sont conscients de cette situation et ils travaillent à la mise en marche d'un programme de surveillance et contrôle des réalisations déjà faites et de leur amélioration. De méme, compte tenu de ce qu'on exposait dans l'épigraphe 3.2, on est en train de prendre des mesures pour l'encouragement et l'appui de nouveaux systèmes de réutilisation agricole des eaux usées, avec la conviction que son intégration dans le cadre d'une gestion d'ensemble des ressources hydriques de l'île de Majorque offre un intérêt évident.

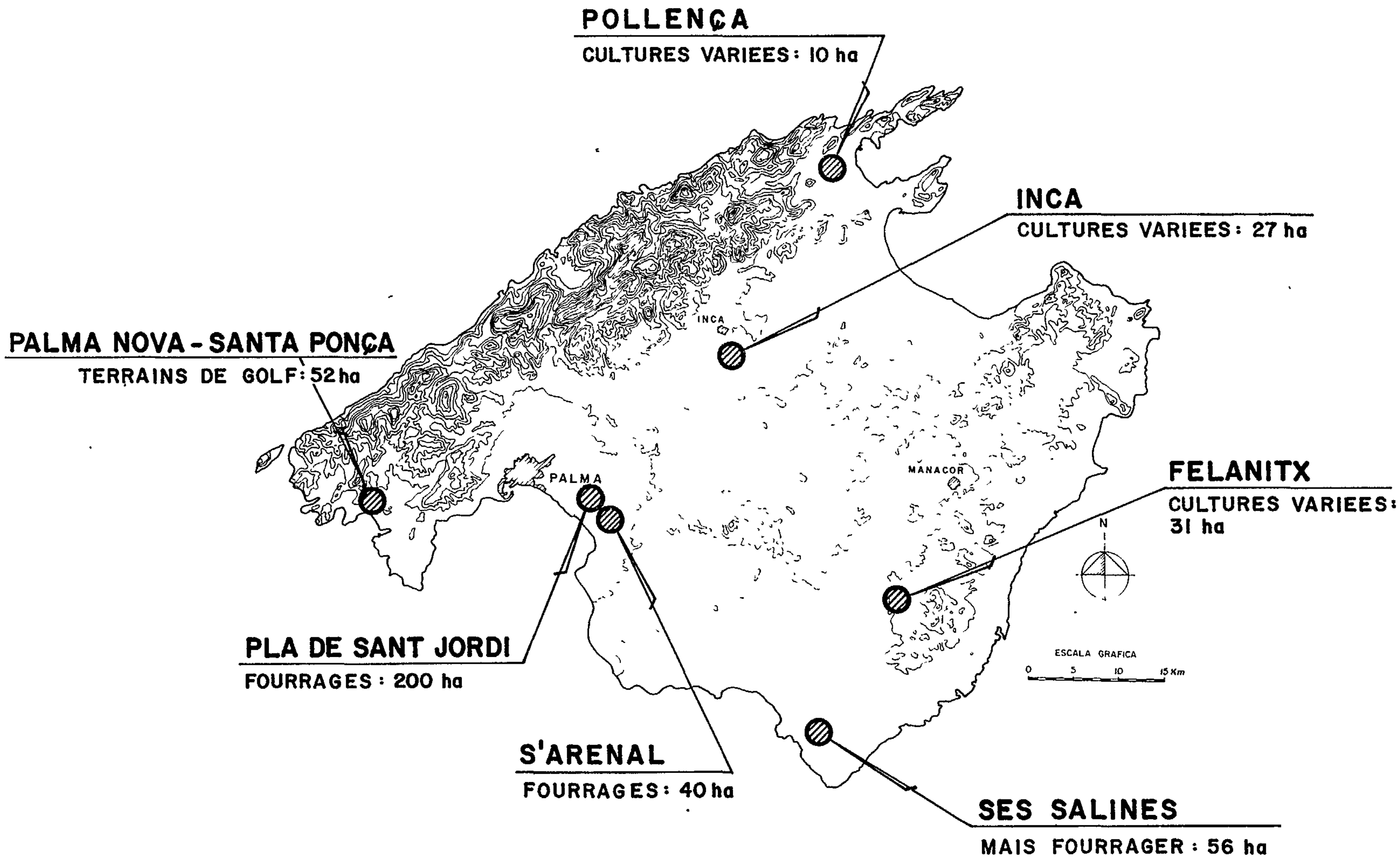


Fig.9
REUTILISATION AGRICOLE ACTUEL D'EAUX USEES

PART II

SANITATION IN LARGE MEDITERRANEAN ISLANDS AND ISOLATED COASTAL AREAS OF FLUCTUATING POPULATION CAUSED BY TOURISM

(CONTRIBUTION OF WHO/EURO)

PROTECTION OF WATER SOURCES FROM POLLUTION

by

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The close association between water pollution and health hazards has been recognised for thousands of years, and firm evidence now establishes beyond doubt that unwholesome water can and does spread certain diseases in many ways.

Understanding the mechanism of disease transmission through water is vital for establishing prevention policies and for defining optimal water treatment methods. In an attempt to define the links between the causes and the pathways of diseases through water, an arbitrary classification has been made to identify the role played by water. Generally speaking, all water-related infections are characterised by four different transmission mechanisms:

- water-borne diseases are those resulting from ingestion of a pathogen through water. However, such diseases are not limited to water and can also be transmitted by ingestion of the pathogen in various foodstuffs;

- water-based diseases are those caused by the pathogenic agents that spend part of their life cycle in water. This group of diseases has also been called "water-contact diseases", referring to the fact that the disease is transmitted through contact with pathogen- or toxin-infested water;

- water-hygiene diseases, also called "water-scarce", or "water-washed" diseases, refer to diseases whose incidence, prevalence and severity can be reduced by the use of enough water to permit improved domestic and personal hygiene; and

- water-related diseases, also called "water-related vector-borne diseases", are those spread by vectors spending part of their life cycle in water.

In addition to pathogen-polluted water, other health risks arise from human exposure to a wide variety of chemical products that enter drinking water in different ways. Industrialised societies increasingly rely on chemical products for routine daily activities, products which also find their way into water sources, polluting them with contaminants whose short or long-term health effects at different concentrations are still largely unknown.

Although the microbiological aspects of drinking water quality still remain of paramount importance, concern is growing about chemicals, i.e. pesticides, radioactive substances and heavy metals in water. However, as the epidemiological information available on the health effects of human exposure to these substances is still insufficient to determine with precision the "maximum permissible concentrations" or, as it has also been called, the "maximum acceptable level", the World Health Organization has proposed limits that act only as guideline values (Guidelines for Drinking Water Quality, Vol.I, WHO/GVA/1984). The levels recommended in the Guidelines are not standards in themselves; rather, they describe the quality of water suitable for drinking uses under all circumstances. They are intended as the basis of national standards developed according to national health and economic priorities. The final decision about what is considered an acceptable risk level, before adopting or rejecting a given guideline value, is the entire responsibility of each country, and it will depend on local factors.

Water sources are broadly classified into two main categories: "surface waters" (rivers, lakes, oceans) and "groundwaters" or subsurface waters. Most water constituents are of natural origin, resulting from physical and chemical interactions involving phenomena such as evaporation, precipitation, run-off and infiltration. However, chemical and biological reactions occurring in the soil and underlying strata may also affect water composition. Moreover, residues of domestic or industrial wastewater plants, together with agrochemicals, can find their way into water sources, thus adding new components. The composition of water, even after treatment, can also change as happens in piped water networks some of which may have been coated with materials such as tar, asbestos and epoxy resins.

The most important inorganic components of drinking water are dissolved substances consisting mainly of bicarbonates, chlorides, sulfates and nitrates of calcium, magnesium, sodium and potassium. The WHO Guidelines for Drinking Water Quality list 37 constituents of inorganic origin of potential health significance. Guideline values are given for arsenic, cadmium, chromium, cyanide, fluoride, lead, mercury, nitrate and selenium.

The Guidelines also list 21 organic constituents of health significance, setting values for 18 of them. However, as water constituents can affect the physical appearance of water (colour, odour, taste), and this appearance affects the perception of the consumer regarding the quality of the water, the Guidelines also examined several water characteristics and constituents affecting the aesthetic quality of water.

The implementation of an effective programme for the protection of water sources from pollution will depend on:

(a) correct identification of water pollutants in soil and in waters;

(b) identification of all sources of contamination, at specific places, (point sources) or of a diffused nature (non-point sources);

(c) identification of the mode of entry of pollutants into the aquatic environment;

(d) assessment of the concentration levels of pollutants and the variations in time of pollution loads;

(e) study of the adverse effect on human health of water pollutants at different concentration levels;

(f) adoption of a land-use code of practice to ensure that agricultural, forestry and industrial activities can reach optimal levels of production without endangering the quality of water resources;

(g) existence of adequate legislation to support adopted national guidelines, standards and codes of practices;

(h) investigation of groundwater rehabilitation techniques and cost-effective water treatment to eliminate undesirable contaminants in already polluted water resources that have to be exploited because of shortage of other sources.

The WHO Regional Office for Europe is involved in several projects aiming at protecting water sources from pollution.

In Portugal, with the financial support of the United Nations Development Programme (UNDP), pollution studies have been carried out in the Tagus River, whose headwaters are in Spain. Because of the multiple uses made of its waters in both countries, the Tagus River is, without doubt, one of the most important rivers in the Iberian Peninsula. Its estuary has been polluted by untreated sewage and major industrial discharges containing mercury, arsenic, cadmium and lead. The main river, with two-thirds of its catchment in Spain, could have easily constituted a source of transboundary pollution. However, thanks to adequate protection policies, at the point of entry in Portugal, the pollution levels of the Tagus River are relatively low. Within Portugal, the river system is monitored on a regular basis by the Water Pollution Control Directorate, a national institution belonging to the General Directorate of the Environment. Most of the pollution loads inside the Portuguese catchment area are of organic origin and are connected with agricultural and industrial activities (olive oil, distilleries, tanneries, paper pulp mills, etc.). The monitoring network has been operating for the last five years, and the project now aims at implementating a practical programme for optimising and coordinating river quality and river uses, including regulations of effluent discharges and polluter-pays policies.

Another intercountry project on controlling transboundary water pollution is due to start in January 1987. This project on "Water Quality Protection of the River Danube" will be supported by UNDP and executed by WHO, with the assistance of several associated agencies (Economic Commission for Europe, Food and Agriculture Organization of the United Nations (FAO), International Atomic Energy Agency and World Meteorological Organization). The countries participating in the activities are Austria, Bulgaria, Czechoslovakia, Federal Republic of Germany, Hungary, Romania, Yugoslavia and the USSR. Water from the Danube is used mainly for drinking and irrigation, but it also receives discharges of industrial and municipal wastes which are resulting in a lowering of water quality. The project aims at developing a common regional strategy towards effectively controlling pollution of this large international river which flows through countries with different socioeconomic systems.

A no-less-important project is also due to start in 1987, supported by UNDP and having WHO as the executing agency in association with FAO. The project is named "Land Use Practices and the Protection of Surface and Groundwater". It is a large project involving 24 countries: Albania, Algeria, Bulgaria, Czechoslovakia, Cyprus, Egypt, France, Greece, Hungary, Iran, Israel, Italy, Lebanon, Libya, Malta, Morocco, Netherlands, Poland, Portugal, Romania, Spain, Tunisia, Turkey and Yugoslavia. The above-mentioned countries, recognising the impact on the aquatic environment of industrial, agricultural and domestic activities which contaminate the soil with pollutants capable of reaching water resources, have agreed to establish a control programme dealing with point and non-point sources, so that surface and groundwater quality targets can be internationally respected in order to safeguard human health. The main output of the project shall be the production of an integrated regional land-use code of practice aimed at protecting water sources.

In Central and East Europe, a large proportion of the water used for drinking purposes is obtained from wells situated along river banks. These wells take advantage of the natural filtration capacity of the alluvial layers along the river -beds. However, although these systems have operated satisfactorily over the past years, providing, for example, water to cities such as Belgrade, Budapest, Bratislava and Vienna, the water is now contaminated with several pollutants such as heavy metals, organic materials and particularly with nitrates at levels close to the maximum WHO guideline value.

The European countries concerned with the protection of bankwell systems have adopted the following measures which have proved to be effective:

- protection of wells against contamination;
- control of industrial discharges in rivers;
- control of domestic sewage discharges;
- control of navigation (transport of hazardous wastes) to avoid accidental pollution;
- agreements among riparian countries on strategies to reduce point and diffused sources of pollution; and
- establishment of regular national and international water quality monitoring systems and of early warning systems in case of accidental pollution.

The above examples illustrate the concern of the countries with regard to the pollution of water bodies and the need to introduce and implement appropriate measures to halt the growing process of pollution, particularly pollution which is directly or indirectly caused by human activity and which endangers human health and leads to the deterioration of the aquatic environment. The United Nations agencies involved in projects related to environmental protection have responded positively to the problem and are actively engaged in developing activities at the national and international levels aimed at an integrated and multisectorial approach to protecting aquatic ecosystems.

An example of this collaboration between the UN systems can be found in the Programme of Protection of the Mediterranean Sea, in which several UN agencies (e.g. IMO, UNEP, UNESCO, WHO, WTO) are directly and indirectly providing support to the Programme.

This meeting, devoted to water and sanitation problems on big Mediterranean islands and in coastal areas with a large fluctuation in tourist population, will contribute to the analysis of the problems and to the formulation of appropriate recommendations for their solution. Our organisation, particularly UNEP(PAP/RAC) and the WHO Regional Office for Europe, are ready to participate in the implementation phase of the measures adopted.

We would like to thank the participants for having responded to our appeal of assisting in this meeting and wish all of you success in your professional endeavours.

HEALTH PROBLEMS RELATED TO WATER AND SANITATION SERVICES IN THE COASTAL AREAS OF ALGARVE

by

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1. INTRODUCTION

The Algarve, occupying all the south coast and a small part of the west coast of Portugal, has been, along the centuries, a region with its own characteristics, separated from the rest of the country by a mountain range and at about three hunderd kilometers from Lisbon, the capital of Portugal.

In the decade of 1960, this isolation began to be brocken by the phenomenon "tourism" and the land began to be shared by three groups of inhabitants with very different characteristics: residents, portuguese tourists and foreign tourists.

In the beginning, the touristic affluence was attracted by a climate of Mediterranean characteristics and by beautiful beaches streching along 215 kilometers of coast. However, the increase in this sector wasn't followed by the relevant infrastructures, the demand being greater than the supply, the quality of services provided was consequently deeply affected.

To give an idea of the dimension of the changes introduced by the tourism, it's sufficient to say that the residents are 324 000 (census of 1981) and that in the summer months there is an estimated increase of 500 000 persons (in 1984).

A quick adaptation to the touristic demand in today's Algarve was needed. The tourism and the activities connected with it became preponderant, competing for the attraction of manpower and of capital with other activities such as irrigated horticulture and mollusciculture, therefore weakening other otherwise relevant activities (fishing, industry, unirrigated horticulture).

In the absence of a correct and time-wise planning, the Algarve bacame a region needing water and sewage infrastructures. There is a water lack for which some responsability belongs to agricultural consumers and to touristic activities and there is a lowering of the freatic level and in the aquiferous there is a danger of pollution and of a serious invasion of salt water. Also, concerning the sanitation, there are deficiencies which could cause ruptures in some systems.

2. PROBLEMS CONCERNING HEALTH AND TOURISM

Although the conceptual model of the official and private structures of health services are the same in all Portugal, the existence of tourims in Algarve conditions the primary health care services and the hospital services, which have different characteristics of the rest of the country in what concerns the dimension of some services.

So, the health services must face the changes of population in the different seasons and its different needs. They must also pay attention to the direct and indirect influence that tourists bring to the residents life.

Some of the particularities of the Algarve's health services are:

a) No need to reinforce the ambulatory services during the high season.

b) A necessity to reinforce the emergency services in health centers and hospitals, which in the high season have a greater demand, particulary in low and medium level acute diseases. In August, the demand is 2.7 to 3.0 times greater than in low season.

c) The necessity to have a bigger network of ambulancies equipped for primary intervention and for distant evacuations (only to Lisbon).

d) The necessity of hospitals equipped for needs in much more quantity than those of the residents and apt to solve almost all of the urgent diseases and to prepare patients to evacuations by air to their countries of origin.

e) The great component of traumatologic diseases. Even the residents have mortality rates double than the other districts of Portugal.

f) The necessity to be always prepared for big accidents. An exemple is the "aircraft accidents emergency plan" of Faro airport and protection areas in which periodic simulations are carried out to test the operationality of all people and institutions involved. More than 2 millions passengers used Faro airport from JAN86 till OCT86.

g) The necessity to create and maintain routines for special operations in the public health area involving, if necessary, a covering simultaneously all Algarve.

h) The necessity to maintain acurate sanitary surveillance in hotels and similar establishements covering facilities and food hygiene.

i) The necessity of continuous epidemiological surveillance in some areas, for example cholera, malaria (the last indigenous case in 1957), kala-alzar.

j) The necessity for an environmental mosquito control program.

k) The necessity of sanitary control of water used for recreational purposes, for which we have a program since APR85 covering the beaches and since 1985 covering also aquatic amusement parks.

3. HEALTH PROBLEMS RELATED WITH DRINKING WATER SUPPLIES

One of the tasks of the health services in Algarve is the continuous sanitary surveillance of drinking water quality in public and semi-public supplies. Ther's a program started many years ago that nowdays monitors the residual chlorine and the bacteriological and chemical quality of the drinking water and has a simple frequency related to the population size.

The assessment of the residual chlorine is realized by sanitary auxiliary technicians, professionals working in all 16 health centers of Algarve and depending from the relevant local health authorities. The samples are made daily and the points are chosen according to the network design. The general recommendation is to maintain 0.2 mg/l in extremities of the distribution system, and if sometihing is wrong the exploitation responsable entity is advised.

The samples for bacteriological and chemical analysis are taken from distribution system and captations by sanitary auxiliary technicians and sent to the Public Health Laboratory of Faro, an official laboratory managed by our services.

To evaluate the microbiological quality of the drinking water in the distribution systems, we have a program for 230 monthly samples and detection of the following indicators:

a) Colonies in Plate Count Agar at 48 hours and 37 degrees C, per 1 ml

b) Coliform organisms, most probable number (MPN) per 100 ml

c) Faecal coliforms, MPN per 100 ml

d) Faecal strptococci, colonies per 100 ml (membrane-filtration technique)

e) Detection of Clostridia perfringens in 10 ml. This parameter is investigated only in captations and reservoirs.

In what concerns the chemical quality of the drinking water the routine program tests includes:

a) Organoleptics parameters:

- colour
- turbidity
- odour

b) Physical and chemical parameters:

- pH
- conductivity, in microSiemens/cm
- chloride, in mg/l of Cl
- sulfate, in mg/l of SO_4
- total hardness, in French degrees
- solids, total dissolved in mg/l (105 degrees C)
- alkalinity, in mg/l of HCO_3

c) Parameters related to undesirable constituents:

- nitrate, in mg/l of NO_3
- nitrite, in mg/l of NO_2
- oxidability, in mg/l of O_2
- hydrogen sulfide, in micro-g/l of S
- iron, in micro-g/l of Fe

d) Other parameters:

- sediment microscopy.

We must note that only the sanitary surveillance belongs to the health services and that entity exploiting the drinking water supply muste make sure that the water has the adequate quality to be consumed. Although in Algarve the water distribution is generaly the responsability of municipalities, they base their quality control on the tests made by the health services and only by exception use their own or third party resources.

It must also be said that almost all public and semi-public drinking water supplies used bored-holes or covered wells as captation. Concerning the water distribution systems networks, some of them have lots of years and need frequent repairs, but there are many new networks. The high rate of building construction creates the necessity of continuous repairs and amplifications of the distribution systems, and this kind of work is now the first cause of drinking water contamination.

During the last few years there have been lots of problems concerning drinking water with short, medium or long term effects such as:

3.1. Problems related with the chemical composition of drinking water

There is a progressive degradation of water supplies having severe consequences at medium or long term to the residents. In some areas the captations must be temporary or definitevely closed, without any other good alternative. The following parameteres are particulary affected:

a) Salinity

The chloride value is above 250 mg/l in 27.9% of the tests done in 1986, and in 5.2% it reached more than 1 000 mg/l. It must be said that the first cause of death in Algarve is cerebrovascular diseases.

b) Hardness

In the tests done in 1986 the following distribution was found:

- 10.0% with 100 or more French degrees
- 20.0% between 50 and 99 degrees
- 60.8% between 20 and 29 degrees
- 2.5% between 10 and 19 degrees
- 6.7% under 10 degrees.

c) Sulphate levels

Sulphate level is not a frequent problem, but sometimes was faound a cause-effect relationship with diarrhoea. In 1986, it was found more than 400/mg/l in 6.7% of the samples, with a maximum value of 1 780 mg/l.

d) Nitrates levels

In 65.5% of the samples the NO_3 value was above 10 mg/l, and in 7.6% above 100 mg/l.

3.2 Problems associated with bacteriological contamination of deinking water

Apart the high levels of salt in drinking water, the main problems are those associated with bacteriological contamination. Some programs for their control are being implemented. Examples of such problems are:

3.2.1 Typhoide and para-typhoide outbreaks

Outbreaks of these diseases with origin in drinking water have affected in the last years some small communities that use fountains. A few years ago there was an outbreak propagated by a public drinking water distribution system following some mistakes of the exploiting entity, and which affected a village of 647 inhabitants. During some years we have also had problems with para-typhoid B in a little touristic resort that had a very defficient sewage system.

3.2.2 Outbreaks with other contaminants

They are rare, but one of them appeared in Algarve in the summer of 1984, in the coastal area of the municipality of Albufeira. Its relevance to the Algarve life was so important that we think it's better to give some details of the occurrence.

On 30/AUG/84, several reports came advising that something abnormal was happening in Albufeira: an outbreak of diarrhea.

The control of the situation was assumed by the Health Authorities of Algarve and measures were taken to determine the extension of the oubreak, its origin and for treating large number of patients. Suspecting a hydric origin, the study of the drinking water supply system started, and big problems were detected, it has been sufficient to say that only one of the 22 captations has the chlorination pump working correctly.

Emergency chlorination of drinking water reduced immediately the number of patients with diarrhea. Meanwhile, the first results of the laboratory tests were coming and showed both, recent and old faecal contamination in almost all the systems, including the catching stations.

Although the public opinion was much more concerned initially with food hygiene, bad sewage systems in the area and effects in the beaches, the investigations showed an hydric source, the drinking water. A graphic document (fig. 1) tries to explain what happened, as it was observed in the emergency service of the Health Center of Albufeira.

To control this outbreak, a system of information based in many sources was set. It was concluded that the outbreak happened from 8/AUG/84 till 24/SEP/84 and it affected some thousands of residents, portuguese tourists and foreign tourists. The pathogenic agents identified were some Shigellas, Salmonellas, Campylobacter and Giardia.

Following the outbreak, an intensive program of sanitary surveillance covering all Albufeira area was implemented and the relevant entities were pressed to solve the problems of drinking water quallity and of sewage systems. As a result of program the endemic level of diarrhea in Albufeira on the years of 1985 and 1986 was reduced to about one third of the value found during the outbreak year. This statement is based in the revision of more than 150 000 clinical files of patients observed in the Health Center of Albufeira since 1982 (fig. 2, fig. 3, fig. 4, fig. 5).

The most important part of the program concerns control of the chlorination level and of bacteriological quality of the drinking water. Some work is also done in beach water control, environmental sanitary conditions, and as sewage treatment plants management. During the balneary seasons, effluents of the treatment plants draining to beach areas were chlorinated. This program needs a little number of people but they should be very motivated towards the task they must accomplish. Quantitative data concerning the work done in 1985 provided the following figures:

- 1 027 bacteriological drinking water tests
- 5 019 residual chlorine tests (fig. 6)
- 104 bacteriological beach water tests
- 110 bacteriologocal sewage treatment plant tests.

Since 1985, many cases of contamination have been investigated, and always we have found points of contamination near the consumers. We should note that in almost all cases with contamination confirmed by laboratory analysis, the residual chlorine was above 0.2 mg/l and the distance between the area of contamination and the consumer was short.

The above program also pretended and succeeded in the establishment of a good relationship with responsables and technicians of Albufeira's Municipality. The efforts they have made to solve correctly the problems and the lot of money spended. Today, Albufeira has a much better management of the drinking water distribution system and of the sewage systems, and some very good sewage treatment plants are completed or under completion, as well as submarine pipes for the outlets of treated effluents or for raw sewage. It is regretable that sometimes only after catastrophes problems related with drinking water and sewage disposal quality (the first time was during the 1971-1975 cholera pandemie in which Algarve was affected in 1974).

3.2.3 Legionnaires' disease

Some years ago, the first patients with legionnaires' disease appeared. The outbreak was associated with three hotels in one of the bigest touristic resorts. The program to control the disease gave good results and the last case was about one year ago and it happened during a breakdown in a chlorine pump used to reinforce the desinfection of the water in one of the hotels. The control program implemented was based in super chlorination of the drinking water in the hotel buildings, in the use of high temperatures for hot water and in hygienic measures in the showers. An alert was made to the doctors working in the city and in a nearby hospital, but we have no cases amongst the 6 195 residents living in the resort.

There were also reports of 3 patients with legionnaires' disease but aparently not related with this outbreak, and the epidemiological inquires were inconclusive.

3.2.4 Contamination without health problems

The sample routine made by the Health Department detects monthly several cases of faecal contamination of the drinking water, most of them in the consumer and not at the captations. The investigations, with few exceptions only, always find the cause-effect relationship with water related diseases, and in almost all the cases the origin of the contamination is found and the problems are solved.

4. SANITATION IN ALGARVE

In sanitation, the Algarve is going progressively from a stage without sewage treatment plants to the existence of efficient sewage systems, sometimes using submarine pipes for treated or untreated sewage.

In OCT85 there were 32 municipal sewage treatement plants in operation, designed to cover 194 800 inhabitants. There were also 8 private plants more, with a total capacity for 25 500 people.

All that time there were plans (at project level or at a construction stage) for new construction of enlargement of 38 sewage systems, designed for a population of more 463 574 inhabitants.

The larger number and greater capacity of the sewage systems is found in the coastal area, the one with the higher density of residents and receiving the majority of the touristic flow.

Most of the sewage plants drain to the sea and the remaining to water bodies. In what concerns situations affecting the human quality of life we have detected some cases of risk due to unauthorized use of effluents for irrigation or discharge of low quality effluents too close of beaches.

Considering the sea as a receiving medium, it should be remembered that Algarve is bathed by the Atlantic Ocean which has purifying capacities and pollution levels very different from the Mediterranen Sea.

In spite of the efforts to improve the disposal conditions of domestic sewage, sometimes serious problems in urbanizations, hotels, touristic complexes, etc. are found, and which are caused by incorrect discharges (for example, raw sewage going to water streams or to the countryside creating sewage lakes). The breeding of mosquitos in areas were there are open field discharges of sewage or when there is an overflow of septic tanks caused by a bad design not covering the high season demands, is also frequent.

The program of control of water quality in the beaches, started in APR84 and allowed to detect some pollution problems and to push on the works to solve them. In 1986 every beach of first and second class, and every beach were could exist some risk of pollution plus other beaches not classified and without risk of pollution were also included in the program giving a total of 38 beaches.

The routine examination of bathing water consists in the detection of:

a) Coliform organisms, most probable number (MPN) per 100 ml
b) Faecal coliforms, MPN per 100 ml
c) Faecal streptococci, colonies per 100 ml (membrane-filtration technique)
d) Salmonnella, MPN per 100 ml. Only on exceptional cases.

The anlyses of the 1986 results, interpreted jointly with the results of previous years, and made according to the 76/160/EEC directive, make us to have some worries about the bacteriological quality of the bathing water in two beaches in the Albufeira area, in Lagos Bay and in the mouth of Odeceixe river.

The problems are due to the following causes:

- illegal conncection of domectic sewage to rain-water drains;
- existence of a sewage treatment plant discharging just a few meters away from the low-tide line;
- total absence of treatment for the sewage system of Lagos with its 10 241 residents (a new sewage system with a designed treatment capacity for 100 000 persons, is under construction);
- and finally, a discharge of a treatment plant into the Odeceixe river, at about 3 km from the beach, without tertiary treatment.

Several measures have been taken to solve above-mentioned problems, such as: improvement in some sewage systems and treatment plants, construction of submarine outfalls for treated sewage (600 mts pipeline), and chlorination of effluents of tretment plants. This last method appeared to be efficient and at low cost but it demands permanent attention.

5. REFERENCES

The data presented is from the Regional Health Administration and some of them belong to the Algarve's Regional Planning Office, based on figures of the 1981 census.

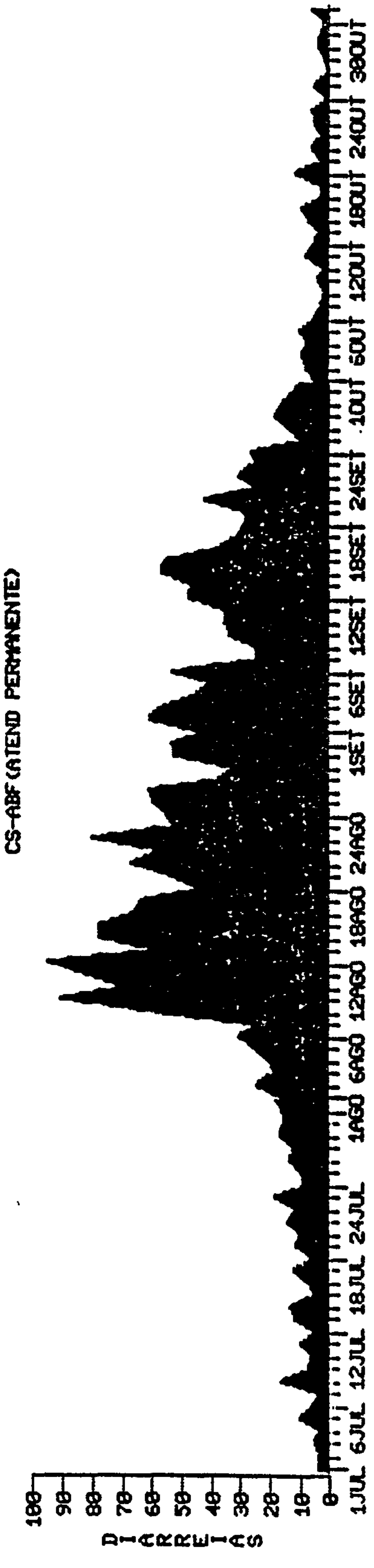

CS-ABF (ATEND PERMANENTE)
DIARREIAS
100
90
80
70
60
50
40
30
20
10
0
1JUL 6JUL 12JUL 18JUL 24JUL 1AGO 6AGO 12AGO 18AGO 24AGO 1SET 6SET 12SET 18SET 24SET 1OUT 6OUT 12OUT 18OUT 24OUT 30OUT

FIGURE 1

	DIARREIAS
JAN	29
FEV	26
MAR	28
ABR	26
MAI	45
JUN	98
JUL	224
AGO	432
SET	416
OUT	141
NOV	51
DEZ	34

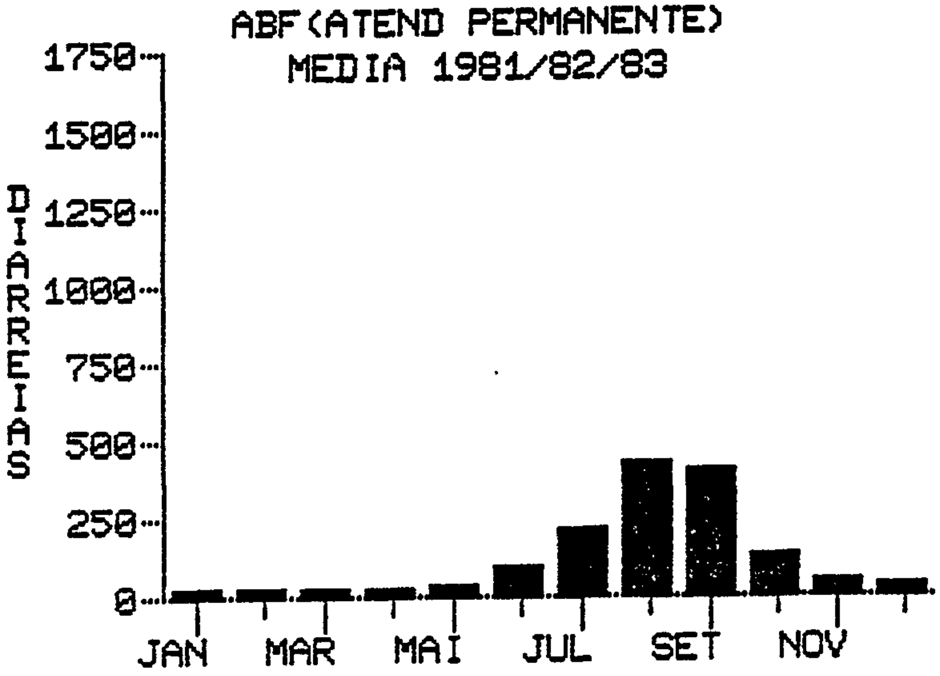


FIGURE 2

	DIARREIAS
JAN	34
FEV	49
MAR	60
ABR	108
MAI	87
JUN	120
JUL	309
AGO	1633
SET	1004
OUT	153
NOV	55
DEZ	44

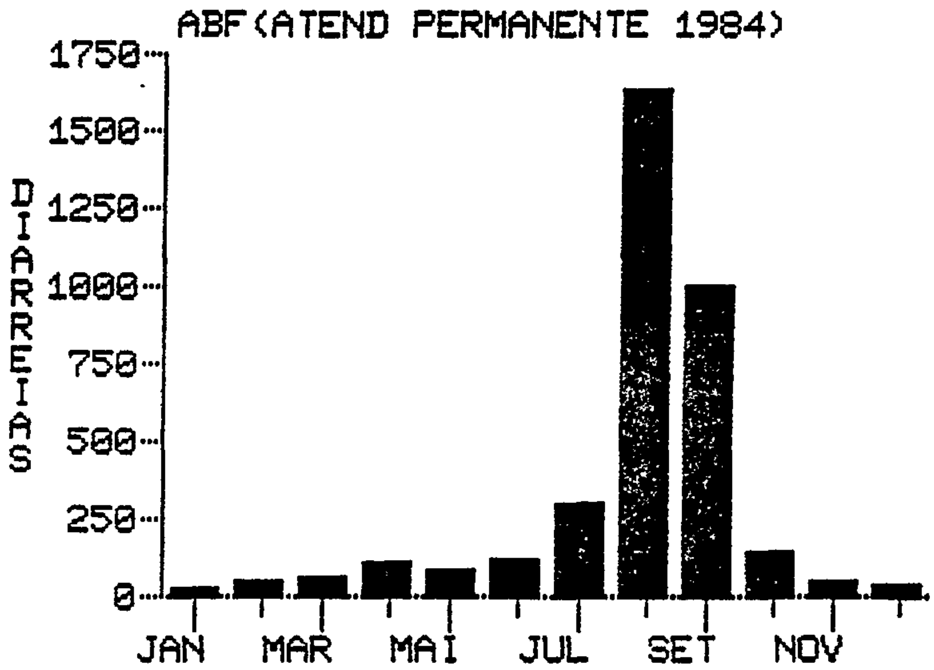


FIGURE 3

	DIARREIAS
JAN	37
FEV	44
MAR	35
ABR	37
MAI	57
JUN	[illegible]3
JUL	114
AGO	176
SET	121
OUT	76
NOV	25
DEZ	28

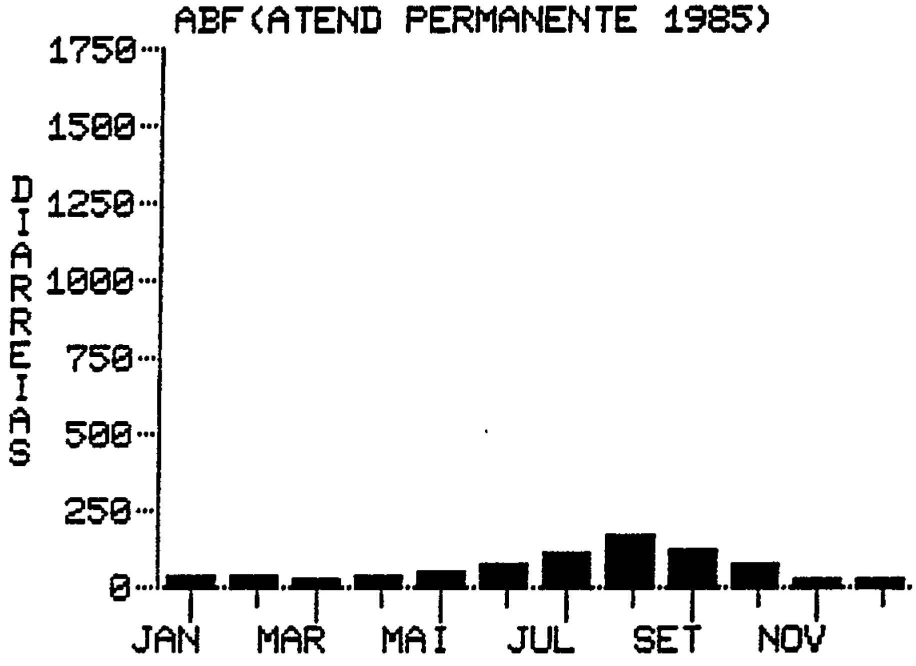


FIGURE 4

	DIARREIAS
JAN	50
FEV	18
MAR	37
ABR	43
MAI	49
JUN	82
JUL	136
AGO	180
SET	140
OUT	57
NOV	46
DEZ	0

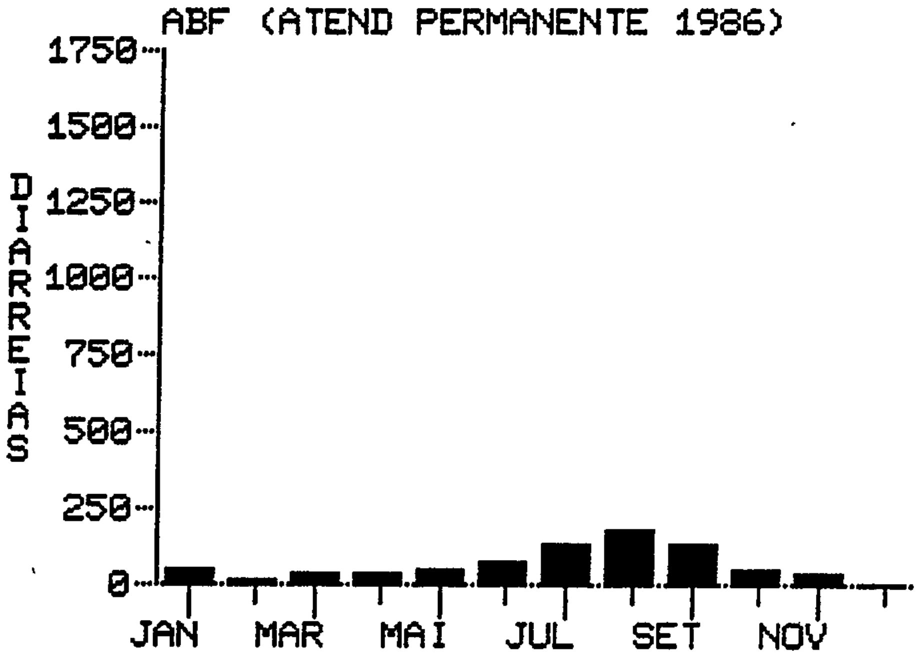
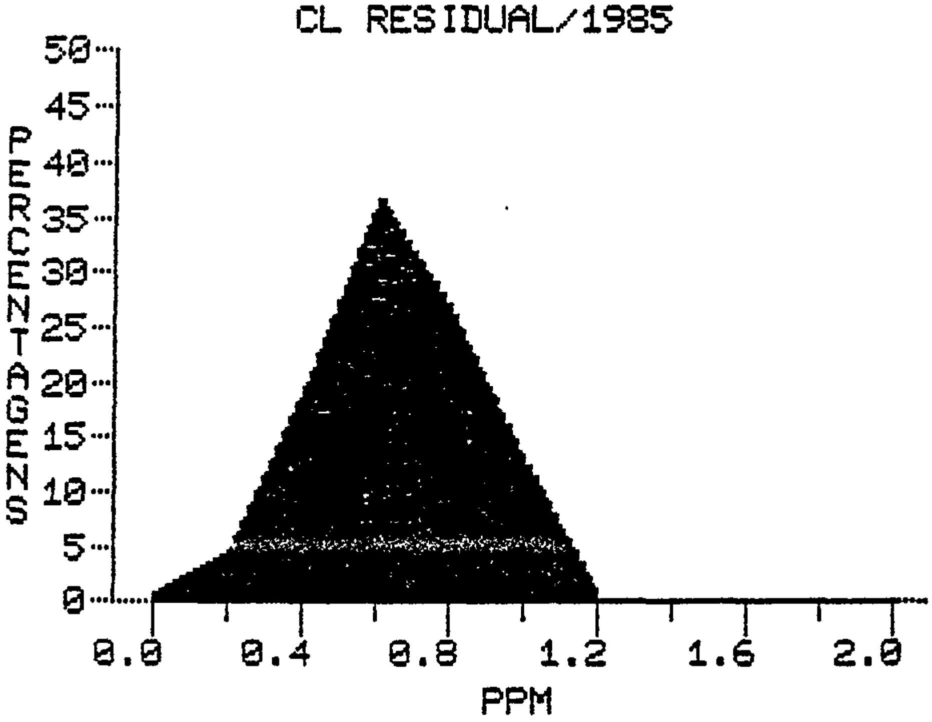


FIGURE 5



PPM	PERCENTAGENS
0.0	1
0.2	4.6
0.4	19.3
0.6	36.4
0.8	25.9
1.0	12.5
1.2	0
1.4	.1
1.6	.1
1.8	0
2.0	.1

TOTAL: 5019 determinações

DIAS: 340 dos 365 dias do ano

$\bar{X}$ = 0.64 ppm

Sx= 0.22 ppm

FIGURE 6

ECOLOGICAL INDICATOR FOR COASTAL WATERS

by

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S U M M A R Y

Chlorophyll a concentration is used as ecological indicator in order to know the level of homeostasis in the bathing sea watersystems. It is shown that the proposed ecological indicator gives a more accurate information than common bacterial indicators according to the aims of sanitary risk assesment. Telemetric determinations of chlorophyll a concentration by Thematic Mapper on-board LANDSAT 5 yield good correlation with field simultaneous measurements in a pilot coastal zone of the Spanish Mediterranean seashore.

1. INTRODUCTION

The Spanish littoral is surrounded by the Atlantic ocean, the Cantabrian sea and the Mediterranean sea. It's nearly 8 000 km long, being more than 36% insular seashore. There are almost 3 000 beaches, 30% of which belong to the Balearic and Canary Islands. (figure 1, table I)

For most of these beaches, the climatological conditions as well as the infrastructural equipment allow for intense recreational use.

During the first years of the Water Decade (1981-1984), wastewater treatment plants covering the needs of 6 millions inhabitants were constructed, and actually new plants are being projected or are under construction to cover the needs of 3 millions inhabitants more.

On the Mediterranean coastal zones tourist fluctuations have their peaks at summer, while on the Cantabrian or in Atlantic zones there are no population overflows. The highly occupation rate in Canary islands is reached during winter.

As in all others European countries, bathing waters quality control and surveillance are based on microbiological criteria.

Generally, the validity of swimmer's morbidity and coliform's concentration relationship have been argued since its setting up arround the 20's, and in the last decade this argument has intensified (1) (2) (3). This contradictory position could be attributed to two hypotheses groups:

i) Swimmer's morbidity are not straitforward associated with coliform's concentration.
   The most common diseases among swimmers are irritations of eyes, nose, skin, throat and years. Vomits and diarrheas have fewer incidence and seems to be more related to food.

ii) Coliform's measurements are not related to the whole state of swimming waters.
Bacterial indicators don't belong to the marine environment, their viability, dilution and dispersion are strongly conditioning.
Sampling methodology is inadequate to get an indicative inofrmation about the marine environment state.

An ecological criterium has proposed an alternative against the microbiological (4) (5) (6) (7) (8) (9). The state of coastal waters is determined through their eutrophic degree measured by the chlorophyll a concentration (10) (11).

This indicator seems to keep a good relationship either with the whole environment state or with the swimmer's morbidity:

A) Chlorophyll a is a photosynthetic pigment from phytoplankton which occupies a central position in the ecosystem, its concentrations are the integrated output from a life cycle average of a complex community which inputs are:

Physical: Light intensity
Temperature
Tides, streams, etc.
Seashores morphology

Chemical: Drains and sewers
Rivers
Oceanic spills.

B) Chlorophyll a concentration is straitforward related with germs survival probability because the higher this concentration is, the phytoplanktonic density will also be higher, and so there will be more spatial sites for superficial linkages between bacteria or viruses and microalgae.

2. FIELD SURVEYS

In the summers of 1981 abd 1982, along the Spanish littoral a research on selected coastal zones: Atlantic (Cadiz and Huelva), Cantabrian (Cantabria), Mediterranean (Castillòn de la Plana, Ibiza and Mallorca) was performed. In each one of these provinces two beaches were chosen, the most cleaned and the most dirty, under infraestructural and bacteriological criteria. In all the places morbidity surveys among the users, coliforms and chlorophyll a measurements were done (11). (Fig. 2, Tab. II, III and IV).

In the summers of 1984 and 1985, in 12 beaches of Castellón de la Plana Chlorophyll a measurements were made simultaneously with the times when the LANDSATS was mapping the zone (12) (13).

3. CONCLUSION

1. Low morbidity, from 1.6 to 8.5 was found. (Morbidity rate per 100 users).

2. When the own morbidity of the users, before coming, is discounted, the rise as the most common diseases appeared to be CONJUNCTIVITIS and RHINITIS.

3. Sex and different nationalities showed similar incidences. The maximum incidence appeared to be located in the age group between 3 and 16 years. It was particularly related to the number of sea-baths, their duration and the habit of being with the head under water.

4. FURUNCLES and MYCOSIS are not related with swim.

5. There is no relation between the microbiological quality and the incidence of the diseases.

6. There are high and positive correlations between chlorophyll a levels and incidence of: CONJUNCTIVITIS, ALLERGIES, DIARRHOEAS, RHINITIS, FURUNCLES and PHARYNGITIS (allergies show low incidence 1.6%).

7. There are good fits between telemetric and in situ chlorophyll a measurements.

8. LANDSATS' information show a wider and multifactorial view of the coastal water, and it seems an open door for seashore management.

4. ACKNOWLEDGEMENT

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5. REFERENCES

Recreational Water Quality. Canada, Environmental Health Directorate, 1980. Ministry of National Health and Welfare.

Mujeriego, R. Sanitary and Aesthetic Quality of the Coastal Waters of Spain. Prog. Wat. Techn. 12: 1, 119-127. Pergamon Press Ltd. G.B. (1980).

Cabelli, V.J. Evaluation of Recreational Water Quality, the EPA Approach. In: James, A. and Evison, L. ed. Biological Indicators of Water Quality. G.B. Wiley, 1979, chap. 14, 1-23.

Informe del Plan Piloto sobre Saneamiento Ambiental en Zonas Turísticas Intensivas. Madrid, Dirección General de Salud Pública, Ministerio de Sanidad y Consumo (1982).

Sieburth, J.M. Sea Microbes. New York, Oxford University Press, 1979.

Tanaka, N.N. Effect of the Ocean Environment on Microbial Activities. Baltimore, University Park Press (1974).

Vacelet, E. Le rôle des vitamines dans les relations bactéries-plancton en eau de mer littorale. Cah. Bid. mar., 16 384-394 (1975).

Swift, D.G. Vitamis and Phytoplankton Growth. In: Morris, I. ed. The Physiological Ecology of Phytoplankton. London. Blackwell (1980). pp 329-370.

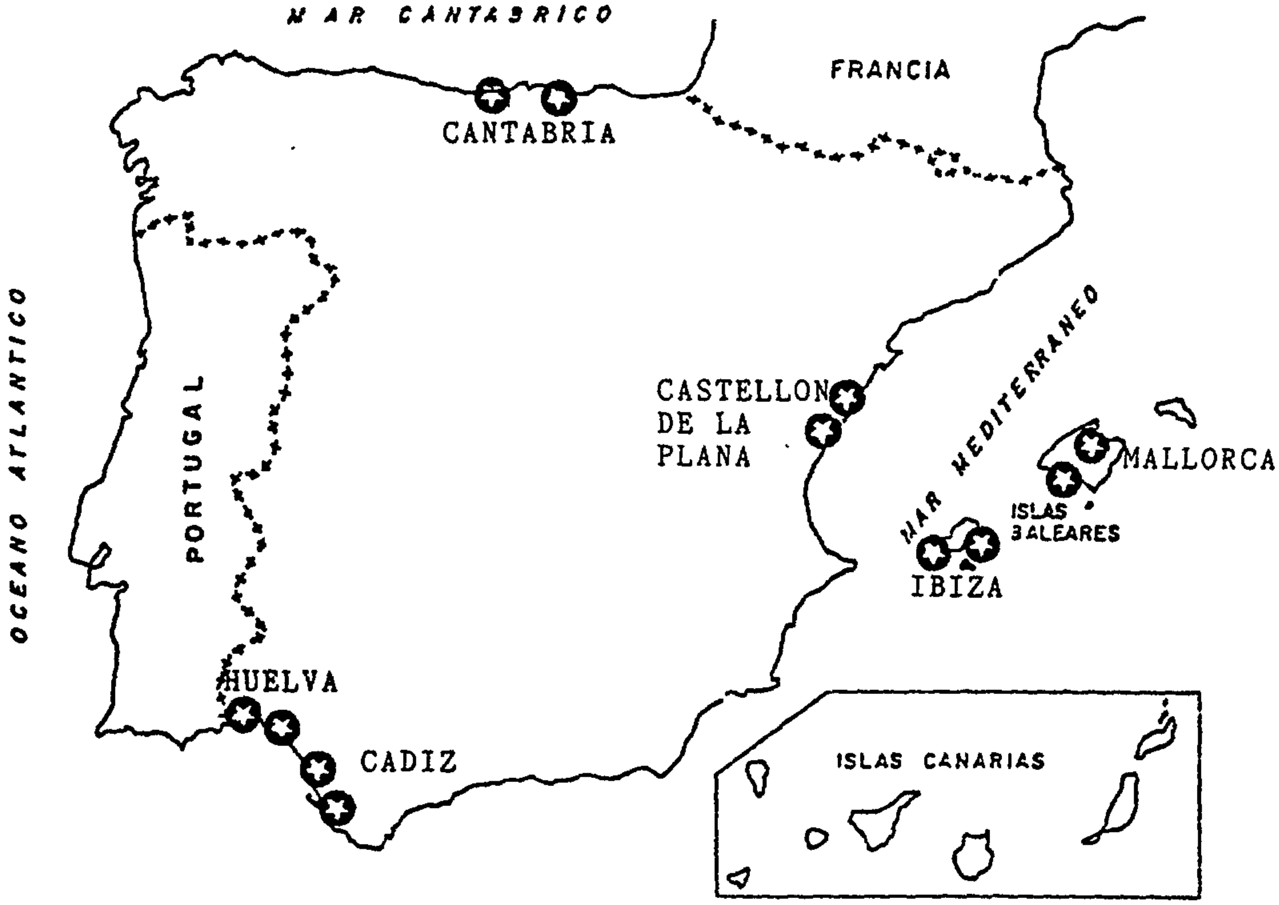
Brisou, F.J. Hygiène de l'environnement maritime. Paris, Masson, 1978.

Determination of Photosynthetic Pigments in Sea Water. Paris, UNESCO, Scor. 1966 (1. Monographs on Oceanographic Methodology).

Pleite, J. Nuevos criterios para la gestión sanitaria de playas. Indicadores ecológicos Rev. San. Hig. Púb. 58: 73-82 (1984).

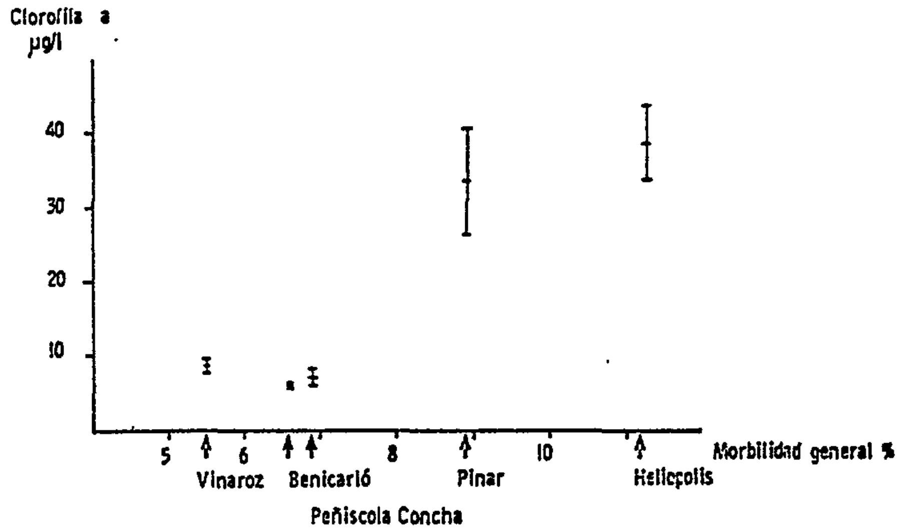
Verdin, J.P. Mapping Surface Water Quality Patterns of Larce Havasu. With thematic. mapper imagery. Denver Applied Sciences. Referral Memorandum. Nª AP-85-4-2.

Tortajada, R. Determinación telemétrica de la calidad de las aguas marinas. San Sebastian, 1985 (I Congreso de conservación de playas).



* Beaches of the Spanish littoral where epidemiological surveys among swimmers, microbiological determinations and chlorphyll a measurements were done in 1981, 1982, 1984 and 1985.

FIGURE 1



Chlorophyll a vs. general morbidity of swimmers in five beaches, Castellón de la Plana, Spain (1984)

FIGURE 2

Table I

	Spanishc littoral			
Sea bodies	Peninsular		Insular	
	km	Beaches	km	Beaches
Atlantic	1 915	771	1 541	713
Cantabrian	1 221	352		
Mediterranean	1 854	824	1 349	258
TOTAL	4 990	1 947	2 890	971

Table II

Diseases	Morbidity rate per 100 users	% Contribution to total morbidity
Conjunctivities	8,5	25,6
Rhinitis	4,9	14,7
Furuncles	3,3	9,9
Mycosis	2,9	8,7
Pharyngitis	2,7	8,1
Diarrheas	2,6	7,8
Otitis	2,3	6,9
Allergies	1,6	4,8
(Burns)	(4,4)	(13,2)

Most common diseases incidence at Spanish beaches (1982)

TABLE III

Beach(Pronvince)	Who Criteria E.coli.	Chlorohyll a average ppm	INCIDENCE PER 100 USERS							
			Conjunc-tivitis	Rhinitis	Furuncles	Pharyngitis	Mycosis	Otitis	Diarrhoeas	Allergies
Covachos(Cantabria)	Satisfactory	2,476	10	3	0,8	2,5	2,5	3	0,8	0
Sardinero(Cantabria)	Not Sat.	2,625	8	2,6	1	1	2	2	0	0,6
Pegina(Cadiz)	Satisfactory	1,743	4	6	6,5	3	4	5	5	1
Puntilla(Cadiz)	Not Sat.	4,489	8,6	5,3	1	5,3	5,3	4	3	0
Peñiscola(Castellón)	Satisfactory	34,666	15,2	11,5	9	8,9	1,5	3	6	4
Piner(Castellón)	Not Sat.	49,175	18,4	7,3	6	4	2,6	4	6,5	6,3
Salinas(Ibiza)	Satisfactory	0,115	0,5	3	1,6	0,5	0	0,5	0	0
En Bossa(Ibiza).	Not Sat.	0,404	1	6	5	2	1	3	0	0,5
(r) Correlation Coeficient			* 0,87	0,62	0,61	0,61	-0,07	0,26	* 0,79	* 0,84

Microbiological and ecological criteria vs. incidence per 100 users of the most commun diseases at four selected coastal zones. Spain 1982

* Significantly correlated

Table IV

CHLOROPHYLL *a* ppm				
Month	August		September	
Day	13	29	14	30
Beach				
1	4,4	4,4	9,7	10,6
2	0,9	6,3	4,1	8,5
3	1,0	4,4	9,9	16,0
4	2,9	5,8	6,2	12,7
5	2,6	5,4	6,6	17,5
6	0,2	3,1	8,7	17,0
7	6,1	8,6	5,7	7,4
8	0,3	3,2	2,2	2,7
9	0,3	6,7	6,6	1,8
10	6,7	26,6	11,0	15,0
11	54,2	38,1	98,0	30,4
12	8,5	97,0	45,5	59,4

Chlorophyll *a* concentrations measured in 12 beaches of Castellón de la Plana simulanteously with the over-fly of LANDSAT 5, Spain (1985).

CHLA = 25 500 + 0,520 Tm4 - 0,325 Tm1
CHLA = Chlorophyll *a* concentration, ppm
Tm4 = Chanell Thematic Mapper
Tm1 = Chanell Thematic Mapper.

THE STATE OF SANITATION AND THE FIGHT AGAINST POLLUTION ON THE MEDITERRANEAN COASTLINE

by

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** Directorate General of Health and Social Wellfare in the Mediterranean Region, Toulouse

1. GENERAL PRESENTATION

In 1987, in Montpellier (France) at a WHO congress about Sanitation of the Environment in European Tourist Areas, some recommendations were given: one of them was to base their conception of sanitation infrastructures on specific technical interests taking into consideration the impact of seasonal population and climatic conditions.

The infrastructures were used only for a few months every year and solutions of higher expenditures of exploitation were preferred to solutions of higher expenditures of investment.

This aspect has been taken into account for 12 years and there is a significant effort for specific legislation on the coastline, through investigation of adaptable systems of sanitation ana the means that are used.

Beyond the recommendations of WHO, two events occured and accelerated this process:

- The consideration of the following instructions of the EEC and their integration into the French rules:

Instruction of the EEC of 8th Dec. 1975 quality of bathing water.

Instruction of the EEC 30. Oct. 1979 quality of shellfish culture water.

Instruction of the ÈEC 17 Dec. 1979 quality of ground water.

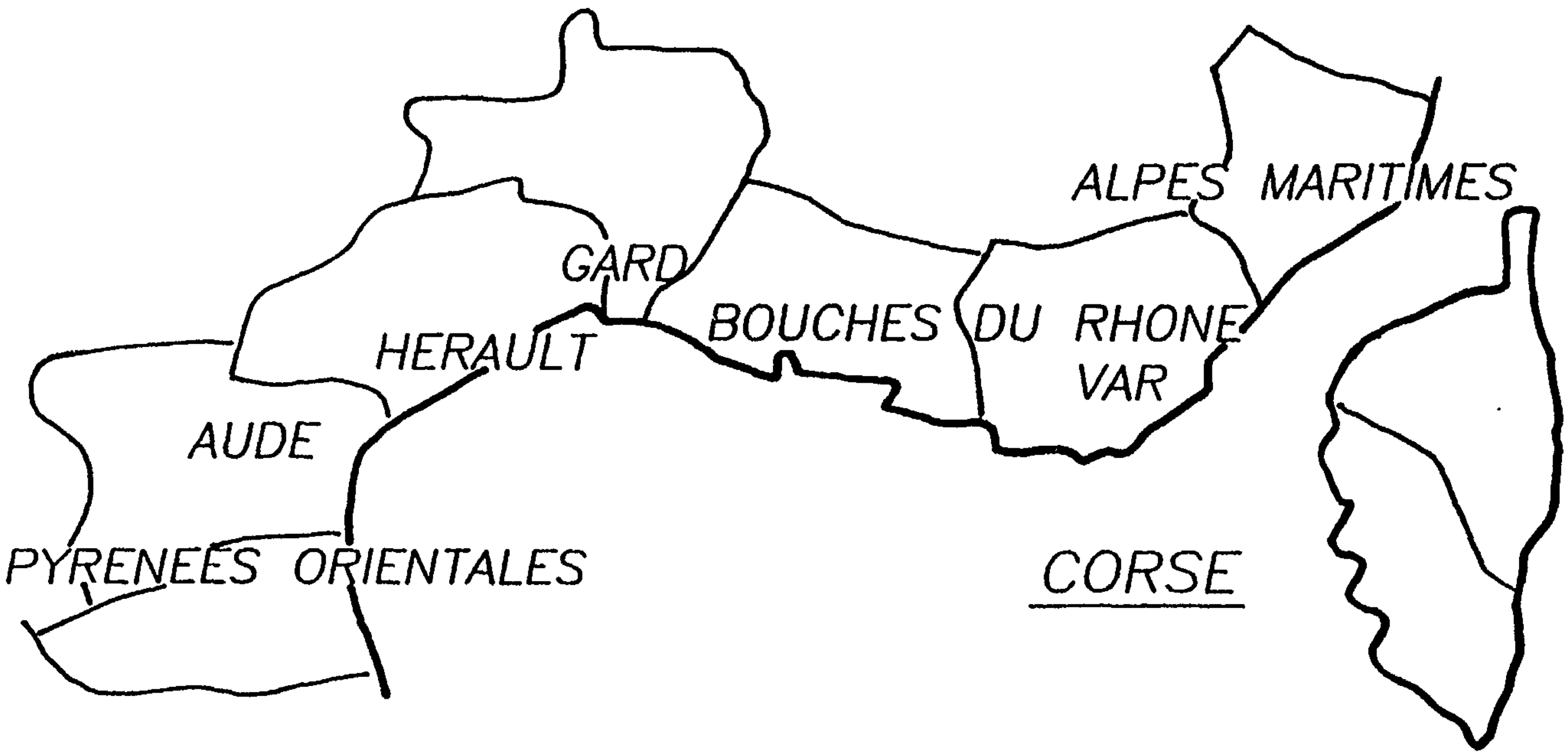
Instruction of the EEC 15 Dec. 1980 quality of drinking water.

- The need from the public of getting information (creation of Consumers Unions and specialized magazines) specially about the topic of water quality, bathing places at sea and at fresh water.

Therefore, the Health Ministry has published since 1975 a sanitary card of the bathing places for the whole coastline. This information has been widely spread and has surely accelerated the process of pollution control on the coastline because of the collective sudden awareness from users and authorities.

In addition, the health authorities have developed their means of intervention in this field, with sanitary engineering services or departments, who have a general function of sanitary prevention and an administrative and technical control and hygiene rules.

FRENCH MEDITERRANEAN COAST



It is worth noting that the recent law of decentralization that brought heavy changes in the present French life maintains the national homogeneity as far as public health is concerned.

2. THE MEDITERRANEAN COASTLINE

As shown through the annexed schema, two regions: Languedoc Roussillon, Provence-Côte-d'Azur, and seven departments constitute the Mediterranean coast without forgetting the region of Corsica.

The significant crowd of tourists for a short period (3 months) specially between July 15th and August 15th has always posed a general problem of infrastructures, of a sanitary nature:

- water distribution
- sanitation
- food control
- bathing
- leisure accomodation (camping, etc...), or

of another nature:

- road networks
- other services...

3. WATER DISTRIBUTION

3.1 The sanitary point of view

"Any water that would be given to human consummation must not be susceptible of harming the health of people who consume it."

This global objective which is defined by the Code of Public Health leads to pressures that have evolved in the process of time for people concerned with water distribution.

In addition to the epidemic aspects of microbilogical origin, other sanitary problems related to chemical elements whose effects upon health might appear in the short, medium or long term, need also to be mentioned.

The integration of European standards into the French Rules has changed the number of analytical monitoring parameters from 25 to about 65.

There is a need of maintaining a balance amongst the different factors affexting water quality, such as:

- the complexity of the phenomenon of pollution in the natural environment;
- the state of the scientific knowledge in analytical determinations and toxicology;
- the concrete evolution of the situations that involve sanitary risks;

- and the means available for monitoring of water quality.

We can also see a clear evolution of the notion of water quality. On one hand, for the technician it expresses the state of the water quality at a certain time in a certain place in a concept that is essentially evolutionary. On the other hand, the consumer demands about orgenoleptic characteristics are increasing, in spite of well controlled bacteriological risks.

The water quality objective is then to secure a "non risk" state, by means of the introduction of appropriate technical and administrative measures.

3.2 Typology of drinking water supply

The Health Ministry has carried out during the last few years national studies about drinking water quality on specific topics, different distribution networks, referring to microbiological quality, and investigating the presence of micro pollutants.

The studies permitted to identify common and local problems.

Data were collected from 4800 "syndicates de communes" and 7500 "communes autonomes", in about 19000 ground waters and superficial water intakes.

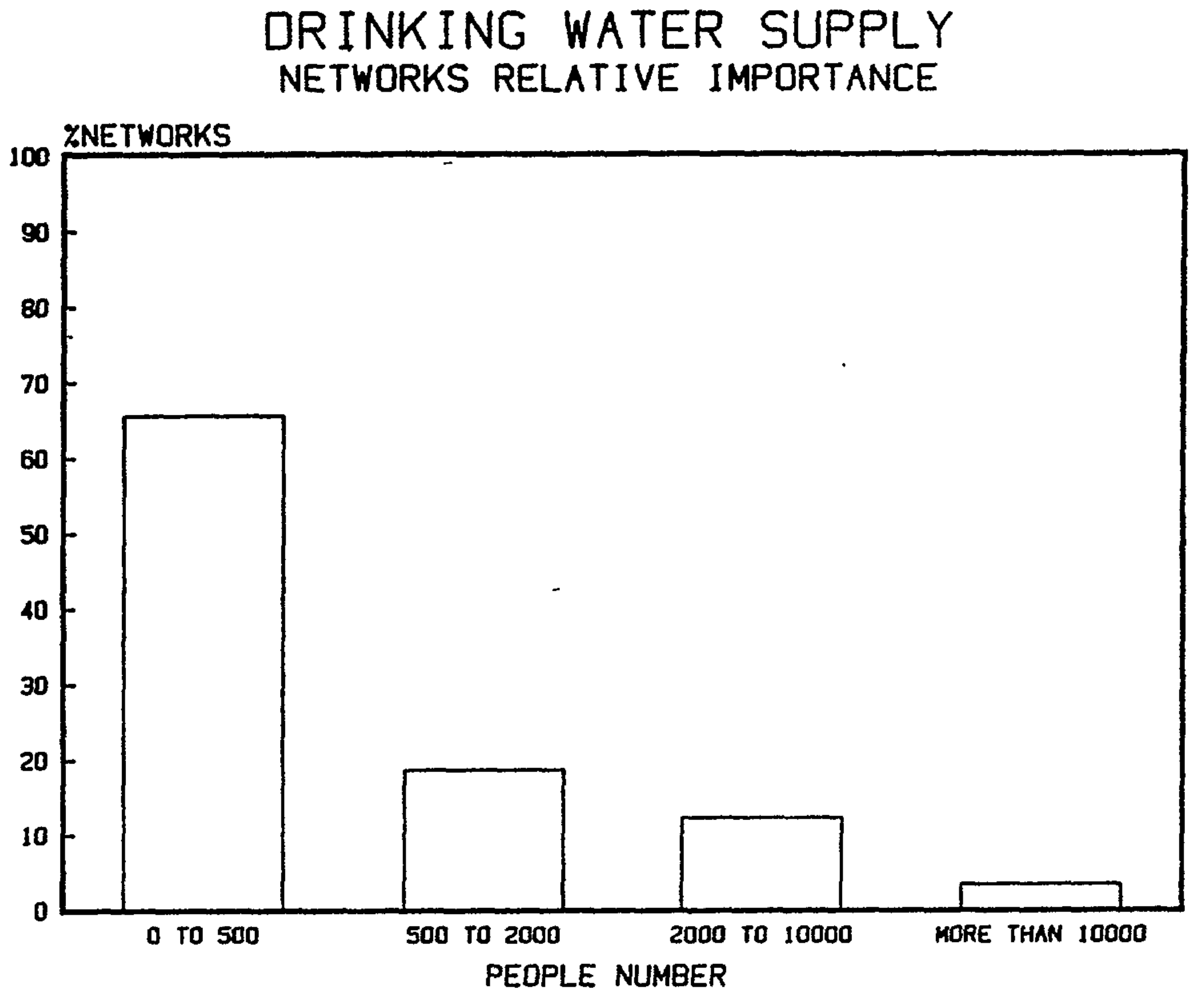
The modalities of sanitary monitoring have been adapted to situations of potential risks:

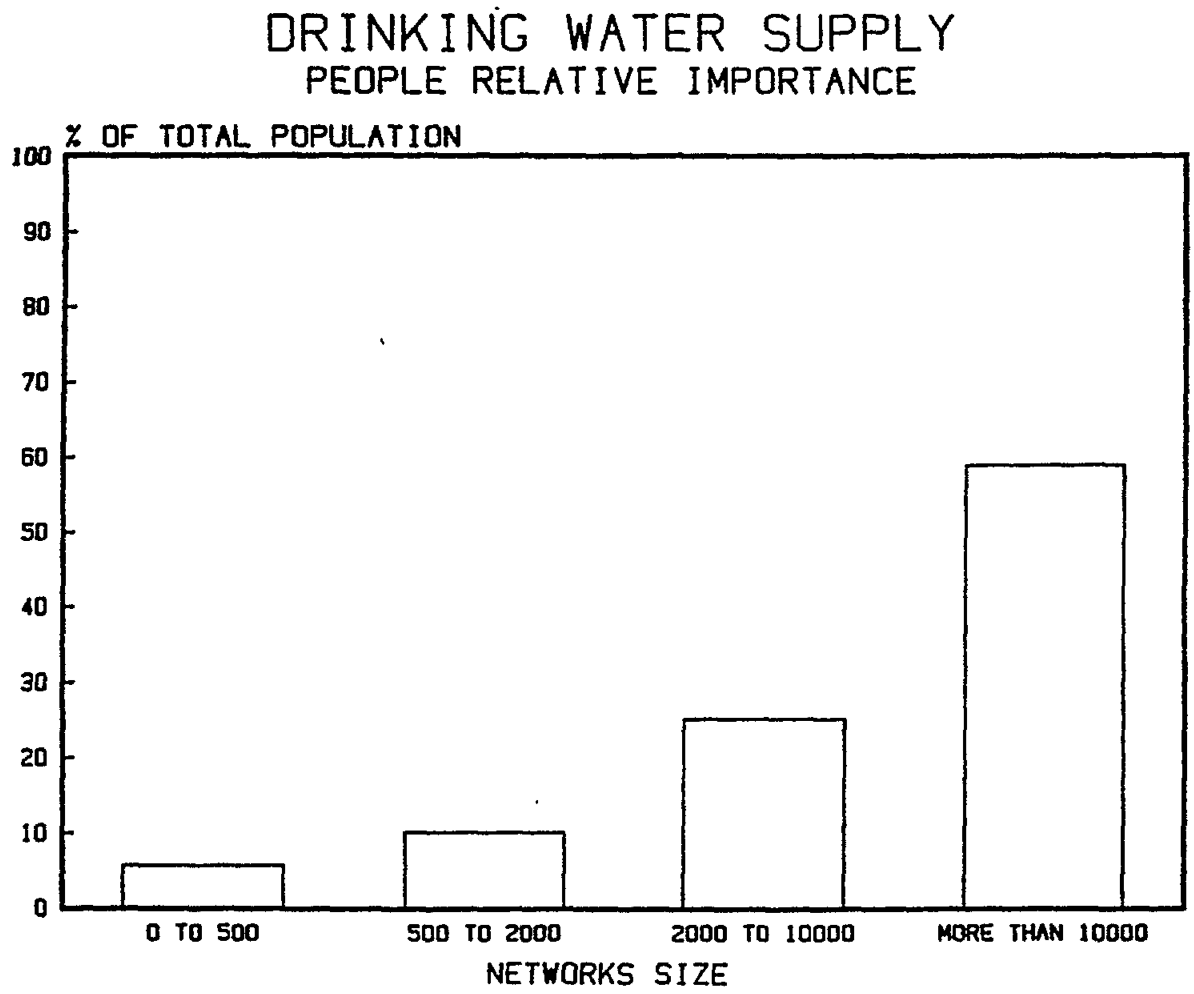
- nature and protection conditions of water resources;
- potabilisation treatment plants;
- nature and importance of distribution networks;
- exploitation conditions.

Only a global approach can define the sanitary priorities that can lead towards an appropriate water management plan of work.

3.3 Mediterranean coastline

There are about 1700 networks distributing water for about 5 million people.


DRINKING WATER SUPPLY
NETWORKS RELATIVE IMPORTANCE
%NETWORKS
100
90
80
70
60
50
40
30
20
10
0
0 TO 500
500 TO 2000
2000 TO 10000
MORE THAN 10000
PEOPLE NUMBER


DRINKING WATER SUPPLY
PEOPLE RELATIVE IMPORTANCE
% OF TOTAL POPULATION
100
90
80
70
60
50
40
30
20
10
0
0 TO 500
500 TO 2000
2000 TO 10000
MORE THAN 10000
NETWORKS SIZE

DEPARTMENTS	COMMUNES	PERMANENT PEOPLE	SUPPLY NETWORKS
PYRENEES ORIENTALES	221	299,506	230
AUDE	437	272,360	360
HERAULT	343	682,600	210
GARD	353	505,100	260
BOUCHES DU RHONE	119	1,700,000	150
VAR	153	643,540	163
ALPES MARITIMES	163	852,000	160
CORSE	360	319,687	200
TOTAL COASTLINE	2,149	5,274,793	1,683

The needs of water supply have increased. For instance, the "department" of Herault consumed twice as much water in 1985 than in 1975 (110 million m^3/year).

Some other examples give us an idea of the problem:

La Grande Motte: winter: 5,000 inhabitants
summer: 50,000
and up to 120,000 inhabitants in the period July 15 to August 15

Gruissan : winter: 1,500 inhabitants
summer: 25,000 inhabitants

Leucate : winter: 1,300 inhabitants
summer: 35,000 inhabitants

This situation poses technical and financial problems.

Technical Problems

Local natural resources are very limited; we must then investigate complementary resources sometimes very far away like in the river Rhône, or in high and middle valleys of neighbouring coastal rivers.

In the region of Provence Alpes Cote d'Azur, 2/3 of the population are supplied by superficial waters located far away and transported by large networks.

$$\text{Peak flow} = \frac{\text{max volume per day}}{\text{average volume per day/year}} = 1.75 \text{ to } 3$$

The whole adduction and distribution systems must then be sized to face the heaviest consumption, and this represents a risk of a sanitary and economical nature.

The solution is to conceive a plan with several parallel blocks.

Distribution storage reservoirs

Designing tanks for peak consumption makes the retention time of water in the tank too long with possible quality degradation.

Transport conditions

During the winter, water flow is divided by 5 or 10, compared with the one in summer time.

One solution may be to reduce pipes diametres and to increase speed.

If possible, it is better to construct two different networks in spite of certain problems inherent to this kind of distribution, but at least this permits to satisfy the demand during the touristic season.

Desinfection treatments

It is interesting to set desinfection treatments on different points of the networks and to check for residual chlorine in the extremities in order to maintain a minimum health protection.

The most difficult period for quality control is in fact during september/october when temperatures are still high and consumption goes down quickly.

Protection of water resources and of distribution networks from accidental pollution needs also to be taken into consideration.

4. SANITATION

4.1 General data

The raw flow before removal of pollution of domestic nature is evaluated to 7 million inhabitants in winter, and 13 million in summer, on the whole French coastline.

These seasonal pressures are very bad, shared on the French coastline, where the region Provence Cote d'Azur, on the Mediterranean, represents more than 48% (in winter) and 38% (in summer) of the total of the French flow of pollution. And this pollution is discharged in less than 13% of the coastline total length.

The city of Marseille in itself represents more than 15% of the national raw flow of domestic wastewaters.

Cities on the Mediterranean with 100,000 inhabitants in summer:

	winter	summer
Marseille	1,014,000	1,051,000
Nice	343,000	410,000
Montpellier	191,000	200,000
Toulon	190,000	193,000
Perpignan	107,000	117,000
Fréjus	28,000	138,000
Le Grau du Roi	5,100	134,000
Cannes	70,000	131,000
Saint Raphael	21,000	121,000
Cagnes sur Mer	29,000	104,000
Antibes	55,000	102,000

In order to obtain a global estimation of raw flows of pollution, it is necessary to take into account the flow of pollution transported by rivers (the Rhône in particular) and by coastal industries.

Domestic pollution coming from local coastal collectivities is not being considered.

Pollution of a pelagic origin and of other origins, transported by rivers, are not taken into account although their influence on the quality of the marine coastal environment are not questioned.

4.2 The equipment

In 1983 as the annexed schemes show, the rate of equipment of French coastal communes was of 80.6%, which was considered satisfactory.

160 communes (Atlantic and Mediterranean) are still to be equipped with collective sanitation.

The total capacity of 648 sewage treatment plants is reaching 9,451,000 equivalent-inhabitant.

Among the 1042 communes of the French coastline, 218 do not need a collective sanitation, but an individual one.

The 648 sewage treatment plants collect wastewaters coming from separative sewerage systems in 509 cases (86.1%), mixed in 57 (9.6%), and combined in 25 cases (4.2%).

On the Mediterranean Sea 3 groups have to be distinguished:

a) the Languedoc-Roussillon coast: 180 kms long, of straight and sandy coast, that was equipped after the creation of an interministerial coordination committee in 1963;

b) the touristic cities that are entirely equipped; amongst the big cities, Perpignan is completing its equipment;

c) the coast Provence-Cote d'Azur, which is a rocky and old touristic place; it has completed its equipment, but as the urbanization is very important, and the relief is very rough, technical sollutions of sanitation are classical biological treatment plants.

For the above mentioned first two groups we have three possibilities:

- a classical and biological sewage treatment plant with a first primary decantation,

- waste stabilization ponds, which is a very common process because of the existence of flat large spaces which are not urbanized, or

- a physico-chemical pollution removal to help in case there are overloaded summer periods.

Corsican island

It represents 802 kms of rocky and irregular coastline.

- urbanized areas: 231 kms
- rural and beaches: 188 kms

Permanent people is 195,000, and we can observe a touristic flow of about 120,000.

The population increase, during holidays reaches 85% in the southern part of Corsica, and only 40% in the northern part.

Among the 65 communes which need collective sanitation equipment, 46 have a sewage treatment plant.

In little and rural cities, direct effluents discharging in natural environment are prohibited, and we tend to replace them with infiltration-bed processes or wastewater reutilization

4.3 The organic and hydraulic load:

More than 50% of the capacity is used in winter, which is normal because the population is twice bigger in summer, on more than 94% of the French coastline.

However, in summer, 175 sewage treatment plants are overloaded representing 28% of the total park. This number reveals that 25% of the plants are bad sized, or that the increase of tourism was under-evaluated at the beginning.

4.4 Sewerage networks operating conditions:

On coastline areas liquid effluents have several particularities - less important water consumption which leads to:

- higher pH
- greater concentrations
- prevalence of ammoniated waters
- very high daily peaks
- difference in nature, caused by nutritional habits in those periods, which means increasing of particule pollution in organic matter (to 75%)
- septicity of effluents, caused by anaerobic phenomena, which are developed in large networks.

4.5 <u>The evolution of technologies on the coastline</u>:

Among the different processes, some would look more adapted to the problems found here, as precised in the Interministerial instruction of May 12th 1981.

A level of type "A" (removal of 90% of total settable solids), is enough in case of direct effluents discharged into the sea, far from sensible areas (bathing and shellfish culture areas).

In other areas, it becomes necessary to find treatment processes performing better, as for instance places where bathing is significant.

The different kinds of sewage treatment plant on the French coastline are:

- activated sludges: 428 units	66%
- trickling filters: 92	14.2%
- waste stabilization ponds: 109	16.8%
- physico chemical: 59	9.1%
- rotating biological disks: 12	1.9%
- simple decantation: 37	5.7%
- desinfection: 169	26.1%

The total of the percentage is higher than 100% because some plants have several kinds of processes for pollution removal, in the same way or in series.

However, these biological processes with activated sludges have the inconvenient of not adapting themselves to daily variations. We estimate that the maximum daily increase cannot go over 20% of the capacity in order, for sewage treatment plant, to keep on with normality.

In Languedoc-Roussillon the development of waste stabilization ponds is important. It permits adaptations to the variation of capacity and presents a rate of reduction of microbiological germs compatible with the demands of the bathing areas. The morphology of the coast permits to avoid direct discharge into the sea. Some units, because they do not have enough space for waste stabilization ponds, have desinfection systems. On the whole French coastline 16 sewage treatment plants are equipped in this way. A very high percentage of these treatments has a relatively low efficiency and are very often out of order.

4.6 Performance:

Its estimation is very difficult for the whole of the French coastline. The performance is calculated on the basis of three parameters which are:

- biological oxigen demand
- chemical oxygen demand
- suspended solids

This performance does not distinguish between summer period and the others. We can consider that on the whole French coastline the situation is as follows:

- 10% of sewage treatment plants do not work well
- 35% work rather well
- 55% work well

5. CONCLUSIONS

For the past 15 years many efforts have been made for the introduction of sewerage networks, and of sewage treatment plants in the Mediterranean coast.

Most of the communes do have one sewage treatment plant adapted to their touristic use.

Superficial waters and bathing waters on the coastline are more and more used as leisure.

The conditions for good efficiency of a sewage treatment plant on the Mediterranean coastline, according to our experiences are:

- the control of urbanization according to schemes of sanitation that will take into consideration population fluctuations.

- the control of effluents will be possible provided that a coordinated action is taken by all competent services (Health, Environment, etc.)

- the collection of waste waters must be made by separative sewer systems, with a severe control of individual effluents, and removal of other waters

- choice of techniques which are well adapted to local conditions (waste stabilization ponds, biological processes, physicochemical ones) and whose efficiency is well known

- the utilization of well treated wastewater will conciliate the imperatives of hygiene and the need for fighting against against wasting of fresh water resources is very often limited or expensive

- the permanent control of the reliability of sanitation equipments

- a continuous effort for maintaining the quality of human resources at the highest possible level.

ANNEXE

QUALITÉ DES EAUX DESTINÉES A LA CONSOMMATION HUMAINE DIRECTIVE 80/778/CEE DU 15 JUILLET 1980

A. PARAMÈTRES ORGANOLEPTIQUES

Paramètres	Expression des résultats	Niveau guide	Concentration maximale admissible	Observations
1 COULEUR	mg/l échelle Pt/Co	1	20	
2 TURBIDITÉ	mg/l Si O_2	1	10	
	unités Jackson	0,4	4	Mesure remplacée en certaines circonstances par celle de la transparence évaluée en mètres au disque de Secchi : — niveau guide : 6 m — concentration maximale admissible : 2 m
3 ODEUR	taux de dilution	0	2 à 12 °C 3 à 25 °C	A rapprocher des déterminations gustatives.
4 SAVEUR	taux de dilution	0	2 à 12 °C 3 à 25 °C	A rapprocher des déterminations olfactives

B. PARAMÈTRES PHYSICO-CHIMIQUES (en relation avec la structure naturelle des eaux)

Paramètres	Expression des résultats	Niveau guide	Concentration maximale admissible	Observations
5 TEMPÉRATURE	°C	12	25	
6 CONCENTRATION en ions hydrogène	unité pH	6,5 ≤ pH ≤ 8,5		L'eau ne devrait pas être agresive. Les valeurs du pH ne s'appliquent pas aux eaux conditionnées. Valeur maximale admissible : 9,5.
7 CONDUCTIVITÉ	μ S cm^{-1} à 20 °C	400		En correspondance avec la minéralisation des eaux. Valeurs correspondantes de la résistivité en ohm/cm : 2 500.
8 - CHLORURE	mg/l Cl	25		Concentration approximative au-delà de laquelles des effets risquent de se produire : 200 mg/l.
9 SULFATES	mg/l SO_4	25	250	
10 SILICE	mg/l SiO_2			Selon traitement.

Paramètres	Expression des résultats	Niveau guide	Concentration maximale admissible	Observations
11 CALCIUM	mg/l Ca	100		
12 MAGNÉSIUM	mg/l Mg	30	50	
13 SODIUM	mg/l Na	20	175 (à partir de 1984 et avec un percentile de 90). 150 (à partir de 1987 et avec un percentile de 80). (Ces percentiles sont à calculer sur une *période de* référence de 3 ans)	Les valeurs de ce paramètre tiennent compte des recommandations d'un groupe de travail de l'Organisation Mondiale de la Santé (OMS) (La Haye, mai 1978) concernant une réduction progressive de l'apport quotidien actuel total en chlorure de sodium à 6 grammes. La Commission présentera au Conseil à partir du 1er janvier 1984 des rapports sur l'évolution concernant l'ingestion totale quotidienne de chlorure de *sodium par la population.* Dans ces rapports, la Commission examinera dans quelle mesure la concentration maximale admissible de *120 mg/l citées par le groupe de travail* de l'OMS est nécessaire pour atteindre un niveau satisfaisant pour l'ingestion totale de chlorure de sodium et proposera, le cas échéant, au Conseil une nouvelle valeur de concentration maximale admissible pour le sodium et un délai pour atteindre une telle valeur. La Commission présentera au Conseil, avant le 1er janvier 1984, un rapport concernant la question de savoir si la période de référence de 3 ans relative au calcul des percentiles est fondée ou non sur le plan scientifique.
14 POTASSIUM	mg/l K	10	12	
15 ALUMINIUM	mg/l Al	0,05	0,2	
16 DURETÉ TOTALE	mg/l .			Voir tableau F
17 RÉSIDUS SECS	mg/l après séchage à 180 °C		1 500	
18 OXYGÈNE DISSOUS	% O_2 de saturation			*Valeur de saturation > 75 % excepté* pour les eaux souterraines.
19 ANHYDRIDE CARBONIQUE LIBRE	mg/l CO_2			L'eau ne devrait pas être aggressive.

C. PARAMETRES CONCERNANT DES SUBSTANCES INDÉSIRABLES (quantités excessives) (1).

Paramètres	Expression des résultats	Niveau guide	Concentration maximale admissible	Observations
20 NITRATES	mg/l NO_3	25	50	
21 NITRITES	mg/l NO_2		0,1	
22 AMMONIUM	mg/l NH_4 0,05	0.5		
23 AZOTE KJELDAHL (N de NO_2 et NO_3 exclus)	mg/l N		1	
24 OXYDABILITÉ (K MnO_4)	mg/l O_2	2	5	Mesure faite à chaud et en milieu acide.
25 CARBONE ORGANIQUE TOTAL (TOC)	mg/l C			Toute cause d'augmentation des concentrations habituelles doit être recherchée.
26 HYDROGÈNE SULFURÉ	µg/l		non détectable organoleptiquement	
27 SUBSTANCES EXTRACTIBLES AU CHLOROFORME	résidu sec mg/l	0,1		
28 HYDROCARBURES dissous ou émulsionnés (après extraction par CCl_4) ; huiles minérales	µg/l		10	
29 PHÉNOLS (indice phénols)	µg/l C_6H_5OH		0.5	A l'exclusion des phénols naturels qui ne réagissent pas au chlore.
30 BORE	µg/l B	1 000		
31 AGENTS DE SURFACE (réagissant au bleu de méthylène)	µg/l (lauryl sulfate)		200	
32 AUTRES COMPOSÉS ORGANO-CHLORÉS ne relevant pas du paramètre n° 55	mg/l	1		La concentration en haloformes doit être réduite dans toute la mesure du possible.
33 FER	mg/l Fe	50	200	
34 MANGANÈSE	mg/l Mn	20	50	

(1) Certaines de ces substances peuvent même être toxiques lorsqu'elles sont presentes en quantités très importantes.

Paramètres	Expression des résultats	Niveau guide	Concentration maximale admissible	Observations
35 CUIVRE	mg/l Cu	100 A la sortie des installations de pompage et/ou de préparation et de leurs annexes 3 000 Après 12 heures de stagnation dans la canalisation et au point de mise à la disposition du consommateur		Au-delà de 3 000 mg/l peuvent apparaître des saveurs astringentes, des colorations et des corrosions.
36 ZINC	mg/l Zn	100 A la sortie des installations de pompage et/ou de préparation et de leurs annexes 5 000 Après 12 heures de stagnation dans la canalisation et au point de mise à la disposition du consommateur		Au-delà de 5 000 mg/l peuvent apparaître des saveurs astringentes, de l'opalescence et des dépôts granuleux.
37 PHOSPHORE	mg/l P_2O_5	400	5 000	
38 FLUOR	μg/l F 8-12 °C 25-30 °C		 1 500 700	Concentration maximale admissible variable suivant la température moyenne de l'aire géographique considérée.
39 COBALT	mg/l CO			
40 MATIÈRES EN SUSPENSION		Absence		
41 CHLORE RÉSIDUEL	mg/l Cl			
42 BARYUM	mg/l Ba	100		
43 ARGENT	mg/l Ag		10	Si, dans un cas exceptionnel, il est fait usage non systématique de l'argent pour le traitement des eaux, une valeur de concentration maximale admissible de 80 mg/l peut être admise.

D. PARAMÈTRES CONCERNANT DES SUBSTANCES TOXIQUES

Paramètres	Expression des résultats	Niveau guide	Concentration maximale admissible	Observations
44 ARSENIC	µg/l As		50	
45 BERYLIUM	µg/l Be			
46 CADMIUM	µg/l Cd		5	
47 CYANURES	µg/l CN		50	
48 CHROME	µg/l Cr		50	
49 MERCURE	µg/l Hg		1	
50 NICKEL	µg/l Ni		50	
51 PLOMB	µg/l Pb		50 (en eau courante)	Dans le cas de canalisations en plomb, la teneur en plomb ne devrait pas être superieure à 50 µg/l dans un échantillon prélevé après écoulement. Si l'échantillon est prélevé directement ou après écoulement et que la teneur en plomb dépasse fréquemment ou sensiblement 100 µg/l, des mesures appropriées doivent être prise afin de réduire les risques d'exposition du consommateur au plomb.
52 ANTIMOINE	µg/l Sb		10	
53 SELENIUM	µg/l Se		10	
54 VANADIUM	µg/l V			
55 PESTICIDES ET PRODUITS APPARENTÉS · par substance individualisée · au total	µg/l		 0,1 0,5	On entend par pesticides et produits apparentés : — les insecticides : — organochlorés persistants — organophosphorés — carbamates — les herbicides — les fongicides — les PCB et PCT
56 HYDROCARBURES POLYCYCLIQUES AROMATIQUES	µg/l		0,2	Substances de référence : — fluoranthène — benzo 3.4 fluoranthène — benzo 11,12 fluoranthene — benzo 3,4 pyrène — benzo 1,12 pérylène — *indeno (1,2,3 — cd) pyrène*

E. PARAMÈTRES MICROBIOLOGIQUES

Paramètres	Résultats : volume de l'échantillon (en ml)	Niveau guide	Concentration maximale admissible	
			Méthodes des membranes filtrantes	Méthodes des tubes multiples (NPP)
57 COLIFORMES TOTAUX (1)	100	—	0	NPP <1
58 COLIFORMES FECAUX	100	—	0	NPP <1
59 STREPTOCOQUES FÉCAUX	100	—	0	NPP <1
60 CLOSTRIDIUMS SULFITORÉDUCTEURS	20	—	—	NPP ≤1

Les eaux destinées à la consommation humaine ne doivent pas contenir d'organismes pathogènes.

En vue de compléter, en tant que de besoin, l'examen microbiologique des eaux destinées à la consommation humaine, il convient de rechercher, outre les germes figurant au tableau E, les germes pathogènes, en particulier :
— les salmonelles,
— les staphylocoques pathogènes,
— les bactériophages fécaux,
— les entérovirus.

Par ailleurs, ces eaux ne devraient contenir :
— ni d'organismes parasites,
— ni d'algues,
— ni d'autres éléments figurés (animalcules).

(1) *Sous réserve qu'un nombre suffisant d'échantillons soit examiné (95 % des résultats conformes).*

Paramètres		Résultats : volumes de l'échantillon (en ml)	Niveau guide	Concentration maximale admissible	Observations
61 Dénombrement des germes totaux pour les eaux livrées à la consommation	37 °C	1	10 (1) (2)	—	
	22 °C	1	100 (1) (2)	—	

(1) *Pour les eaux désinfectées les valeurs correspondantes doivent être nettement inférieures à la sortie de la station de traitement.*
(2) *Tout dépassement de ces valeurs persistant au cours de prélèvements successifs doit donner lieu à vérification.*

Paramètres		Résultats : volumes de l'échantillon (en ml)	Niveau guide	Concentration maximale admissible	Observations
62 **Dénombrement des germes totaux *pour les eaux* conditionnées**	37 °C	1	5	20	Les États membres peuvent, sous leur responsabilité, lorsque sont respectés les paramètres 57,58,59 et 60 et en l'absence de germes pathogènes, conditionner, pour leur usage interne, des eaux dont le dénombrement des germes totaux dépasse les valeurs de concentration maximale admissible prescrites pour le paramètre 62. Les valeurs de concentration maximale admissible doivent être mesurées dans les 12 heures suivant le conditionnement, l'eau des échantillons étant maintenue à une température constante pendant cette période de 12 heures.
	22 °C	1	20	100	

F CONCENTRATION MINIMALE REQUISE POUR LES EAUX LIVRÉES A LA CONSOMMATION HUMAINE ET AYANT SUBI UN TRAITEMENT D'ADOUCISSEMENT

Paramètres	Expression des résultats	Concentration minimale requise (eaux adoucies)	Observations
1 **DURETÉ TOTALE**	mg/l Ca	60	Calcium ou cations équivalents
2 **CONCENTRATION EN IONS HYDROGENE**	pH		l'eau ne devrait pas être agressive.
3 **ALCALINITÉ**	mg/l HCO_3	30	
4 **OXYGENE DISSOUS**			

NB – Les dispositions relatives à la dureté, à la concentration en ions hydrogène, à l'oxygène dissous et au calcium s'appliquent aussi aux eaux provenant de dessalement.

Si, du fait de sa dureté naturelle excessive l'eau est adoucie conformément au tableau F, avant d'être livrée à la consommation, sa teneur en sodium peut, dans des cas exceptionnels, être supérieure aux valeurs figurant dans la colonne des concentrations maximales admissibles. On s'efforcera toutefois de maintenir cette teneur à un niveau aussi bas que possible et il ne pourra pas être fait abstraction des impératifs imposés par la protection de la santé publique.

ANNEXE

ANALYSES TYPES
(Circulaire du 15 mars 1962)

TYPE I — Analyse complète	Type II — Analyse sommaire ou de surveillance	TYPE III — Analyse de surveillance réduite
Analyse bactériologique :	**Analyse bactériologique :**	**Analyse bactériologique :**
— Dénombrement des germes. — Recherche et dénombrement des coliformes avec identification de l'Escherichia Coli. — Recherche et dénombrement des streptocoques fécaux. — Recherche et dénombrement des clostridium sulfito-réducteurs.	— Denombrement des germes. — Recherche et dénombrement des coliformes avec identification de l'Escherichia Coli. — Recherche et denombrement des clostridium sulfito-réducteur en cas d'eau traitée ou recherche et dénombrement des streptocoques fécaux en cas d'eau non traitée.	— Recherche et dénombrement des coliformes avec identification de l'Escherichia Coli. — Recherche et dénombrement des clostridium sulfito-réducteurs en cas d'eau traitée ou recherche et dénombrement des streptocoques fécaux en cas d'eau non traitée.
Examen physique :	**Examen physique :**	**Examen physique :**
Température, turbidité, résistivité électrique, pH, couleur, odeur. saveur, pouvoir colmatant	— Turbidité, résistivité électrique, pH, couleur, odeur, saveur.	— Mesure de la résistivité électrique.
Analyse chimique :	**Analyse chimique :**	
- Oxygène cédé par $KMnO_4$ à chaud en milieu alcalin, dureté totale, titre alcalimétrique complet silice, anhydride carbonique hydrogène sulfuré. oxygène dissous. chlore libre. résidu sec à 105°-110°C et 500°C, essai au marbre. - Calcium, magnésium, ammonium, sodium, potassium, fer, manganèse, aluminium. Carbonates, bicarbonates, chlorures, sulfates, nitrites, nitrates. phosphates.	— Oxygène cédé par $KMnO_4$ à chaud en milieu alcalin, durete totale. titre alcalimétrique complet. ammoniaque. nitrites. nitrates, chlorures, sulfates, fer.	

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No. 9 PNUE: Programme coordonné de surveillance continue et de recherche en matière de pollution dans la Méditerranée (MED POL - PHASE I). Rapport final. 1975 - 1980. MAP Technical Reports Series No. 9. UNEP, Athens 1986.

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