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UNEP

PROCEEDINGS

OF THE EXPERT GROUP MEETING ON
THE IMPLICATIONS OF

AGENDA 21

FOR INTEGRATED WATER MANAGEMENT
IN THE ESCWA REGION

Amman, 2-5 October 1995

UNITED NATIONS

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Foreword

Ever since the text of principles and guidelines were agreed upon at the United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil, during the first half of June 1992, the concept of sustainable development and awareness of environmental degradation have gained an unprecedented momentum at both the local and global levels. Indeed, in reaffirming previous declarations on environment and recognizing the high price of the world's self-consumptive activities, Rio Declaration on Environment and Development was a historic turning point towards more balanced, equitable and safer exploitation of the earth's limited and depletable natural resources.

Faced with such crucial issues and pressing problems stemming from impoverishment and poorly managed ecosystems in so many countries, the Governments represented at the United Nations Conference on Environment and Development had no other alternative but to agree on a clearly spelled out programme of action based on integration of environment and development. It is in this context that Agenda 21 was formulated and then endorsed by more than 178 countries.

Undoubtedly, the achievement of the goals set in the action-oriented chapters of Agenda 21 depends on how much resources the Governments can make available and the extent to which the national plans and policies are appropriately designed and implemented. This is mainly because there are reasons to question the commitment to meet the huge cost of protecting the environment and to deal with the often disastrous effects of disregarding the need for environmentally sound management of natural resources. Concerted action on the part of Governments as well as funding agencies is therefore a *sine qua non* for the fulfilment of Agenda 21's objectives, particularly as far as the developing countries are concerned.

Regional and international organizations can be of immense help in supplementing the necessary means to confront the challenges addressed by the various chapters of Agenda 21, promoting close cooperation among States and securing, to the extent possible, avenues to success in the implementation of national plans. A case in point is the close cooperation between the ESCWA secretariat and UNEP, of which the project on the implications of Agenda 21 for integrated water management in Western Asia is among the salient examples.

ESCWA is indebted to UNEP and its staff, not only for the support provided from the beginning of the project until the last stage of its implementation, but also for agreeing to select chapter 18 of Agenda 21 on "Protection of the quality and supply of freshwater resources: application of integrated approaches to the development, management and use of water resources". The paramount importance of water management to growth and development in Western Asia calls for a joint vision to seek rational solutions at the national, regional and international levels.

In examining the report and the papers included in the present publication, I was impressed by the outcome of the cooperation between ESCWA and UNEP. There was scarcely any issue of importance to the development and management of water resources that escaped the attention of the experts who took part in the preparation of documents and the deliberations of the Expert Group Meeting.

By making this publication available to a wider audience within and outside our region, we hope that similar approaches will be developed and closer regional and international cooperation will be established and maintained. However, any remarks or suggestions towards improvement or correction will be seriously taken into consideration by the ESCWA secretariat, not only as regards this work but also our future activities.

Hazem El-Beblawi
Executive Secretary

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ANNEXES

Abbreviations

ACSAD	Arab Centre for the Studies of Arid Zones and Dry Lands
AFESD	Arab Fund for Economic and Social Development
ALESCO	Arab League Educational, Cultural and Scientific Organization
ASCEND21	An Agenda of Science for Environment and Development into the 21st Century, ICSU Conference, Vienna, November 1991
AWSA	Amman Water Supply and Sewerage Authority
BCM	Billion cubic metres
BGR	Federal Institute for Geosciences and Natural Resources/Germany
CM	Cubic metre
EMINWA	Environmentally Sound Management of Inland Water
ESCAP	Economic and Social Commission for Asia and the Pacific
ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agricultural Organization of the United Nations
FD	Freeze Desalination
GCC	Gulf Cooperation Countries
GEMS	Global Environmental Monitoring System (UNEP)
GEMS/WATER	Global Water Quality Monitoring Programme
GIS	Geographical Information Systems
GRID	Global Resource Information Database
ha	hectare
IAEA	International Atomic Energy Agency
IAP-WASAD	International Action Programme on Water and Sustainable Agricultural Development
ICSU	International Council of Scientific Unions
ICWE	International Conference on Water and the Environment; Development Issues for the 21st Century, Dublin; January, 1992
KFAED	Kuwait Fund for Arab Economic Development.
Km	Kilometre
Km^2	Square kilometres
Km^3	Cubic kilometres
l/c/d	Litres per capita per day
l/d	Litres per day
L	Litre
m	Metres
m^3/s	Cubic metres per second
MCM	Million cubic metres
MCM/a	Million cubic metres per annum
MED	Multi-effect Distillation
METAP	Mediterranean Environmental Technical Assistance Programme
mg	Milligrams
mgd	Million gallons per day

Abbreviations (*continued*)

ml	Millilitres
mm/a	Millimetres per annum
mm	Millimetres
MSF	Multi-Stage Flash
MSS	Multi-Spectral Scanned Sensing
NOAA-AVHRR	National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer
PPM	Parts per million
RO	Reverse Osmosis
ROSTAS	Regional Office for Science and Technology for the Arab States
TDS	Total Dissolved Solids
UNCED	United Nations Conference on Environment and Development, Rio de Janeiro, June 1992
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UNWC	United Nations Water Conference
μg	Microgram
μm	Micrometer
μS	Microsiemens
VC	Vapour Compression
WB	World Bank
WHO	World Health Organization
WMO	World Meteorological Organization
WRAP	Water Resources Assessment Project (Yemen)
WRDM	Water Resources Development and Management
WRM	Water Resources Management

I. REPORT OF THE EXPERT GROUP MEETING ON THE IMPLICATIONS OF AGENDA 21 FOR INTEGRATED WATER MANAGEMENT IN THE ESCWA REGION*
Amman, 2-5 October 1995

A. ORGANIZATION OF WORK

1. The Expert Group Meeting on the Implications of Agenda 21 for Integrated Water Management in the ESCWA Region was held in Amman from 2 to 5 October 1995. It was jointly sponsored by the United Nations Economic and Social Commission for Western Asia (ESCWA) and the United Nations Environment Programme (UNEP) as a follow-up activity to implement the recommendations of chapter 18 and other water-related chapters of Agenda 21 in the ESCWA region.

2. The Meeting was attended by government-designated experts on water and environment. Representatives of several regional and international organizations also attended the Meeting (see list of participants in annex I).

3. The documentation of the Meeting consisted of background documents prepared by the ESCWA secretariat; a document prepared by a consultant on behalf of UNEP; country papers prepared by government-designated experts; and papers prepared by United Nations, regional and international organizations (see list of documents in annex II).

4. The Meeting was convened under the patronage of His Excellency Mr. Salih Irsheidat, Minister of Water and Irrigation of the Hashemite Kingdom of Jordan. The Meeting was opened with an address by the Chief of the Energy, Natural Resources and Environment Division of ESCWA.

5. In his statement, the representative of UNEP enumerated the programme areas under chapter 18 of Agenda 21 and stressed the need for evaluating the status of its implementation on a regional basis. He also briefed the audience on the regional workshops jointly sponsored by UNEP, its regional offices and the United Nations regional commissions.

6. In addressing the Meeting, the Executive Secretary of ESCWA expressed his gratitude to the Minister of Water and Irrigation of Jordan for accepting the invitation from ESCWA to take part in the opening session. He also welcomed the participants and expressed his appreciation to UNEP for their cooperation in co-financing and convening the Meeting and for their support of the ongoing ESCWA/UNEP joint activity on the use of remote-sensing techniques in the assessment of water resources in the ESCWA region.

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* This paper was originally issued under the symbol E/ESCWA/ENR/1995/WG.1/20/Rev.1.

7. Referring to the purpose of the Meeting, the Executive Secretary stressed that it was arranged to discuss one of the most important chapters of Agenda 21, at least with regard to the ESCWA region, namely chapter 18, which dealt with the quality and quantity of the freshwater supply and the management of water resources. The importance of the chapter lay in its emphasis on an integrated approach for the development, management and utilization of water resources. He highlighted the main topics of the documents prepared by the secretariat of ESCWA, which provided background material on the chapters of Agenda 21 relevant to the development and management of water resources in the region.

8. His Excellency Mr. Salih Irsheidat, Minister of Water and Irrigation of Jordan, called for closer regional cooperation in order to make available the necessary requirements for facing water shortages. He emphasized that regional cooperation would assist countries in dealing with water supply limitations to overcome difficulties resulting from tensions over water. On the national level, there were many activities in the Ministry of Water and Irrigation that needed to be implemented, such as the formulation of a comprehensive national water strategy and policies, updating of the water master plan, and carrying out a conservation and national public awareness campaign.

9. The participants in the Meeting elected the following officers:

Chairman, Bassam Adib Jabir (Lebanon);
Vice-Chairman, Mohammed Al-Iryani (Yemen);
Rapporteur, Nadia Al-Jawhari (Jordan).

10. The Meeting adopted the agenda and the programme of work with slight changes regarding the timing of the sessions and the sequence of presentations (see annexes III and IV).

B. ACCOUNT OF PROCEEDINGS

11. Ten documents, including the paper prepared by the UNEP consultant, were presented by the secretariat of ESCWA as background material covering various programme areas of chapter 18 and other water-related chapters under Agenda 21.

(a) The first paper addressed the concept of integrated water resources management as outlined in Agenda 21. The paper also contained ideas and specific suggestions for national work programmes and recommendations for the inclusion of the objectives of Agenda 21 in national water plans in the ESCWA region.

(b) The second paper was devoted to methodologies for preparation of water master plans.

(c) In view of the importance of regional cooperation in developing national technical skills, the third paper concentrated on suggestions regarding the establishment of a regional training network in different areas of water management.

(d) Owing to the complexity of water quality issues, three papers were presented on the assessment and control of water quality, the increasing groundwater salinity, and identification of water quality indicators.

(e) In the seventh paper, special emphasis was placed on the applications of advanced technologies in the assessment, development and monitoring of water resources. The paper addressed the application of isotope techniques in applied hydrology and the progress achieved by ESCWA member States in that field, as did the eighth paper, which included comparative studies of selected water basins in the ESCWA region using remote-sensing techniques.

(f) The ninth paper addressed technical and economic aspects of water desalination and reviewed the potential of as well as the constraints on water desalination techniques currently in use, compared with other water resources.

(g) The last paper reviewed the low-cost wastewater treatment using filtration techniques from groundwater recharge basins and its recovery and reuse for agricultural and industrial purposes.

12. The country papers presented by the government-designated experts focused on the respective national experiences in the implementation of different water-related components of Agenda 21, through their master water plans and/or other water resources development programmes. Most of the country papers reviewed the situation pertaining to the availability of water resources and covered issues related to water supply and demand.

13. In general, papers from countries in the northern part of the ESCWA region reflected reliance on surface water and, to a limited extent, on shallow groundwater in meeting domestic and irrigation requirements, while the southern part of the region appeared to depend heavily on desalination and shallow and deep groundwater reserves.

14. The presentation of the country papers revealed that the degree of implementation of programme areas under chapter 18 of Agenda 21 differed widely from one country to another. Some countries geared their efforts to water resources assessment, protection of water quality and sustainable urban development through adequate water supply, while water policies of other countries concentrated on improvement of drinking-water and sanitation, and sustainable utilization of groundwater.

15. Achievements in the implementation of Agenda 21 appeared to vary throughout the region owing to differences in the availability of financing resources for executing water projects, the availability of skilled manpower, and the utilization of appropriate technologies and institutional capabilities.

16. Papers presented by the representatives of regional and international organizations described the role of those organizations in promoting the development of the water sector, with particular emphasis on the implementation of various programme areas of Agenda 21. The presentations highlighted such crucial issues as training activities to upgrade manpower capabilities, mainly in the field of wastewater and environmental health; potential role and contributions of isotope methods in the water sector; technical and financial support for more effective water policies, institutional reforms, and water supply and sanitation improvement; the role of the World Hydrological Cycle Observation System (WHYCOS) in the improvement of collection, dissemination, standardization and use of hydrological information at the national, regional and international levels; and identification of quantified criteria for the use of more efficient methods for balancing water supply and demand, taking into account water contributions to overall socio-economic development.

17. The participants recognized that the water situation in the ESCWA region was becoming more and more serious. The ESCWA region consisted mostly of arid and semi-arid zones and therefore faced chronic water shortages with marked deficiencies in the management of the available water resources. The region was in urgent need of a long-term vision considering future prospects within the framework of overall socio-economic development and closer subregional, regional and international cooperation.

18. In many ESCWA member countries substantial technical and financial assistance was required for the proper implementation of Agenda 21.

C. CONCLUSIONS AND RECOMMENDATIONS

19. The Expert Group Meeting reviewed the efforts made in the ESCWA member countries in implementing the activities identified in chapter 18 of Agenda 21. The Meeting recognized with appreciation the importance and relevance of the documents prepared by the ESCWA secretariat, the national experts and those presented by the representatives of other United Nations, regional and international agencies.

20. The Meeting acknowledged that, in spite of the progress so far achieved by ESCWA member countries, intensive efforts were still needed to fulfil the objectives of Agenda 21 for integrated management of water resources. The Meeting noted the following in particular:

(a) The continued seriousness of the water situation in the ESCWA member countries;

(b) Water scarcity, increasing pollution, and uneven distribution of water;

(c) Inappropriate allocation of water among various sectors in many countries;

(d) Fragmented institutional and organizational framework with overlapping functions and lack of coordination, in some ESCWA member countries;

(e) Inadequate water legislation and/or insufficient enforcement of existing rules and regulations;

(f) The need to make a clear distinction between water assessment, planning and resource management functions on the one hand, and the operational development and water use functions on the other hand;

(g) The need for closer cooperation for the development and exploitation of shared water resources among the ESCWA member countries, and on the international level;

(h) Inadequate and unreliable databases in several ESCWA member countries;

(i) Financial constraints in most of the ESCWA member countries with respect to the support of integrated water management projects;

(j) Shortage of qualified personnel in the water sector in some of the ESCWA member countries;

(k) Lack of comprehensive water master plans and national water policies in most of the ESCWA member countries;

(l) Persistence of many difficulties in the implementation of water conservation programmes in the ESCWA member countries.

21. Therefore, the Meeting recommended the following:

(a) For the consideration of member States

(i) The Meeting called on the concerned government authorities: to gear their efforts towards sustainable socio-economic development through integrated water management, taking into account the interrelationship of water resources and environmental issues;

(ii) To activate the preparation and/or updating of national water master plans, emphasizing the integrated approach to water resources development and management. The master plan should include alternative scenarios, taking into account possible climatic change;

(iii) To conduct systematic and comprehensive water resources assessments, as such assessments would furnish the basic information for any current and future water plans and strategies;

(iv) To seek all possible approaches to develop shared water resources by means of clear and well-defined water agreements;

(v) To develop and apply water quality and water supply criteria for public health protection, and the maintenance of ecosystems;

(vi) To improve efforts to inform decision makers, and the public at large, about the critical situation in the water sector, resulting from the inefficient water utilization, and deterioration of water quantity and quality;

(vii) To promote capacity-building programmes in the field of water resources and to strengthen the relevant institutional framework to ensure adequate training of personnel at all levels;

(viii) To promote and enhance the exchange of technical and scientific experience among ESCWA member countries and at international levels;

(ix) To promote more effective use of modern technology, such as telemetry, remote-sensing, isotope hydrology, GIS (Geographic Information System), and modelling techniques, in hydrological and hydrogeological assessment, development, and integrated management;

(x) To coordinate the functions of the different entities concerned for ensuring the integration of environmental considerations in national water strategies in order to achieve overall sustainable socio-economic development;

(xi) To improve water demand management including water allocations among different sectors;

(xii) To encourage and strengthen water conservation programmes by all available means, including financial incentives, regulatory and technical measures;

(xiii) To promote and conduct research pertaining to the use of brackish water for agricultural activities and to encourage the reuse of treated wastewater and agricultural drainage water in accordance with national and international criteria;

(xiv) To encourage research and development to reduce sea and brackish water desalination costs;

(xv) To participate actively in the formulation and adoption of international resolutions on water issues;

(xvi) To enhance cooperation and coordination in the field of water resources development and management among ESCWA member countries.

(b) Recommendation to regional and international organizations

(i) To provide technical assistance to facilitate the formulation of national water policies in the ESCWA member countries in need of such assistance;

(ii) To request donors to provide new and additional funds for the implementation of the various programme areas of chapter 18 of Agenda 21, particularly for water resources development in countries faced with financial constraints;

(iii) To contribute to the promotion and development of the World Hydrological Cycle Observations System components within the ESCWA region for the benefit of the countries, and of the regional and international communities, in cooperation with the regional and international organizations involved in the water sector;

(iv) To organize and sponsor ad hoc training courses in line with the main components of each programme area of chapter 18 of Agenda 21, taking into account existing capabilities in the ESCWA member countries;

(v) To follow up on the implementation of the various components of Agenda 21 through the organization of seminars, workshops and meetings to identify any potential technical constraints that might hamper the progress of activities;

(vi) To enhance cooperation and coordination in the field of water resources among regional and international organizations through the pooling of resources and undertaking of joint activities.

تقرير الاجتمـــاع

ألف- تنظيم الأعمال

١- عقد اجتماع فريق الخبراء المعني بأثر تطبيق جدول أعمال القرن ٢١ في إدارة المياه المتكاملة في منطقة الإسكوا في عمَّان، الأردن، خلال الفترة من ٢ الى ٥ تشرين الأول/أكتوبر ١٩٩٥. واشترك في رعاية هذا الاجتماع اللجنة الاقتصادية والاجتماعية لغربي آسيا (الإسكوا) وبرنامج الأمم المتحدة للبيئة (اليونيب)، وذلك في إطار متابعة تنفيذ توصيات الفصل ١٨ وغيره من الفصول المتعلقة بالمياه من جدول أعمال القرن ٢١ في منطقة الإسكوا.

٢- وحضر هذا الاجتماع خبراء في مجالي المياه والبيئة عينتهم الحكومات. كما حضره ممثلون عن عدة منظمات اقليمية ودولية (ترد قائمة المشاركين في المرفق الأول).

٣- وكانت وثائق الاجتماع تتألف من الوثائق الأساسية التالية التي أعدتها أمانة الإسكوا: وثيقة أعدها خبير استشاري لحساب اليونيب، وورقات قطرية أعدها الخبراء الذين عينتهم الحكومات، ودراسات أعدتها الأمم المتحدة ومنظمات اقليمية ودولية (ترد قائمة الوثائق في المرفق الثاني).

٤- وعقد اجتماع فريق الخبراء تحت رعاية معالي وزير المياه والري بالمملكة الأردنية الهاشمية، السيد صالح ارشيدات. واستُهلت الجلسة الافتتاحية للاجتماع بكلمة ترحيب ألقاها رئيس شُعبة الطاقة والموارد الطبيعية والبيئة بالإسكوا.

٥- وسرد ممثل اليونيب في كلمته المجالات البرنامجية التي يشتمل عليها الفصل ١٨ من جدول أعمال القرن ٢١ وأكد على ضرورة تقييم حالة تنفيذه على أساس إقليمي. كما أطلع الحضور على ورشات العمل الاقليمية التي اشترك في رعايتها اليونيب ومكاتبه الاقليمية واللجان الاقليمية للأمم المتحدة.

٦- وأعرب الأمين التنفيذي للإسكوا عن امتنانه لوزير المياه والري في الحكومة الاردنية لقبوله دعوة الإسكوا للمشاركة في الجلسة الافتتاحية. كما رحب بالمشاركين وأعرب عن تقديره لليونيب لتعاونه في تمويل وعقد الاجتماع ولدعمه النشاط المشترك بينه وبين الإسكوا في مجال استخدام تقنيات الاستشعار عن بُعد في تقييم الموارد المائية في منطقة الإسكوا.

٧- وشدد الأمين التنفيذي على أن الهدف من هذا الاجتماع هو مناقشة واحد من أهم فصول جدول أعمال القرن ٢١، على الأقل بالنسبة لمنطقة الإسكوا، ألا وهو الفصل ١٨ الذي يتناول نوعية وكمية إمدادات المياه العذبة وإدارة الموارد المائية. وأوضح أن أهمية هذا الفصل تكمن في تركيزه على نهج متكامل لتنمية الموارد المائية وإدارتها واستخدامها. كما ألقى الضوء على المواضيع الرئيسية التي تتناولها الوثائق التي أعدتها أمانة الإسكوا والتي تتضمن مواد أساسية عن فصول جدول أعمال القرن ٢١ المتعلقة بتنمية وإدارة الموارد المائية في المنطقة.

٨- ودعا معالي وزير المياه والري في الحكومة الاردنية، السيد صالح أرشيدات، الى توثيق التعاون الاقليمي من أجل توفير ما يلزم لمواجهة النقص في المياه. وأكد أن التعاون الاقليمي

من شأنه أن يساعد البلدان في معالجة مشكلة النقص في إمدادات المياه والتغلب على التوترات الناشئة عن ذلك. وأضاف قائلاً ان هناك على المستوى الوطني كثيرا من الأنشطة في وزارة المياه والري التي ينبغي تنفيذها مثل صياغة استراتيجية وسياسات وطنية شاملة للمياه، وتحديث الخطة الرئيسية للمياه، والقيام بحملة وطنية للحث على حفظ المياه وارهاف الوعي العام.

٩- وانتخب المشاركون في الاجتماع أعضاء المكتب التالية أسماؤهم:

- السيد بسام أديب جابر (لبنان)، رئيسا؛
- السيد محمد الارياني (اليمن)، نائبا للرئيس؛
- الآنسة نادية الجوهري (الأردن)، مقررا.

١٠- وأقر الاجتماع جدول الأعمال وبرنامج العمل بعد ادخال تعديلات طفيفة على مواعيد الجلسات وترتيب العروض (كما هو مبيَّن في المرفقين الثالث والرابع).

باء- وقائع جلسات عمل الاجتماع

١١- قدمت أمانة الإسكوا عشر وثائق بما فيها الوثيقة التي أعدها الخبير الاستشاري لليونيب باعتبارها مواد أساسية تغطي مختلف المجالات البرنامجية التي يشتمل عليها الفصل ١٨ والفصول الأخرى المتعلقة بالمياه من جدول أعمال القرن ٢١.

(أ) وتناولت الورقة الأولى مفهوم الإدارة المتكاملة للموارد المائية كما هو مبيَّن في جدول أعمال القرن ٢١. كما تتضمن الدراسة أفكارا ومقترحات محددة تتعلق ببرامج العمل الوطنية وكذلك توصيات تتعلق بإدراج أهداف جدول أعمال القرن ٢١ في خطط المياه الوطنية في منطقة الإسكوا؛

(ب) وخصصت الورقة الثانية لمنهجيات إعداد خطط المياه الرئيسية؛

(ج) ونظرا لأهمية التعاون الاقليمي في تطوير المهارات التقنية الوطنية، فقد ركزت الورقة الثالثة على مقترحات تتعلق بانشاء شبكة تدريب اقليمية في مختلف مجالات إدارة المياه؛

(د) ونظرا للتعقيد الذي تتسم به المسائل المتعلقة بنوعية المياه، فقد قدمت ثلاث ورقات تتعلق بتقييم ومراقبة نوعية المياه، وارتفاع درجة ملوحة المياه الجوفية وتحديد مؤشرات لنوعية المياه؛

(هـ) وركزت الورقة السابعة بصفة خاصة على تطبيقات التكنولوجيات المتقدمة في تقييم وتنمية ورصد الموارد المائية كما تناولت موضوع تطبيق تقنيات النظائر المشعة في الهيدرولوجيا التطبيقية وأوضحت التقدم الذي أحرزته بلدان الإسكوا في هذا المجال، شأنها في ذلك شأن الورقة الثامنة التي تضمنت دراسات مقارنة لأحواض مائية مختارة في منطقة الإسكوا أجريت باستخدام تقنيات الاستشعار عن بعد؛

(و) وتناولت الورقة التاسعة الجوانب الفنية والاقتصادية لتحلية المياه واستعرضت الامكانيات وكذلك القيود التي تنطوي عليها التقنيات المستخدمة حاليا في تحلية المياه، بالمقارنة مع الموارد المائية الأخرى؛

(ز) وناقشت الورقة الأخيرة المعالجة المنخفضة الكلفة للمياه المستعملة باستخدام تقنيات الترشيح من أحواض تغذية المياه الجوفية واستخلاص تلك المياه واعادة استخدامها في الأغراض الزراعية والصناعية.

١٢- وركزت الأوراق القطرية التي قدمها الخبراء المعنيون من قبل الحكومات على التجارب الوطنية في تنفيذ مختلف عناصر جدول أعمال القرن ٢١ المتعلقة بالمياه من خلال خططها الرئيسية للمياه و/أو غيرها من برامج تنمية الموارد المائية. ووصفت معظم الأوراق القطرية الحالة فيما يتعلق بتوفر الموارد المائية وبحثت بالتفصيل مسائل تتعلق بامدادات المياه والطلب عليها.

١٣- وبوجه عام، أظهرت الورقات المقدمة من البلدان في الجزء الشمالي من منطقة الإسكوا اعتماداً على المياه السطحية وبدرجة أقل على المياه الجوفية الضحلة في تلبية الاحتياجات المحلية وفي الري في حين أن الجزء الجنوبي من المنطقة يعتمد اعتماداً كبيراً فيما يبدو على التحلية وعلى احتياطيات المياه الجوفية الضحلة والعميقة.

١٤- واتضح من عرض الأوراق القطرية أن درجة تنفيذ المجالات البرنامجية التي يشتمل عليها الفصل ١٨ من جدول أعمال القرن ٢١ تختلف اختلافاً كبيراً من بلد الى آخر. فبعض البلدان توجه جهودها نحو تقييم الموارد المائية وحماية نوعية المياه والتنمية الحضرية المستدامة من خلال تأمين امدادات المياه الكافية في حين تركز السياسات التي تنتهجها البلدان الاخرى في مجال المياه على تحسين مياه الشرب والمرافق الصحية والاستخدام المستدام للمياه الجوفية.

١٥- ويبدا أن الانجازات التي تم تحقيقها في تنفيذ جدول أعمال القرن ٢١ تختلف من بلد الى آخر نظراً للتفاوت في درجة توفر الموارد المالية اللازمة لتنفيذ المشاريع المائية والقوى العاملة الماهرة، وفي استخدام التكنولوجيات الملائمة والقدرات المؤسسية.

١٦- ووصفت الورقات التي قدمها ممثلو المنظمات الاقليمية والدولية دور هذه المنظمات في تعزيز تنمية قطاع المياه مع التركيز بصفة خاصة على تنفيذ مختلف المجالات البرنامجية لجدول أعمال القرن ٢١. وركزت العروض الأضواء بصفة خاصة على مسائل أساسية مثل أنشطة التدريب لتحسين مستوى قدرات القوى العاملة، لا سيما في مجال المياه المستعملة والصحة البيئية؛ والدور الذي يمكن أن تلعبه تقنيات النظائر المشعة في قطاع المياه؛ والدعم الفني والمالي اللازم لزيادة فعالية سياسات المياه، والاصلاحات المؤسسية، وتحسين امدادات المياه والمرافق الصحية، ودور نظام المراقبة العالمي لعناصر الدورة الهيدرولوجية في تحسين جمع ونشر وتوحيد واستخدام المعلومات الهيدرولوجية على الأصعدة الوطنية والاقليمية والدولية؛ وتحديد معايير كمية لاستخدام طرق أكثر فعالية لتحقيق التوازن بين امدادات المياه والطلب عليها، مع مراعاة مساهمة المياه في التنمية الاجتماعية الاقتصادية الشاملة.

١٧- واعترف المشاركون بأن وضع المياه في منطقة الإسكوا يزداد سوءاً. فمنطقة الإسكوا تتكون في معظمها من مناطق قاحلة وشبه قاحلة وتواجه بالتالي نقصاً مزمناً في المياه مع قصور واضح في ادارة الموارد المائية المتاحة. والمنطقة الآن بحاجة ماسة الى تصور طويل الأجل يأخذ في الاعتبار آفاق المستقبل في اطار التنمية الاجتماعية الاقتصادية الشاملة وتعاون أوثق على الصعد دون الاقليمية والاقليمية والدولية.

١٨- كثير من بلدان الإسكوا تحتاج الى مساعدة فنية ومالية هامة لتنفيذ جدول أعمال القرن ٢١ على النحو اللازم.

جيم- الاستنتاجات والتوصيات

١٩- استعرض اجتماع فريق الخبراء الجهود المبذولة في بلدان الإسكوا من أجل تنفيذ الأنشطة المحددة في الفصل ١٨ من جدول أعمال القرن ٢١، واعترف مع التقدير بأهمية الوثائق التي أعدتها أمانة الإسكوا والخبراء الوطنيون وتلك التي قدمها ممثلو وكالات الأمم المتحدة الأخرى وغيرها من الوكالات الاقليمية والدولية.

٢٠- كما اعترف اجتماع فريق الخبراء بأنه على الرغم من التقدم الذي أحرزته حتى الآن بلدان الإسكوا، فإنه ما زالت هناك حاجة الى بذل جهود مكثفة لتحقيق أهداف جدول أعمال القرن ٢١ فيما يتعلق بالادارة المتكاملة للموارد المائية.

ولاحظ الاجتماع بصفة خاصة ما يلي:

(أ) الخطورة المستمرة لوضع المياه في بلدان الإسكوا؛

(ب) ندرة المياه، وتزايد التلوث، والتفاوت في توزيع المياه؛

(ج) التوزيع غير المناسب للمياه على مختلف القطاعات في الكثير من البلدان؛

(د) وجود إطار مؤسسي وتنظيمي مجزأ مع تداخل الوظائف وعدم التنسيق في بعض بلدان الإسكوا؛

(هـ) تشريعات غير ملائمة في مجال المياه و/أو تنفيذ غير كاف للقواعد والأنظمة القائمة؛

(و) الحاجة الى التمييز بصورة واضحة بين وظائف تقييم الموارد المائية وتخطيطها وادارتها من جهة وبين تنميتها بالفعل واستخدامها، من جهة أخرى؛

(ز) الحاجة الى توثيق التعاون بين بلدان الإسكوا وعلى المستوى الدولي من أجل تنمية واستغلال الموارد المائية المشتركة؛

(ح) وجود قواعد بيانات غير كافية وغير مأمونة في عدد من بلدان الإسكوا؛

(ط) وجود قيود مالية في معظم بلدان الإسكوا فيما يتعلق بدعم مشاريع الادارة المتكاملة للمياه؛

(ي) نقص الموظفين المؤهلين في قطاع المياه في بعض بلدان الإسكوا؛

(ك) عدم وجود خطط رئيسية وشاملة للمياه وسياسات وطنية خاصة بالمياه في معظم بلدان الإسكوا؛

(ل) استمرار وجود كثير من الصعوبات في تنفيذ برامج حفظ المياه في بلدان الإسكوا.

٢١- وبالتالي، أوصى اجتماع فريق الخبراء بما يلي:

(أ) بالنسبة للسلطات المعنية في الدول الأعضاء:

'١' توجيه الجهود نحو التنمية الاجتماعية الاقتصادية عن طريق الادارة المتكاملة للمياه، مع مراعاة الترابط القائم بين الموارد المائية والقضايا البيئية؛

'٢' تنشيط اعداد و/أو تحديث خطط وطنية رئيسية للمياه والتأكيد على اتباع نهج متكامل في تنمية الموارد المائية وادارتها. وينبغي أن تشتمل الخطة الرئيسية على سيناريوهات تأخذ في الاعتبار التغير الذي يمكن ان يطرأ على المناخ؛

'٣' اجراء تقييمات منهجية وشاملة للموارد المائية حيث أن هذه التقييمات ستوفر المعلومات الأساسية اللازمة لخطط واستراتيجيات المياه الحالية والمقبلة؛

'٤' استطلاع كل الطرق الممكنة لتنمية الموارد المائية المشتركة بواسطة اتفاقات واضحة ومحددة في مجال المياه؛

'٥' وضع وتطبيق معايير خاصة بنوعية المياه وإمداداتها لحماية الصحة العامة وحفظ النظم الايكولوجية؛

'٦' تكثيف الجهود لاطلاع مقرري السياسة والجمهور عامة على خطورة الوضع في قطاع المياه والناشئة عن عدم كفاءة استخدام المياه وتدهور المياه كما ونوعا؛

‘٧‘ النهوض ببرامج بناء القدرات في مجال الموارد المائية وتدعيم الاطار المؤسسي ذي الصلة لتوفير التدريب الملائم للموظفين على جميع المستويات؛

‘٨‘ تشجيع وزيادة تبادل الخبرات الفنية والعلمية بين بلدان الإسكوا وعلى المستوى الدولي؛

‘٩‘ تشجيع الاستخدام الفعال للتكنولوجيا الحديثة مثل القياس عن بُعد، والاستشعار عن بُعد، والهيدرولوجيا القائمة على استخدام النظائر المشِعة، ونظام المعلومات الجغرافية، وتقنيات التنميط في التقييم الهيدرولوجي والهيدروجيولوجي وتنمية الموارد المائية وادارتها بصورة متكاملة؛

‘١٠‘ تنسيق وظائف مختلف الكيانات المعنية لضمان دمج الاعتبارات البيئية في استراتيجيات المياه الوطنية من أجل تحقيق تنمية اجتماعية اقتصادية مستدامة وشاملة؛

‘١١‘ تحسين ادارة الطلب على المياه بما في ذلك توزيع المياه على مختلف القطاعات؛

‘١٢‘ تشجيع ودعم برامج حفظ المياه بكل الوسائل المتاحة، بما في ذلك الحوافز المالية والتدابير التنظيمية والفنية؛

‘١٣‘ تشجيع واجراء بحوث تتعلق باستخدام المياه المالحة في الأنشطة الزراعية، وكذلك تشجيع اعادة استخدام المياه المستعملة ومياه الصرف الزراعية وفقاً للمعايير الوطنية والدولية؛

‘١٤‘ تشجيع البحث والتطوير لتخفيض تكاليف تحلية ماء البحر والمياه المالحة؛

‘١٥‘ المشاركة بفعالية في صياغة واعتماد قرارات دولية بشأن القضايا المتعلقة بالمياه؛

‘١٦‘ تعزيز التعاون والتنسيق فيما بين بلدان الإسكوا في مجال تنمية وادارة الموارد المائية.

(ب) بالنسبة للمنظمات الاقليمية والدولية:

‘١‘ تقديم المساعدة الفنية لتسهيل صياغة سياسات مائية وطنية في بلدان الإسكوا التي تحتاج الى مثل هذه المساعدة؛

'٢' دعوة المانحين الى تقديم أموال جديدة واضافية لتنفيذ مختلف المجالات البرنامجية التي يشتمل عليها الفصل ١٨ من جدول أعمال القرن ٢١، وبخاصة لتنمية الموارد المائية في البلدان التي تواجه قيوداً مالية؛

'٣' المساهمة في تعزيز وتطوير عناصر نظام المراقبة العالمي لعناصر الدورة الهيدرولوجية في منطقة الإسكوا لصالح البلدان والمجتمعات الاقليمية والدولية، وذلك بالتعاون مع المنظمات الاقليمية والدولية التي تقوم بأنشطة في قطاع المياه؛

'٤' تنظيم ورعاية دورات تدريبية مخصصة تمشياً مع العناصر الرئيسية لكل مجال من المجالات البرنامجية لجدول أعمال القرن ٢١، مع مراعاة القدرات الحالية في بلدان الإسكوا؛

'٥' متابعة تنفيذ العناصر المختلفة لجدول أعمال القرن ٢١ من خلال تنظيم حلقات دراسية وورشات عمل واجتماعات لتحديد القيود الفنية التي يمكن أن تعيق تقدم الأنشطة؛

'٦' تعزيز التعاون والتنسيق بين المنظمات الاقليمية والدولية في مجال الموارد المائية، وذلك من خلال جمع الموارد والاضطلاع بأنشطة مشتركة.

PART ONE

ESCWA PAPERS

II. IMPLICATIONS OF AGENDA 21 FOR INTEGRATED WATER MANAGEMENT IN THE ESCWA REGION*

by

Kamal Farid Saad

Introduction

Water in the Arab region, including the countries in the ESCWA region, is becoming scarce and its quality is deteriorating, owing mainly to demand exceeding supply. If the prevailing attitudes and patterns of water utilization remain unchanged, water problems will constitute major constraints and challenges facing overall economic and social development in the region. Therefore, immediate measures should be endorsed and action should be taken with a view to mitigating the impact of water shortages and deterioration of water quality, while maintaining an acceptable level of sustainable development.

In this regard, Agenda 21, particularly chapter 18 pertaining to water resources, offers a comprehensive blueprint for action to be taken by all countries. The contents of the Agenda were agreed upon by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED), known as the Earth Summit, held in Rio de Janeiro, Brazil, from 3 to 14 June 1992. Chapter 18 includes seven programme areas which give an integrated coverage for water resources issues and problems.

As both ESCWA and UNEP recognize the complexity of factors affecting the safety and sustainability of water resources in the ESCWA region, there is a need to identify the extent to which the objectives and activities of the various programme areas of chapter 18 of the Agenda have been incorporated in the national water policy of each country. To achieve this goal, ESCWA and UNEP invited the countries in the region to participate in an expert group meeting, which was held in Amman from 2 to 5 October 1995, with the attendance of 10 countries and regional and international organizations.

The present document, which incorporates the main findings of the country reports presented during the expert group meeting reviews the major components of Agenda 21 as applied in the ESCWA region. Section A of the present document gives a synopsis of the seven programme areas in respect of their basis for action and the major targets of each. While the actual Agenda 21 naturally contains more detailed information, the material presented herein allows the reader to become immediately

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* In the preparation of this document, Mr. Kamal Farid Saad served as a consultant to the Economic and Social Commission for Western Asia (ESCWA).

acquainted with the general background and scope of each programme area discussed in the present document.

Section B deals with the current status of water resources potentialities, in respect of their availability, and usage as well as future demand. This also shows the magnitude of the challenges confronting achievement of a water balance in the region. In addition, the main water constraints prevailing in each country of the region are listed. Accordingly, the effort that should be devoted to the water sector, aiming primarily at achieving an acceptable level of water and food security, can be depicted.

Section C gives the general features of the national water strategies and policies prevailing in the region as well as general regional reflections and principal indicators of the implications of the various programme areas of Agenda 21 for the countries of the ESCWA region.

Section D is devoted to the specific implications of each of the seven programme areas listed in chapter 18 of Agenda 21 for each of the countries of the ESCWA region. At the same time, it shows the extent to which these countries have incorporated the various objectives of the programme areas in their national water policies.

Section E gives conclusions and a number of recommendations addressed to international and regional agencies organizations and to the ESCWA member countries, including the researchers and planners responsible for the development and management of water resources.

A. THE PROGRAMME AREAS OF CHAPTER 18 OF AGENDA 21 ON PROTECTION OF QUALITY AND SUPPLY OF FRESHWATER RESOURCES

1. *Background*

In December 1989, the General Assembly called for a global conference that would devise strategies to halt and reverse the effects of environmental degradation in the context of increased national and international efforts to promote sustainable and environmentally sound development in all countries. Following the call declared by the General Assembly, a number of international meetings were held in order to make, *inter alia*, a contribution to the preparation for the United Nations Conference on Environment and Development (UNCED), which is known as the Earth Summit.

In this regard, two major particular conferences are cited. The first is the International Conference on an Agenda of Science for Environment and Development into the Twenty-first Century (ASCEND 21), which was convened by the International

Council of Scientific Unions (ICSU) in Vienna in November 1991. The second is the International Conference on Water and Environment (ICWE), which was held in Dublin in January 1992.

In the light of the outcome of the above-mentioned two major conferences, together with other ad hoc preparatory meetings, UNCED was held in Rio de Janeiro, Brazil, from 3 to 14 June 1992, with the participation of more than 178 Governments. The Conference adopted a programme of action for sustainable development worldwide, the Rio Declaration on Environment and Development, and the statement of principles for the sustainable management of forests. These documents comprise Agenda 21. In addition, the General Assembly, in response to a request from the Conference, established the Commission on Sustainable Development, made up of government representatives, for the purpose of examining progress made in implementing Agenda 21 globally. In this regard, UNEP has initiated a forum for government-designated experts to discuss the implications of Agenda 21 for integrated management and use of water resources. Consequently, several meetings were organized in cooperation with the United Nations regional commissions.

2. *Agenda 21*

Agenda 21 stands as a comprehensive blueprint for action to be taken globally into the twenty-first century, by Governments, United Nations organizations, development agencies, non-governmental organizations and independent-sector groups, in every area in which human activity has an impact on the environment. It addresses the pressing problems of today and also aims at preparing the world for the challenges of the next century.

Agenda 21 comprises four main sections covering the following programmes of action for sustainable development: (a) Social and Economic Dimensions; (b) Conservation and Management of Resources for Development; (c) Strengthening the Role of Major Groups; and (d) Means of Implementation. These four sections are divided into 40 chapters that contain a number of programme areas. Each programme area included in Agenda 21 is described in terms of basis for action, objectives, activities and means of implementation. Of particular interest to the ESCWA region are the programme areas dealing with protection and management of freshwater resources, which are found mainly in chapter 18 of Agenda 21.

3. *The programme areas of chapter 18 (freshwater sector)*

Chapter 18 of Agenda 21 deals specifically with the protection of the quality and supply of freshwater resources through the application of integrated approaches to the development, management and use of water resources. Seven programme areas are proposed for the freshwater sector:

(a) Integrated water resources development and management (WRDM);
(b) Water resources assessment (WRA);
(c) Protection of water resources, water quality and aquatic ecosystems;
(d) Drinking-water supply and sanitation;
(e) Water and sustainable urban development;
(f) Water for sustainable food production and rural development;
(g) Impact of climate change on water resources.

The objectives, activities and means of implementation of each of the above-mentioned programme areas are described in the final text of agreements signed by the Governments at UNCED. However, it was deemed necessary to quote the basis for action and major targets of each of these programme areas in order to allow for a systematic follow-up of the present document.

(a) *Integrated water resources development and management (WRDM)*

The basis for action of this programme area is associated with the holistic management of freshwater and the integration of sectoral water plans and programmes within the framework of national economic and social policy. The major targets of this programme area are the following:

(a) By the year 2000, designed and initiated costed and targeted national action programmes, and to have put in place appropriate institutional structures and legal instruments;

(b) By the year 2000, to have established efficient water-use programmes to attain sustainable resource utilization patterns;

(c) By the year 2025, to have achieved subsectoral targets of all freshwater programme areas.

(b) *Water resources assessment*

The basis for action of this programme area implies the identification of potential sources of freshwater, which comprises the continuing determination of sources, extent, dependability and quality of water resources, and of the human activities that affect these sources. Such water resources assessment constitutes the practical basis for their sustainable management and a prerequisite for evaluating the possibilities for their development. The major targets of this programme area are the following:

(a) By the year 2000, to have studied the feasibility of installing WRA services;

(b) As a long-term target, to have fully operational services.

(c) *Protection of water resources, water quality and aquatic ecosystems*

The basis for action of this programme is mainly the diversity of the causes of degradation of water quality and pollution of surface water and groundwater sources, along with the widespread lack of perception of the linkages between the development, management, use and treatment of water resources and aquatic systems. Therefore, a preventive approach is crucial so as to avoid costly subsequent rehabilitative, treatment and developmental measures. The major targets of this programme area are the following:

(a) Identification of surface water and groundwater resources that could be developed for use on a sustainable basis;

(b) Initiation of effective water pollution prevention and control programmes based on preset water quality criteria for various usages;

(c) Adoption of an integrated approach to environmentally sustainable management of water resources;

(d) Participation in international water-quality monitoring and management programmes, such as the Global Water Quality Monitoring Programme (GEMS/WATER), the UNEP Environmentally Sound Management of Inland Waters (EMINWA) and the FAO regional inland fishery bodies.

(d) *Drinking-water supply and sanitation*

The basis for action of this programme area is the fact that safe water supplies and environmental sanitation are vital for protecting the environment, improving health and alleviating poverty. The major targets of this programme area are the following:

(a) Protection of the environment and safeguarding of health;
(b) Institutional reforms and community management of services;
(c) Sound financial practices and use of appropriate technologies.

(e) *Water and sustainable urban development*

The basis for action of this programme area is the rapid urban population growth and industrialization, which put severe strains on the water resources and environmental protection capabilities of many cities. The major targets of this programme area by the year 2000 are the following:

(a) To ensure that all urban residents have access to at least 40 litres per capita per day of safe water and 75% of the urban population are provided with on-site or community facilities for sanitation;

(b) To establish and apply quantitative and qualitative discharge standards for municipal and industrial effluents;

(c) To ensure that 75% of solid waste generated in urban areas is collected and recycled or disposed of in an environmentally safe way.

(f) *Water for sustainable food production and rural development*

The basis for action of this programme area is the primary importance of maintaining food security, which depends on sound and efficient water use and conservation practices for irrigation development and management, including water management with respect to rain-fed areas, livestock water supply, inland fisheries and agro-forestry.

In accordance with the International Action Programme on Water and Sustainable Agricultural Development (IAP-WASAD) initiated by FAO in cooperation with other international organizations, the main objective is set to assist developing countries in planning, developing and managing water resources on an integrated basis to meet present and future needs for agricultural production, taking into account environmental considerations. These require setting quantitative targets for new irrigation development, improvement of existing irrigation schemes and reclamation of waterlogged and salinized lands, as primary objectives.

(g) *Impact of climate change on water resources*

The basis for action of this programme area is mainly the uncertainty with respect to the prediction of climate change and to their impact at the global level. In this connection, the Ministerial Declaration of the Second World Climate Conference states that "the potential impact of such climate change could pose an environmental threat of an up to now unknown magnitude... and could even threaten survival in some small island States, and in low-lying coastal, arid and semi-arid areas." The major targets of this programme area are the following:

(a) To understand and quantify the threat of the impact of climate change on freshwater resources;

(b) To implement national countermeasures whenever the threatening impact is confirmed;

(c) To study the potential impacts of climate change on areas prone to droughts and floods.

B. CURRENT STATUS OF WATER RESOURCES POTENTIALITIES IN THE ESCWA REGION

The water situation in most of the countries in the ESCWA region has been uncertain and precarious until recently, when some intensive efforts were undertaken in order to identify water resources potentialities. However, the current manner in which water resources are developed and managed so as to meet the ever-increasing demand for water, and, at the same time, to achieve sustainable economic development, are probably insufficient to bridge the gap between actual water availability and anticipated demand. If such trends persist, the water situation will ultimately reach grave proportions. Therefore, finding new methods to evaluate, develop and manage water resources should receive urgent priority if the water situation is to improve. Table 1 contains some basic parameters in respect of population growth, annual rainfall and agricultural land-use.

1. *Available water resources*

The extreme variability and complexity of the hydrologic pattern through which water resources in arid and semi-arid regions are naturally recharged and discharged pose enormous difficulties for exact identification and evaluation of the actual availability of these resources. The situation in the ESCWA region is no exception, and the presence of rivers and riparian countries possibly poses some acute additional challenges. Therefore, in the absence of a reliable evaluation of water resources potentialities, appropriate planning and sustainable development prove to be a difficult task.

The countries in the ESCWA region are continuously endeavouring to identify and evaluate their water resources. They have achieved varying degrees of performance and accuracy, depending on their respective capacities in terms of both financial and experienced human resources.

The water supplies in the ESCWA member countries are derived from conventional and non-conventional sources. The available data on the magnitude of the various water sources are both sporadic and inconsistent, as they do not reflect the water availability in all countries at a specific time. This is due mainly to the fact that in some countries the water resources assessment or updating dates as far back as 10 years or more, while others have not performed any systematic assessment. Therefore, considerable discrepancies can be observed in the literature available, regarding the figures for water resources availability. However, despite these obvious inconsistencies in respect of the period of evaluation as well as sources of information, some representative figures can be quoted for the purpose of shedding light on the importance of the various resources in determining realistic prospects for economic development.

TABLE 1. PHYSICAL, RAINFALL AND LAND-USE PARAMETERS IN THE ESCWA REGION

Country	Area[1] 1,000 km^2	Population[2] (million)			Annual population growth rate (%)	Average[3] rainfall (mm/y)	Agricultural land-use[4] (1,000 hectares)						
								Rain-fed		Irrigated			
		1990	2000	2025			Total arable land	1990	2000	1990	2000	Forests	Pastures
Bahrain	0.68	0.52	0.68	1.00	3.1	75	7	--	--	3.8	7.0	--	4
Egypt	1 001.45	52.47	64.21	90.35	2.2	20-200	4 452	--	--	2 690	3 945	2	--
Iraq	438.32	18.92	26.34	50.00	3.4	50-650	11 500	2 493	1 416	3 257	4 334	500	4 000
Jordan	97.74	3.45	4.85[5]	9.97	3.3	50-650	1 450	1 305	1 205	60	75	125	100
Kuwait	17.82	2.04	2.64	3.77	2.8	30-140	163	--	--	1	102	--	1 340
Lebanon	10.40	5.20[5]	7.10[5]	--	2.2	200-1500	350	275	275	70	70	95	10
Oman	212.46	1.50	2.18	4.75	3.4	80-400	56	--	--	46.2	56	--	1 000
Qatar	11.00	0.37	0.50	0.86	3.4	75	6	--	--	2.6	6	--	5
Saudi Arabia	2 149.69	14.13	20.70	44.75	3.8	35-400	4 500	385	400	201	426	1 600	85 000
Syrian Arab Republic	185.18	12.12[5]	17.50[5]	38.68[5]	3.6	150-1000	5 864	3 336	--	693[5]	1 482[5]	452	8 531
United Arab Emirates	83.60	1.59	1.95	2.65	2.2	80-160	15	--	--	8.9	10.9	--	300
Yemen	527.97	9.20	13.22	28.17	3.7	10-1000	3 708	3 342	3 400	408	608	125	16 000

Sources: (1) UNESCO Statistical Yearbook, 1990; (2) Egyptian Statistical Yearbook, 1992; (3) ESCWA, 1992; (4) League of Arab States, Economic Report, 1990; and (5) Updated from country reports (1995).

Table 2 gives estimates for both the conventional and non-conventional water sources available in the countries of the ESCWA region. In view of the scarcity of conventional water resources in some countries, non-conventional water resources are expected to play an important role in supplying sufficient water to meet increasing demand. For example, desalination of salt and brackish water and treatment and reuse of wastewater, particularly in the Gulf countries, are becoming important sources of water for domestic use and for agriculture, respectively. In addition, the figures in table 2 regarding the available conventional water resources do not necessarily take into account water resources already conserved and developed but which require the construction of relevant structures along with appropriate water management, i.e., integrated water resources development and management. Table 2 shows also that, on average, surface water makes up 50% of the total available water resources, and groundwater and non-conventional water sources make up 25% each. However, the latter percentage rises sharply in the Gulf countries.

2. *Water resources requirements*

Estimates of water resources required to satisfy future needs depend entirely on the national strategy of socio-economic development and the standard of living targeted within the natural and financial resources of each particular country. While some countries aim at achieving self-sufficiency in food production, others may plan to rely on partial food imports. Also, with respect to domestic water supply and industrial development, the national policies and plans differ considerably from one country to another.

Several endeavours for projecting future water requirements have been presented by the concerned countries and specialized international and regional organizations. As a result of the discrepancies in the basic assumptions used by the various parties for water requirement projections, considerable variations can be noted in the available literature (ACSAD [1986], UNESCO [1988], ESCWA [1991] and ALECSO [1992]). Table 3 gives estimates, derived mainly from the above-mentioned literature, for the expected quantities of water that will be required for various purposes for the years 2000 and 2030. However, the figures can only be considered indicative and should be used for comparative purposes only.

3. *Challenges confronting the achievement of a water balance*

A critical analysis of the aforementioned information regarding water resources availability and requirements clearly indicates a water imbalance for the years 2000 and 2030. Table 4 shows that only 73% of the overall water resources available in the ESCWA region is developed and utilized. This percentage is even lower if the current water losses and low efficiency of the various water systems are taken into account. Such inefficiency is due to the inadequate practices that prevail in the utilization of water for irrigation and domestic and industrial purposes. In order to satisfy all water demands by the year 2000, the proportion of developed water resources as a percentage of those available should be raised to 85%, on the assumption that all water losses can be technically avoided and the water-use efficiency can be practically promoted. The situation by the year 2030 will be much more challenging since it will be necessary to develop all available water resources in addition to providing new water resources amounting to 62,291 million m^3, or at a rate of about 1,557 million m^3/year in the ESCWA region.

Table 4 also shows the water situation in each country in the region, and the figures indicate wide variation in the percentage of readily developed and utilized water resources relative to those available. However, the high percentages recorded in some countries do not necessarily indicate appropriate development, but rather may be due to overexploitation, which results in deterioration of both the quantity and quality of water. On the other hand, the apparent surplus in water resources in some countries are impeded from being appropriately developed, or conveniently used, unless firm water agreements between those countries and riparian countries are endorsed, maintained and respected. This issue, by itself, constitutes a major challenge. In addition, the possibility of developing all the water resources estimated to be available remains not only challenging but doubtful unless sufficient financial resources are allocated and invested.

With the ever-increasing demand for water, the term "sustainable development" tends to be relative. However, in order to achieve a relative balance between water availability and demand in any particular country, the major challenges should be progressively confronted. Although the nature of these challenges varies from one country to another, they can be grouped into two broad categories that prevail in the ESCWA region:

(a) The Gulf countries, where surface water is scare and groundwater has limited potentialities; in view of this situation and in order to meet present and future demand, these countries will continue to exhaust their water-bearing formations, which will ultimately deteriorate in both quantity and quality. In addition, in order to achieve a water balance, their reliance on non-conventional sources will increase. Although this practice occurs all over the world, it is considered a costly process, and it is not fully environmentally sound if it constitutes the principal water supply in a country;

(b) The riparian countries, which share their main surface-water resources with other countries; this situation implies the tailoring of water demands and accordingly water allocations for the various purposes so as to suit the prevailing limitations and the water agreements in force. Accordingly, future water demand will necessitate constructional development at the upper reaches of the river drainage basins.

In addition to the above, each of the countries in the ESCWA region is currently witnessing a number of constraints which may worsen with time (table 5). In this regard, the activities endorsed in the various programme areas of chapter 18 of Agenda 21 offer the most appropriate methodology for relieving the current water constraints in the region. However, some basic considerations should be adopted as primary

TABLE 2. ESTIMATES OF AVAILABLE WATER RESOURCES IN THE ESCWA REGION

(Million m^3/year)

Country	Volume of rainfall	Conventional water resources[1]			Non-conventional water resources[1] (NCWR)		Total available water resources	SW as percentage of total water resources	GW as percentage of total water resources	NCWR as percentage of total water resources
		Surface water (SW)	Renewable groundwater (GW)	Treatment of wastewater	Reuse of agricultural water	Desalinated water				
Bahrain	50	--	(219)+	8[2]	--	63[2]	290	0	75.5	24.5
Egypt	15 300	55 500	8 500	200	4 300	19	68 519	81	12.5	6.5
Iraq	70 000	{80 000}	2 000	--	--	7.4	{82 007.4}	97.5	2.4	0.1
Jordan	8 500	555	277	56	--	2.5	890.5	62	31	7
Kuwait	2 400	--	160	113	--	485	758	0	21	79
Lebanon	8 600	1 650	500	--	--	1.7	2 151.7	77	23	--
Oman	15 000	1 470	560	26	--	47	2 103	70	22	3
Qatar	800	--	40	22	--	93	155	0	24	74
Saudi Arabia	126 800	3 200	2 240	400[2]	--	2 920	8 760	36.5	25.5	38
Syrian Arab Republic	46 000	{22 100}	3 000	177	--	2	{25 279}	87	12	1
United Arab Emirates	2 400	150	100	70	--	477	797	19	12.5	68.5
Yemen	67 200	3 500	1 400	--	--	1.9	4 901.9	71.4	28.5	0.1
Total	363 050	168 125	18 996	1 072	4 300	41 195	196 612.5	50	25	25

Sources: (1) ACSAD (1990, 1993), ALECSO (1993), ESCWA (1992), UNESCO (1988); and (2) Figures updated from country reports (1995).

Notes: Figures are assumed to be representative for the year 1990. Figures in parentheses ( ) followed by a plus sign (+) denote groundwater subject to overexploitation exceeding renewable rates. Figures in braces { } denote anticipated agreements with riparian countries.

TABLE 3. ESTIMATES OF WATER REQUIREMENTS IN THE ESCWA REGION[1]

Country	Domestic water demand		Industrial water demand		Irrigation water demand		All water demands	
	2000	2030	2000	2030	2000	2030	2000	2030
Bahrain	169[2]	243	12[2]	73	124[2]	300	305	616
Egypt	3 100[2]	5 000[2]	6 100[2]	10 667	59 900[2]	82 100	69 100	97 767
Iraq	(4 600)[3]	(12 000)[3]	(7 000)[3]	(12 000)[3]	(52 000)[3]	(68 800)[3]	(63 600)[3]	(92 800)[3]
Jordan	354[2]	(800)[3]	78[2]	(230)[3]	(1 088)[3]	(1 200)[3]	1 520	(2 230)[3]
Kuwait	377	1 284	105	542	1 100[2]	1 700[2]	1 582	3 526
Lebanon	550	981	156	491	1 200	1 700	1 906	3 172
Oman	171	629	85	346	800	1 140	1 056	2 115
Qatar	89	256	10	57	150	200	249	513
Saudi Arabia	2 363	7 307	416	1 658	3 200	4 400	5 979	13 365
Syrian Arab Republic	1 276[2]	3 500[2]	447[2]	(1 471)[3]	14 820	(27 000)[3]	16 543	(31 971)[3]
United Arab Emirates	239	777	30	233	1 500	2 140	1 769	3 150
Yemen	984	2 499	149	839	2 225[2]	4 340	3 358	7 678
Total	14 272	35 276	14 588	28 607	138 107	195 020	166 967	258 903

Sources: (1) ACSAD (1986). UNESCO (1988). ESCWA (1991). ALECSO (1992); (2) Figures updated from country reports (1995); and (3) Figures assumed by authors of country reports (1995).

TABLE 4. THE WATER SITUATION IN THE ESCWA REGION

(Million m^3/year)

Country	Total available water resources[a]	Total utilized (developed) water resources[a]	Percentage of water resources utilized relative to available water resources	Water demand for all purposes	
				Year 2000	Year 2030
Bahrain	290[b]	290[b]	100[b]	305	616
Egypt	68 519	64 500	94	69 100	97 767
Iraq	{82 007}	60 000	73	63 600	92 800
Jordan	890	712	80	1 520	2 230
Kuwait	758	654	86	1 582	3 526
Lebanon	2 152	1 200	43	1 906	3 172
Oman	2 103	424	21	1 056	2 115
Qatar	155	199[b]	128[b]	249	513
Saudi Arabia	8 760	4 570	53	5 979	13 365
Syrian Arab Republic	{25 279}	7 726	31	16 543	31 971
United Arab Emirates	797	577	72	1 769	3 150
Yemen	4 902	2 650	54	3 358	7 678
Total	196 612	143 502	73	166 967	258 903

Note: Figures enclosed in braces { } denote anticipated water agreements with riparian countries.

a/ Figure assumed as representative for 1990.
b/ Figures indicate overexploitation.

purview for any endeavour aimed at alleviating the current water constraints and challenges. Some important considerations are the following:

(a) Maintenance and respect of existing water agreements between riparian countries;

(b) Conservation and protection of various water sources, including surface water and groundwater;

(c) Integration of water resources development with management;

(d) Optimization of food production per unit volume of water;

(e) Rationalization of water usage, particularly in agriculture;

(f) Development of non-conventional water sources, such as reuse of agricultural drainage water, treatment and reuse of wastewater and desalination of salt water and brackish water, or in other words, promotion of water multipliers and recycling issues;

(g) Adoption of realistic policies pertaining to water-usage allocations, within the framework of the particular national water strategies and priorities;

(h) Promotion of an institutional framework and capacity-building;

(i) Enhancement of public awareness and the participation of the non-governmental sector.

C. GENERAL FEATURES OF THE NATIONAL WATER STRATEGIES AND POLICIES IN THE ESCWA REGION AND THEIR REFLECTIONS ON THE IMPLICATIONS OF AGENDA 21

1. *Basic concepts of national water strategies*

Successful implementation of a national water strategy requires some basic concepts, important among which are: (a) well studied and achievable water policy based on known water resources potentialities and future demand; (b) alternative scenarios for water plans and programmes; and (c) development of feasible projects within the available financial and human resources. Since these three components are tightly interrelated, any deviation or ill-definition of any of them may raise major difficulties in the adequate implementation of the strategy. However, long-term water policies and plans may not be appropriate as an ever-lasting water strategy, owing mainly to the fact that projections of future water demand depend on, among other considerations, eventual changes in economic, environmental, social, political and technological aspects. For example, the United States Office of Technology estimates that, by the year 2000, about five sixths of annual increases in food production will be due to the application of new biotechnologies, while the remainder will be due to horizontal expansion of cultivable lands.

In the countries of the ESCWA region, as in many other developing countries, the situation does not deviate much from that mentioned above, although the water situation here is perhaps more critical and faces many challenges, owing mainly to the prevalence of aridity in the Gulf countries in the south and the sharing of most of the water resources among the riparian countries in the north. The countries in the ESCWA region should focus on integrated non-structural water management and structural water development in view of the general inefficiency in the management of water resources, while the possibilities for development of additional water resources are considerably limited in view of the scarcity of such resources. However, these two basic models, water management and water development, will continue to be unavoidably interrelated, and their integration will remain a must.

As regards the implications of the various programme areas included in chapter 18 of Agenda 21 for the countries of the ESCWA region, it is imperative to review the already endorsed national water strategies and/or water policies, as these normally have a significant bearing on the extent of conformity and harmony between the general scope of the activities associated with these strategies and policies and the general scope of those associated with the programme areas of chapter 18 of Agenda 21.

2. *General features of national water strategies and policies*

(a) *Bahrain*

The water strategy set in the early 1970s was designed to increase the total production of water to meet increased demand and to improve water quality standards. In fulfilment of this strategy, the development programme included the construction of desalination plants and the upgrading of the water supply distribution network. However, this strategy failed to reduce the dependence of the country on groundwater abstraction, which presently reached as much as double the safety limits are resulted in further deterioration of quantity and quality.

In order to mitigate the prevailing water problems, the country endorsed a new national water management strategy to be implemented through a project entitled "Planning for water resources development" for the period 1990 to 2010. The development programme for this recent strategy includes mainly the following (Bahrain, 1992 and 1995):

(a) Increasing desalinated water production in order to reduce dependence on groundwater and improve its quality;

TABLE 5. MAJOR WATER RESOURCES CONSTRAINTS AND CHALLENGES IN THE ESCWA REGION

Constraint	Bahrain	Egypt	Iraq	Jordan	Kuwait	Lebanon	Oman	Qatar	Saudi Arabia	Syrian Arab Republic	United Arab Emirates	Yemen
Absence/inadequacy of water strategy, policy or plans			•			•		•		•	•	•
Surface water scarcity	•				•		•	•	•		•	•
Absence of water agreement with riparian countries			•	•		•				•		
Groundwater overexploitation	•		•	•	•	•	•	•	•	•	•	•
Groundwater quality deterioration	•		•	•	•	•	•	•	•	•	•	•
Salt-water intrusion into aquifers	•				•	•	•	•	•	•		•
Urbanization and environmental problems	•	•	•	•	•	•		•		•		•
Economic and financial difficulties				•		•				•		•
Inadequacy of infrastructure	•					•		•				•
Multiplicity of institutional authorities				•		•					•	•
Shortage of professional personnel	•						•	•			•	•
Inadequacy of educational systems							•	•			•	•
Inadequacy of monitoring system			•	•	•	•		•		•	•	•
Diversity of water pollutants		•	•	•	•				•	•	•	•

Note: A dot (•) denotes the prevalence of the water constraint in the country.

(b) Adopting a demand management policy that would curb excessive consumption by implementing a leak detection/reduction and system renewal programme, metering all water services and applying progressive water tariffs, enforcing water pumping regulations, and implementing a public education programme;

(c) Reforming the agricultural sector by expanding the use of treated wastewater for irrigation, promoting efficient irrigation systems, reconsidering the crop pattern, considering the application of a tariff on groundwater used for irrigation, and regulating abstraction from private groundwater wells. The planning for the water resources development project comprises three main phases (Bahrain 1992):

(a) Phase I is devoted to problem identification, which includes comprehensive reconnaissance and review of data and previous work, water resources evaluation, identification of water consumption patterns and efficiencies, projection of future demand, and establishment of a water resources database;

(b) Phase II involves the development of curative and preventive studies, including alternative scenarios of water problems, impact evaluation, simulation and management methods;

(c) Phase III is the implementation and monitoring phase in cooperation with the relevant executing agencies.

The project will ultimately expand according to the actual results of the final phase.

(b) *Egypt*

The water strategy of Egypt is linked mainly to the development of the Nile River as it constitutes the main and virtually the sole source of water in a country whose agricultural sector constitutes the principal water consumer. However, water demand in Egypt has increased not only parallel to the agricultural expansion plan but also in relation to industrial development and the increase in population. It is anticipated that the share per person will be reduced from the currently prevailing rate of 950 m^3/year to about 500 m^3/year by the year 2025 (Egypt, 1995).

The need for strategic water resources planning in Egypt has long been recognized. The endeavours associated with the development of "National Water Master Planning", which started in 1977 and ended in 1980 as phase I, were followed by a second phase that continued up to 1986. A third phase was still operating during 1995. The framework plan deals with the period up to the year 2000 and beyond. It contains a detailed and exhaustive statement of the water management and development needs of the country, including descriptions, reviews, analyses, plans and recommendations for projects and programmes in all water-related sectors of the economy. It includes investment and implementation schedules, production targets, means of implementation, economic costs and benefits of projects and programmes, rural employment and demographic impacts, and surface water and groundwater distribution plans. In the implementation of this strategy, planning methods received high priority, while less emphasis was placed on the preparation of specific proposals. This was due mainly to the rapid changes in technology and relative economic values which make it more prudent to make the right decision on each new potential development than to adhere to a rigid plan based on assumptions that may be subject to eventual changes (Egypt, 1995).

The national water master plan allows for the presentation and evaluation of three development scenarios (Egypt, 1994):

(a) Scenario 1 assumes that water conservation projects are constructed. Projected growth in water demand for the non-agricultural sector is to be deducted, and the water balance which can be made available for the development of new lands is then computed;

(b) Scenario 2 assumes that there will be a high rate of growth in the agricultural sector (14.9% annually, which is compatible with the national optimistic projections for the economy). Some of that growth is assigned to the old lands, and the balance to new lands. The water requirements for non-agricultural uses are determined in order to find the total water demand;

(c) Scenario 3 assumes that there will be a moderate rate of growth in the agricultural sector (3% annually). Some of that growth is assigned to the old lands, and the balance to new lands. The water requirements for the resulting increase in new lands (50,000 feddans/year) are determined, and the water requirements for non-agricultural uses are added to find the total demand.

The three scenarios depicted above assume that sufficient water will be provided to satisfy the water requirements of each. The major opportunities for increasing the water supply are drainage reuse projects, improved water management, and water conservation projects in the Sudan to reduce evaporation losses in the area known as the "Sudd" or swamps. Minor but potentially considerable opportunities include wastewater treatment and reuse and ultimately desalination of sea water.

(c) *Iraq*

The establishment of a national water strategy in Iraq depends mainly on the stability and continuity of the surface water derived from the Tigris and Euphrates rivers. The Tigris is recharged mainly from the Turkish highs with some tributaries from Iraq, Turkey and the Islamic Republic of Iran; it crosses both Iraq and the Syrian Arab Republic, and its annual rate of flow is of the order of 49.5 billion m^3. The

Euphrates is recharged totally from the Turkish lands, and also crosses Iraq and the Syrian Arab Republic with an average annual discharge of about 28.3 billion m^3. The absence of a firm and concrete agreement for the division of these common water resources among the three riparian countries, Iraq, the Syrian Arab Republic and Turkey, impedes the formulation of a national water policy in Iraq. As a result of this situation, the national strategy in Iraq focuses, in general, on two main directions (Iraq/ALECSO, 1992 and Iraq, 1995):

(a) To reach a just agreement among the riparian countries so as to be able to allot a specific portion of the shared water, a matter that has been in dispute since 1960, and the dispute has continued into the present despite the formation of an ad hoc committee in 1983;

(b) To continue implementing water development projects as originally planned and as resources permit, including an integrated water development and management scheme through the construction of 133 irrigation projects and various types of dams, the reclamation of deteriorating lands, the construction of a main agricultural drain with a designed capacity of about 200 m^3/sec, the reformation of swampy lowlands and river-tails, and the reduction of water losses in the streams and main canals.

(d) *Jordan*

The formulation of a water resources policy and of a national water master plan was first initiated in 1976 and was made one of the development programmes within the scope of the 1976-1980 five-year plan for economic and social development. The objectives of the plan were in line with the prevailing water problems and constraints at that particular time. These objectives were mainly centred on aspects pertaining to development priorities, allocation of water resources, consequences regarding existing development plans and consequences regarding regional development (Jordan, 1977).

As a result of many changes revealed since the first endeavour towards the establishment of a national water master plan, it has been deemed necessary to update the scope and views of the nationwide water sector and to improve its development and implementation. With this view in mind, the Ministry of Water and Irrigation is currently developing a water policy and making strategic plans that include the development of the following: a water management information system; a water monitoring network programme; a central laboratory; an artificial recharge feasibility study; industrial wastewater discharge prevention; irrigation water management; water management education; and public awareness. However, despite the clarity of the strategic plan currently in force, its implementation remains problematic, owing principally to the sharing of considerable surface water (the Yarmouk River with the Syrian Arab Republic, and the Jordan River with Lebanon) and of groundwater sources (the Disi aquifer with Saudi Arabia), the non-renewability of some groundwater reservoirs, and the exhaustibility of most of the groundwater basins (Jordan, 1995).

In addition, as a result of the peace treaty signed by Jordan and Israel in October 1994, some regional water schemes have been put forth which have to be studied and investigated. These schemes will allow Jordan to receive an additional 215 million m^3/year, water to be stored in Lake Tiberias in the winter and supplied to Jordan in the summer, and new possibilities of supplying Jordan with 50 million m^3/year of drinking-water. These regional schemes imply the introduction of corresponding arrangements into the national strategic plan for years to come (Jordan, 1995).

Parallel to the national strategic water plan, Jordan initiated a national environmental strategy, the guidelines of which were officially approved by the Government in 1991. Furthermore, a proposal for the establishment of a general authority for environmental protection is currently under preparation. At the sector level, priority is given to water issues and to maintaining agriculturally productive lands since both of these will have serious long-term impacts if they are not addressed urgently (Jordan, 1991).

(e) *Kuwait*

The water supply in Kuwait is confined to three main sources; desalinated sea water, groundwater and treated and reused sanitary wastewater. Accordingly, the national water strategy focuses primarily on rational utilization, optimization of water usage, and the search for new water sources. The corresponding water plan aims mainly at the development of the three above-mentioned sources (ACSAD, 1993).

Desalination of sea water has received top priority, rendering Kuwait a pioneering country in the development of this technology. Several techniques have been applied and promoted, for which the multi-stage flash evaporation has proved the most appropriate and economical. The development of the groundwater basins is constrained owing to overexploitation of the water-bearing formations and a corresponding depletion of the groundwater along with the spread of salt-water intrusion along the coastal aquifers. The treatment and reuse of wastewater is receiving considerable attention, but only for limited agricultural purposes (ACSAD, 1993 and ESCWA, 1992).

In view of the scarcity of the water sources in Kuwait the strategy does not include scenarios other than those dealing with conventional issues pertaining to the application of relevant legislative acts to impede groundwater deterioration, minimization of water losses in pipes, and promotion of irrigation water management.

(f) *Lebanon*

The national water strategy in Lebanon has two main goals: the maintenance of a water balance and the maintenance of good quality water through its protection from pollution and the provision of adequate sanitary and wastewater services. The implementation of this strategy has short-, medium- and long-term technical aspects (Lebanon, 1995).

The short-term technical aspects involve reducing water losses, maintaining water supply services, and promoting public awareness. The medium-term technical aspects involve formulating a water master plan, conducting a water resources assessment, using modern irrigation techniques, upgrading monitoring systems, and promoting methods for wastewater treatment and reuse for irrigation. The long-term technical aspects involve controlling surface water; controlling and recharging groundwater; establishing large water projects; and protecting surface water and groundwater from pollution.

In view of the prevailing constraints and problems in Lebanon, the implementation of the above-mentioned technical aspects are partially precluded. However, some activities are carried out whenever and wherever possible.

(g) *Oman*

The establishment of a national water master plan was only conceptualized as recently as 1990. Prior to that, the national policy included a number of water conservation projects that were implemented according to prevailing needs. However, with the creation of the Ministry of Water Resources in 1990, a comprehensive study on the establishment of a water master plan was completed by the end of 1991 with the following goals (UNESCO/Oman, 1993):

(a) Strengthening of the institutional and legal framework to provide effective management of water resources in the interest of the country's long-term development;

(b) Giving priority to domestic and industrial water supplies by using desalinated sea water;

(c) Managing domestic water demand and improving the efficiency of agricultural water use;

(d) Restricting agricultural development in line with the available water resources and reducing agriculture where resources are overexploited;

(e) Controlling the development of non-renewable water resources;

(f) Augmenting water resources wherever possible.

The water master plan implies the establishment of a national water resources assessment programme through the establishment of a national water well inventory project; a similar project for surface water investigation is being undertaken. Therefore, a full and clear picture of a national water development plan can only be expected shortly after completion of the two above-mentioned national projects. Meanwhile, a number of recharge and conservation dams are being constructed within the framework of the current five-year national economic and social development plan (UNESCO/Oman, 1993).

At present, the general features of the water policy are governed by a number of decrees issued mainly for purposes of conservation and protection of water resources. In particular the 1988 decree implies that the resources in the country are considered a national wealth, while decrees from 1988, 1989 and 1990 allow for regulation of water utilization through the issuance of water permits. The aspects pertaining to environmental protection are being objectively considered, and perhaps this country is a pioneer in the creation of a specialized institution responsible for environmental affairs.

(h) *Qatar*

The development of a national water policy in Qatar is governed by a number of variable parameters: the instability of the national economy, which depends on oil revenue, and the changing population pattern, along with a lack of information and data on water resources. These parameters constitute the major constraints to predicting future water demand, and accordingly they hinder the formulation of a national water policy (Qatar, 1992). However, the general features of the water master plan currently in force focus on two main issues: minimizing deterioration of water quality and stopping desertification. In this regard, priority in allocation is given to water for domestic use, followed by agricultural and industrial uses. Accordingly, the water plan stresses studying the feasibility of constructing desalination plants and developing a green-pipe project to import water from the Islamic Republic of Iran (Qatar, 1992).

The activities pertaining to the implementation of the prevailing action plan are: use of treated sewage effluent and saline water for irrigation; recharge of the groundwater artificially; development of deep aquifers; protection of groundwater in landfill sites from pollution; and leaching salinity out of arable soils (Qatar, 1995).

(i) *Saudi Arabia*

The national water strategy in Saudi Arabia was established in the 1980s. The strategy, which is considered comprehensive in both scope and nature, covers the national water policy with respect to water supply and demand up to the year 2020. The strategy gives priority to the domestic water supply, and it is anticipated that, by the year 2000, about 95% of the urban and rural areas will be provided with freshwater facilities from either desalination plants or groundwater. Agricultural expansion is also being promoted, but within available water resources. However, through the reuse of treated wastewater and the introduction of modern irrigation techniques, it is anticipated that irrigated lands will expand to about 0.4 million hectares (Saudi Arabia, 1992).

The implementation of this strategy requires adequate quantitative and qualitative control over all water sources. In this regard the action plan includes, among other issues, the establishment of dams (currently numbering more than 200) for surface water conservation and groundwater recharge, protection of groundwater resources from deterioration, rational utilization and allocation of water, and capacity-building and public awareness. However, in view of the eventual socio-economic and climatic changes, the national water policy continues to be subject to revision and updating, including the issue of supporting laws and regulations.

(j) *Syrian Arab Republic*

The national water policy and the national environmental policy follow, in principle, medium-term plans, each lasting five years through which long-term goals are progressively achieved. The general objectives of the medium-term plans are:

(a) Expansion of irrigated lands;
(b) Protection of water resources from pollution;
(c) Increase in power generation;
(d) Protection from eventual run-off floods;
(e) Development of fisheries and animal production;
(f) Promotion of social standards and population stability;
(g) Provision of work for manpower;
(h) Reuse of treated wastewater.

Specifically, the medium-term water plan aims at achieving full control over water resources in order to realize food security. Meanwhile, in order to achieve adequate development and management of available water resources in the Syrian Arab Republic, two particular approaches have been recommended: (a) a long-term approach involving policy, legislation, institution-strengthening and water planning; and (b) a short-term programme designed to act on urgent water-related problems that threaten the quantity and quality of the water resources (Syrian Arab Republic, 1992).

At present, the apparent absence of a long-term policy and/or a water master plan constitutes a major constraint for water resources development and, in particular, for irrigation. In addition, the Government's effort to promote food self-sufficiency has resulted in some undesirable water-related problems. Three major environmental issues seem to affect the sustainability of water resources development (FAO, 1993): (a) a rapid decline of groundwater levels and deterioration of groundwater quality; (b) waterlogging and salinization of agricultural lands; and (c) pollution of surface water and groundwater owing to the discharge of drainage water and untreated effluent from municipalities and manufacturing industries. On the other hand, the increase in the population, particularly in urban centres and proliferation of industries in major cities and elsewhere have contributed to the exploitation of the limited surface water resources, which depend on the sharing of river waters with riparian countries (Syrian Arab Republic, 1995).

(k) *United Arab Emirates*

Water resources in the United Arab Emirates are managed by national and local authorities. The Ministries of Agriculture and Fisheries and of Electricity and Water as well as the General Water Authority and the water departments of the seven Emirates share the responsibility for the development and management of the water resources in the country (United Arab Emirates, 1995). This multiplicity of water authorities, with overlapping and conflicting functions, constitutes a major impediment to the establishment of a national water strategy and, accordingly, to efficient water management.

The country depends on two main sources for water supplies: desalinated water and groundwater. There are also limited amounts from surface water and reuse of treated wastewater. In the absence of a national water strategy and in view of the inadequacy of water resources management, both surface water and groundwater are subject to continuous deterioration in quality as well as in quantity. Accordingly, efforts are directed towards increasing the capacity of desalination plants.

The conventionally agreed upon national water policy ranks the municipal water supply as top priority in the water resources allocation plan. Desalinated water and the small contribution from groundwater are the main sources. The agricultural water supply, which is considered second in priority, comes from groundwater, while the landscaping and beautification of cities, side-road trees and parks, the third priority, is done with treated wastewater. Therefore, the water development plans give emphasis to: application of modern irrigation systems, construction of dams for groundwater recharge, introduction of salt-tolerant plants, explorations for new groundwater resources, and promotion of capacity-building (United Arab Emirates, 1995).

(e) *Yemen*

Water is scarce in Yemen, and large quantities of groundwater are currently being used to support the growing economy and the increasing population. Since the existing laws and regulations are insufficient to cope with the situation, the groundwater sources will remain unrestrained and ill-managed.

Although Yemen has been in possession of comprehensive studies on a water master plan and policies since 1992, there is currently no water planning at the national level. Instead, the drinking, irrigation and industrial water projects are implemented by various public and private entities, each to serve its overall sectoral objectives (Yemen, 1995). These studies include, among others, programmes for: water resources assessment, current and future water requirements for all purposes up to the year 2010, and assessment of the current status and future development of wastewater, sanitation and the water supply. Environmental issues related to water studies and the need for environmental impact assessments are also prescribed (Yemen, 1992). However, the implementation of these integrated studies and programmes is virtually unforeseen, at least at the present time, owing mainly to the prevailing economic constraints and lack of an adequate institutional and policy framework. Therefore, the challenges facing appropriate development and management of the water resources in Yemen will persist unless adequate financial and technical support are provided.

Therefore, it was not until 1995 that an idea for establishing a National Water Resources Authority (NWRA) became politically feasible, and accordingly it is expected to be functional by 1996. According to the agreed-upon mandate for the establishment of the NWRA, its goal is to conserve the water resources of the country and prescribe strategies, policies and plans to ensure proper management and sustainable development of these resources within the context of socio-economic development plans (Yemen, 1995).

3. *General regional reflections of the national water strategies and policies*

In the light of the above-mentioned water strategies, policies and plans, and in view of the available literature pertaining to water resources development plans and conservation in the ESCWA member countries, the extent of the implications of the various programme areas listed in chapter 18 of Agenda 21 are expected to vary considerably from one country to another. However, these variations are closely related to the current views and aspirations of each particular country towards the development, management and use of its water resources, and those views are expressed in the national water strategies and policies. Accordingly, the implementation of the various components of the programme areas, as originally endorsed in Agenda 21, should be normally seen as direct reflections of the prevailing water strategies and policies in the region.

The general regional features of the implications of the programme areas of chapter 18 of Agenda 21 for the ESCWA region are outlined below.

(a) *Integrated water resources development and management*

The basis for action and objectives of this programme area are well acknowledged in the ESCWA region and seem to be, in general, in conformity with those included in Agenda 21. However, the activities actually in force or those proposed for the future are quite different. While a few countries are endeavouring to integrate development of water resources with their management at the national level, others are confining their activities to particular surface-water and/or groundwater basins or are far from reaching any sensible achievement to an integrated approach to water resources. The means of implementation with respect to financing, scientific and technological means and human resources development and capacity-building also differ from one country to another. These variations depend mainly on the actual water policy of each country regarding this programme area, along with its prevailing economic situation and professional and institutional capacity.

(b) *Water resources assessment (WRA)*

This programme area is of paramount importance to all countries, including those in the ESCWA region, as it constitutes the practical basis and a prerequisite for both water development and management. However, this activity is considered, by all measures, a costly process needing special expertise. While some countries in the region possess reliable WRAs and continue to update them periodically, other countries can only afford to assess their water resources sporadically. However, this particular programme area is taken seriously and is currently acted on by all countries in the ESCWA region, albeit at varying levels of activity in respect of areal coverage and accuracy and in accordance with the availability of means of implementation.

(c) *Protection of water resources, water quality and aquatic ecosystems*

Water resources in the ESCWA region, as in many other places around the world, are continuously threatened by various activities that ultimately lead to deterioration of water resources through depletion or contamination or both. These harmful activities have long been recognized in the region, but measures to mitigate their impacts have been considered only recently in some countries. Protection of water resources, though imperative for sustainable development, seems uncontrollable to some countries in the region owing mainly to the diversity of the activities causing their deterioration, along with the obvious lack of infrastructures, laws and regulations and appropriate appreciation for the need to protect the environment. Therefore, some countries are handling this programme area through adequate water resources management practices and the issuance of environmental laws and regulations binding on all water users. However, some countries have kept a low profile in dealing with this subject, owing mainly to some major impediments in respect of financing and means of implementation.

(d) *Drinking-water supply and sanitation*

This programme area is a target common to all countries in the region and is predominant in their national economic and social development policies. The prevailing scarcity of water sources in the region, along with the uneven demographic distribution of the population, may hinder the achievement of full-scale satisfaction to all people with respect to water supplies of adequate quality, and to sanitation facilities at all times and in all areas. However, this particular programme area is receiving priority in any national activity, but its achievement follows a progressive plan in accordance with the availability of adequate means of implementation.

(e) *Water and sustainable urban development*

Most of the countries in the ESCWA region are characterized by a continued growth of urbanization, which results in severe strains on the water supplies and environmental-protection capabilities of many cities and towns in the region. In addition, owing to the growing population, some communities started to sprout up randomly around some major cities, which in turn placed additional strain on planned programmes for water supply and sanitary facilities. The concentration of industrial and commercial activities in most of the cities and coastal areas of the region constitutes a major concern to local and municipal authorities. In this regard, some countries have succeeded in transferring some industrial and commercial activities from urban areas to rural localities or newly reclaimed lands by establishing satellite cities and encouraging migration through the creation of jobs outside urban areas. Other countries in the region have failed to do so, owing mainly to prevailing economic constraints. However, all the countries in the region take this programme area seriously, but the methods employed to achieve the objectives, as originally outlined in Agenda 21, are not strictly in line with the nature or time-frame of the projected activities. This particular problem is directly related to some prevailing social patterns and behaviour of the people in the region, in addition to some financial constraints that may preclude the construction of water-supply and sanitary projects whenever and wherever needed.

(f) *Water for sustainable food production and rural development*

The matter of food security in the Arab countries, including those in the ESCWA region, has been propounded as a regional strategy by the League of Arab States since 1980. Several studies and programmes have been advanced on various occasions but have never materialized. Most of the countries of the ESCWA region are currently witnessing shortages in national food production, particularly in cereals and wheat, in which self-sufficiency is about 40% for the former and about 30% for the latter. Vegetables and fruits are possibly the only food products available in great quantities, approaching about 90% of the total food needs in the region. Therefore, dependency on food importation prevails in most of the countries in the ESCWA region. It is evident, however, that sustainability and security of food production is only possible within a regional scope and with cooperation between the countries of the region and the rest of the Arab world. There is no doubt that the integration of water, land and financial potentialities, along with the available human resources at the regional level, can lead ultimately and conveniently to self-sufficiency in food production. However, individual national endeavours to overcome this problem will face various challenges represented by some of all of the following: scarcity of water resources, inadequacy of soil fertility, shortage of experienced labourers, or financial constraints. Therefore, the activities proposed for this particular programme area, as included in Agenda 21, although useful in relieving the food challenge in the region, can hardly be reckoned as appropriate approaches to solve this specific problem at the national level. However, this programme area constitutes a major concern and is currently receiving high priority in all water strategies in the countries of the region.

(g) *Impact of climate change on water resources*

International debate on the climate change issue is becoming ardent nowadays, but the ability to predict its impact is still a controversial matter. However, the uncertainties in projecting information and knowledge should not reduce the importance of this issue or disregard its anticipated environmental impact. The countries in the ESCWA region, regarding this particular issue, are more concerned with regional and local climate changes rather than global changes. This is rather due to the fact that the region witnesses severe local seasonal and annual climate changes represented by long droughts followed by relatively short periods of heavy rains and sometimes floods. Although this is a completely different problem from that which is being debated globally, the local and regional climate changes have serious impacts on the potentialities of the water sources and their sustainability in a region which is extremely vulnerable to climate changes. Therefore, activities for this programme area are currently focused on mitigating the impact of drought, developing agriculture based on brackish water and promoting traditional techniques for water conservation. However, international research and debate on this matter are closely followed up at the scientific level through participation in ad hoc conferences and meetings.

D. IMPLICATIONS OF CHAPTER 18 OF AGENDA 21 FOR ESCWA MEMBER COUNTRIES

1. *Basic considerations*

Agenda 21 is considered a relatively recent document (1992) addressed to the international community with the primary aim of facing the present environment and development problems, and also taking a balanced and integrated approach towards relieving future challenges. The successful implementation of the programme areas, as identified in Agenda 21, remains principally the responsibility of the individual Governments. National strategies, policies and plans are therefore crucial in achieving this.

With respect to the subject of water resources, chapter 18 of Agenda 21 has identified seven major programme areas (see section A of the present report) which are described in terms of basis for action, objectives and means of implementation. However, the extent to which the particulars of the terms of these programme areas are achieved in the ESCWA region at the national level is governed by a number of basic considerations, important among which are the following:

(a) The nature and scope of the national documents pertaining to water strategies and policies: there is no doubt that the countries which produced such documents prior to the endorsement of Agenda 21 may find it premature or relatively late to incorporate the full terms of the various programme areas of Agenda 21, or even parts of them, into their original documents. Therefore, the nature and scope of these already endorsed documents certainly constitute an important governing factor which determines the extent to which they can be adapted to conform with, or revolve around, the scope and particulars of the various components comprising Agenda 21. On the other hand, the countries which do not possess water strategies and policy documents, or are in the process of preparing them, may find it more convenient to incorporate the relevant terms of Agenda 21 into their documents, provided that other considerations are satisfied;

(b) The financial and institutional capacities: despite the fact that the objectives, activities and means of implementation of the various programme areas of Agenda 21 are comprehensive in nature and integrative in scope, apart from being indispensable for appropriate development and management of water resources, their successful implementation depends, among other considerations, on the availability of sufficient financial resources and an adequate institutional framework supported by qualified professionals. Any shortage in these will lead ultimately to disruption and inconvenience in achieving the projected goals;

(c) The physical setting and potentialities of the prevailing water sources: the physical nature of the hydrologic and hydrogeologic setting, as well as the magnitude of the available water sources potentialities, with respect to sufficiency, scarcity and diversity, constitute the main factors which enable the identification of feasible alternative scenarios and options for the allocation and usage of water resources. Accordingly, these parameters govern the choice of relevant activities and means of implementation pertaining to each programme area;

(d) The sharing of water sources with neighbouring countries: the absence of firm and well-defined water agreements between riparian countries constitutes a major constraint for sustainable national water resources development. Accordingly, integrated development and management at the river basins are only feasible at the subregional level and with due consideration and respect for the mutual interests of all parties sharing the river basin;

(e) The national socio-economic development strategy: there is no doubt that the national water strategy constitutes a vital component of the overall national socio-economic strategy. Therefore, the magnitude of investments allocated to the water resources sector is directly related to the cost/benefit studies of all other available natural sources at the national level. Accordingly, this issue in particular is one of the main factors governing the extent to which the available water resources are allocated to urban and to rural development.

2. *Status*

In the light of the foregoing review of the various components pertaining to the extent to which the programme areas of chapter 18 of Agenda 21 are reflected in the activities of the water resources sector in the ESCWA region, the status of each country in each programme area is explained below.

(a) *Bahrain*

(i) *Integrated water resources development and management*

Planning for water resources development is incorporated into the national water management strategy and currently consists of three phases to cover water action plans, with various scenarios through the year 2010. A demand management policy to curb excessive consumption has been adopted. Activities related to this programme area include: (a) implementation of leak detection/reduction and a system renewal programme; (b) application of metering systems to all services with a progressive water tariff; (c) enforcement of water plumbing regulations for all plumbing systems; and (d) implementation of public education and awareness programmes.

(ii) *Water resources assessment*

This programme area is currently included in the integrated water resources development project which started in 1990. This subprogramme constitutes phase I of the project and covers assessment of natural water resources, whereas current and future needs are balanced by non-conventional sources. The current water resources assessment indicates that the safety limit of groundwater abstraction is about 90 million m^3/year. However, groundwater abstraction has reached about 200 million m^3/year; but confining groundwater abstraction to the safety limit will necessitate a considerable increase in desalinated water, which is far in excess of what was originally envisaged. Accordingly, further water resources assessment is still needed in order to balance between availability of and demand for water resources.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

Maintaining good water quality is of prime concern to the Ministry of Works, Power and Water. Excessive abstraction from groundwater aquifers has resulted in continued deterioration of the groundwater quality due mainly to excessive salt-water intrusion. It is anticipated, however, that the construction of more desalinated plants may relieve the burden imposed on groundwater and allow quality tests to be carried out regularly to check for the most likely contaminants. In addition, with the establishment of the comprehensive water management scheme, protection of water resources and water quality will be feasible.

(iv) *Drinking-water supply and sanitation*

This programme area is receiving top priority in the national water policy, and any deficiency can be avoided through desalination of sea water. The distribution systems with built-in flexibility are being extended and modernized. At present, distribution networks cover all developed areas in Bahrain. With respect to quality, residual chlorine monitoring and bacteriological tests indicate that levels of chlorine and bacteria fall within the permissible WHO limits for drinking-water. Sanitation services, which fall under the responsibility of municipalities, are also receiving considerable attention. Meanwhile, treatment and reuse of sewage effluent is being activated in order to reduce the demand on groundwater for agricultural purposes.

(v) *Water and sustainable urban development*

Urban development in Bahrain ranks on top as compared with other Arab countries in the region, owing mainly to the concentration of more than 80% of the population in the islands of Bahrain and Mahrak. Therefore, serious action to avoid the negative impact of urbanization is currently being taken or is under consideration. Supplying water to urban areas with the aim achieving sustainable development requires almost complete dependence on desalinated water. It is envisaged, therefore, that desalination plants with capacities of about 30 million to 45 million gallons per day will be added by 1998/1999.

(vi) *Water for sustainable food production and rural development*

Although the agricultural sector consumes about 70% of the total groundwater resources, the country will continue to depend to a large extent on imported food. Wastewater treatment and reuse for irrigation is being considered as an additional water source, and this is expected to total about 70 million m^3/year by the year 2000. Meanwhile, the use of efficient and modern irrigation systems are being expanded, and it is estimated that about 20% of the irrigated area will be covered with such systems. In addition, the establishment of relevant crop pattern is being reconsidered. There is currently no proper crop mix, and water-demanding crops, such as alfalfa, predominate. The application of a tariff on groundwater consumption for irrigation will enter into force shortly.

(vii) *Impact of climate change on water resources*

There are no obvious plans or actions in this programme area with respect to global climate change. However, national activities focus on impacts of local seasonal climate change, and use of brackish water in agriculture.

(a) *Egypt*

(i) *Integrated water resources development and management*

The National Water Master Plan, which is currently in force, requires the integration of the Nile water development and management. The irrigation system in Egypt permits full control over water and its uses for agriculture. In addition, there are ongoing projects to promote efficiency and reduce water losses. Relevant water research institutions and strategic units have been established. The water management research institute and the national water information centre serve all organizations involved in water development and give appropriate support to decision makers, enabling them to make the right decision at the right time. In addition, cooperation between all water users with respect to agriculture, industry, domestic water, navigation and hydroelectric power are continuously promoted.

(ii) *Water resources assessment*

Assessment of all water resources in Egypt is continuously updated. A monitoring network and a telemetric system give adequate coverage. There are reliable sets of maps pertaining to water resources and land use which are periodically updated. The current water resources assessment covers conventional and non-conventional water sources, as both are included in the overall national water balance.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

Pollution of both surface water and groundwater is a major concern owing mainly to increased industrial activity and population growth, along with the inadequacy of wastewater disposal projects in some areas. However, environmental protection is being promoted in all water-user sectors. Within the frame of this programme area, the following main activities are being undertaken:

(a) Establishing a water quality monitoring network covering the Nile River, Lake Nasser and the main canals as well as the drainage network, as long as it is being used for irrigation;

(b) Launching a national project to prevent discharge of industrial wastewater into the Nile or any other waterway;

(c) Studying the characteristics of sediment material and the mechanics of its movement in the Nile River;

(d) Monitoring and evaluating the sedimentation in Lake Nasser and its effect on the reservoir storage capacity and Aswan Dam operation;

(e) Carrying out aquatic weed control manually, mechanically and biologically;

(f) Producing studies and recommendations to protect the heavily populated northern Egyptian coast, with its valuable agricultural lands and infrastructures.

(iv) *Drinking-water supply and sanitation*

A comprehensive plan was set up to provide all megacities, cities and villages with freshwater supplies. In addition, water purification plants are being reactivated and new ones constructed in order to cope with the rapid increase in public demand for water for domestic and industrial purposes. The current five-year plan includes 388 projects for drinking-water and sanitation. By the year 2002, some 4,000 villages and 12,000 communities will have domestic freshwater supplies and sanitary facilities. Local water purification plants are being manufactured for the first time in Egypt through the contribution of the private sector. The Ministry of Health is responsible for monitoring the potability of water for domestic use.

(v) *Water for sustainable urban development*

Urbanization constitutes a serious social problem in Egypt owing to continuous migration of people to large cities. It has a serious impact not only on the water supply but also on the overall environment. Firm and objective measures to reverse the migration have been taken through the establishment of industrial and commercial centres in areas away from the major cities. The Ministry of Rehabilitation and New Communities has been established specifically for the purpose of relieving the prevailing burden imposed on the urban areas. This will ultimately enable adequate provision of water supplies for sustainable urban development.

(vi) *Water for sustainable food production and rural development*

The national economic strategy aims primarily at achieving sustainable food security. Land reclamation and agricultural development, both horizontally and vertically, are given priority among other economic development projects. Full cooperation between the water and agricultural sectors exists. Current activities pertaining to this programme area are numerous and diversified, important among which are the following:

(a) Construction of the Al Salam canal to cultivate 0.6 million feddans;

(b) Construction of new pumping stations on the Al Nasr Canal to irrigate 0.13 million feddans in Nubaria area;

(c) Construction of New Esna Barrage to provide more water to downstream lands as well as to generate power and improve navigation on the Nile River;

(d) Widening of the Ismailia Canal to provide irrigation water for about 0.9 million feddans;

(e) Drilling of about 200 deep wells to increase the conjunctive use of surface water and groundwater;

(f) Extension of the tile drainage programmes to cover all old cultivated lands, and development and improvement of drainage projects;

(g) Study of crop water requirements and development of a relevant crop pattern.

(vii) *Impact of climate change on water resources*

A number of institutions dealing with the mitigation of climate change impacts on water resource development have been established. These are concerned primarily with the protection of coastal areas adjacent to the Nile Delta which are affected by water-related problems. However, their activities can be expanded to contribute to global climate change problems whenever such problems are detected and verified. In this regard, two institutions have been established: the Coastal Research Institute and the Institute for Research on Climatic Changes and their impact on water resources.

(c) *Iraq*

(i) *Integrated water resources development and management*

The national water policy in Iraq is directly attached to the continuity of river flows from the Tigris and Euphrates rivers, which are shared with Turkey and the Syrian Arab Republic. Integrated water resources development and management are being executed as planned; however, their sustainability depend on river agreements. The Ministry of Irrigation is the agency responsible for the development and management of all water resources in Iraq.

(ii) *Water resources assessment*

Normally there is activity related to this programme area, and information is updated periodically. However, reliable assessment is constrained by the vagueness of water agreements between riparian countries; such agreements are the subject to intense debates. The country is planning to establish a central monitoring network which will allow updating and promotion of water resources assessment activities.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

Deterioration of river-water quality, particularly in the Euphrates, is due mainly to attitudes and patterns of water utilization by the upstream riparian countries. An inadequate agricultural drainage network combined with waste-disposal projects and increased industrial activities exacerbate the problem. However, corrective action is being taken: environmentally sound areas for water disposal have been allocated, and adequate treatment plants are being constructed. The main drain project, which started in 1992, is being completed. This main drain will protect the water channels and lands in central and southern Iraq from contamination. An environmental impact assessment is being conducted on all new agricultural and industrial projects. A number of environmental laws and regulations have been enacted to protect the water resources from being contaminated.

(iv) *Drinking-water supply and sanitation*

The national policy and action plans regarding the drinking-water supply and sanitation are currently operational within the context of five-year programmes.

(v) *Water and sustainable urban development*

Urbanization, owing to population growth and industrial activity, constitutes a major concern for the local authorities. However, adequate plans to provide water for sustainable development in urban areas are being implemented within the framework of environmentally sound conditions.

(vi) *Water for sustainable food production and rural development*

The agricultural sector in Iraq is receiving top priority. National plans call for increasing irrigated lands from 3 million hectares to about 4 million hectares by the year 2020. However, achievement of these targets for sustainable food security are subject to successful implementation of land reform, soil salinity reduction, construction of dams, canals and a drainage network. In this regard, the dams on the Tigris and Euphrates rivers are constructed for seasonal storage. Also, the main drain will enable the cultivation of about 1.5 million hectares, which will contribute considerably to food security in the country.

(vii) *Impact of climate change on water resources*

There is no mention of this programme area in the National Water Policy, but some measures are expected to be taken to combat drought and desertification in remote areas.

(d) *Jordan*

(i) *Integrated water resources development and management*

Jordan is very much aware of the need to adopt sound water-sector management as part of its economic development schemes. Studies are in progress to restructure the institutional framework so that it may be incorporated into the updated national water master plan currently under preparation. However, the main target is to bridge the gap in the supply/demand equation with projects that are economically feasible, environmentally sound and socially acceptable. In this regard, the demand-side management option is viewed as the most feasible solution to augment freshwater resources, and it also bears environmental benefits (win-win solution). Jordan tries to pursue this option by reallocating water among different users and instituting proper pricing mechanisms and structural adjustment programmes. In addition, water conservation techniques in both the agricultural and domestic sectors were introduced. In general, several options are to be investigated on the supply-side management to develop new and alternative sources of water, such as sea-water desalination, artificial groundwater recharge, use of marginal-quality water, wastewater reuse and water-recycling. Meanwhile, a participatory approach involving users, planners and policy makers with respect to water resources development and management is being encouraged.

(ii) *Water resources assessment*

Several institutions are involved in the data collection processes; however, to date no major deficiencies in the available database have been identified. Water resources assessment continues to be implemented according to the general order of the five-year development plan (1993-1997). This requires: (a) evaluation of the quantity and quality of renewable and non-renewable surface water and groundwater resources; (b) completion of specific studies on fossil water, brackish water and deep groundwater; (c) centralization of water resources data collection and processing; and (d) modernization of the surface water and groundwater monitoring system in respect of quantity and quality. In addition, the facilities and procedures used to store, process and analyse the hydrologic data are being upgraded. The cooperation in the assessment of transboundary water resources, subject to the agreements with the riparian countries, should be strengthened further to allow for precise assessment of these resources.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

The national policy with respect to protecting water resources from pollution consists of: (a) enacting a comprehensive environmental protection law; (b) creating a comprehensive water quality monitoring system; and (c) enforcing water quality standards on industrial and commercial effluents. However, the water quality is thought to be considerably affected by the newly introduced practice of water rationing and timely distribution, along with the prevailing inadequacy of the wastewater disposal network and groundwater over-exploitation. Thus, the Government has initiated several projects which will improve and conserve water quality and quantity. Important among these are an industrial pollution control programme covering 30 industries in the Amman-Zarqa basin and an ongoing water quality improvement and conservation project. Since 1975, the Government has established some seven protection zones with a total area of about 129 hectares in Ajloun, Aqaba, Azraq, Madaba and Tafila. The newly issued Environmental Act stresses water pollution prevention and control through several articles calling for: (a) application of the "polluter pays" principle; (b) promotion of the construction of treatment facilities for domestic and industrial effluents; and (c) establishment of standards for the discharge of effluents and for receiving water.

(iv) *Drinking-water supply and sanitation*

At present, about 97% of Jordan's population is served by a drinking-water supply system, and about 60% of the population's domestic disposals is connected to the public sewage system. The issues of proper maintenance and repair of drinking-water and sanitation facilities are being stressed, and relevant development plans for expansion of these facilities are under way. Wastewater reuse for irrigation is also receiving substantial attention. The Government is embarking on a programme to rehabilitate the operating wastewater treatment plants and construct new ones. In this regard, the operational water supply and wastewater utility functions may be gradually privatized. Meanwhile, the Government is undertaking systematic public education and awareness programmes.

(v) *Water and sustainable urban development*

Economic activity is centred in urban areas which currently house more than 77% of the population. The annual growth rate of urban population is about 4.3%, which is considerably higher than the national population growth rate of 3.5% per year. Accordingly, the environmental impact is likely to worsen with the growth of urbanization and industrialization. On the other hand, in view of the constraints imposed by climate, soil and water, Jordan has limited potentialities for activities away from urban areas. Meanwhile, as the water resources in the main urban centres are overexploited, the Government is implementing costly water conveyance projects to be able to meet the growing demand for water for domestic and industrial purposes in urban areas. The environmental problems of sewage disposal also constitute a major concern for the Government. Therefore, reconciliation of city development planning with the availability and sustainability of water resources is being optimized in order to satisfy the basic water needs for sustainable urban development. The major issue of the water policy in urban areas is the preparation of systematic water audits and master plans for municipal systems, and the upgrading and development of municipal networks. In doing these things, the Government will enhance the existing block tariff system in urban areas and regulate private water delivery in these areas in accordance with resource management objectives and the regulations for drinking-water quality. Public awareness campaigns are also being initiated.

(vi) *Water for sustainable food production and rural development*

The agricultural sector contributes only 7% to 8% to the national income and employs about 10% of manpower. Accordingly, self-sufficiency in food production has been replaced by the economic sustainability of other sectors, not including agricultural expansion. Although agriculture, with its limited economic contribution, is consuming almost three quarters of Jordan's water, the competition among different water users in agriculture, industry and municipalities will continue to be a major challenge to Jordan's planners and decision makers. Sustainability of food production and development of rural areas thus require the endorsement of the following specific policies: (a) treatment and reuse of wastewater; (b) potential utilization of brackish water in agriculture; (c) use of a cropping pattern that would provide a high return on water; and (d) promotion of modern irrigation techniques.

(vii) *Impact of climate change on water resources*

The Government acknowledges that this issue is fraught with uncertainty; therefore, the plan will stress facts rather than potentials, but liaison will be maintained with the scientific and academic international community so as to follow up this issue and react accordingly. Local seasonal climate changes, as a result of the predicted global temperature rise, may result in a decrease in rainfall, which may have a disastrous impact on agriculture and water resources. An upcoming project in capacity-building in Jordan, funded by GEF, will provide technical services to assist in climate change mitigation and adaptation through the advancement of national priorities in areas such as energy efficiency, fuel substitution, renewable energy development, and forest conservation and management. Meanwhile, local capacity to respond to the Framework Convention on Climate Change will be promoted to enable investigating the impact of climate change.

(e) *Kuwait*

(i) *Integrated water resources development and management*

The national water policy in Kuwait includes the development of three main water sources: the desalination of sea water, groundwater and reuse of treated wastewater. Management of these water resources is limited mainly to water allocation policy according to the quality of the water source. In this regard, groundwater development and management practices focus on; (a) application of relevant laws and regulations to groundwater extraction; (b) rational utilization; (c) artificial recharge; and (d) modernization of irrigation techniques. In respect of development and management of desalinated water, emphasis is given to continued research and studies on the efficiency of the various relevant desalination methods. Extremely valuable information has been extracted in this regard, particularly on the multi-stage flash evaporation method, which has proved to be the most relevant. In addition, with the establishment of the Water Resources Development Centre, research and studies will continue to be promoted.

(ii) *Water resources assessment*

Owing to the limited water sources, water resources assessment constitutes only a modest component of the national water activities. However, the search for unexplored groundwater basins continues, and their potentialities are assessed and managed.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

Groundwater is the main concern in this programme area. Deterioration of this source, which is due to overexploitation and the prevalence of salt-water intrusion, is mitigated through a number of protective measures: legislation; restrictions on water use; artificial replenishment, reform of irrigation techniques; and close supervision of water-well drilling.

(iv) *Drinking-water supply and sanitation*

This programme area has priority among other national activities. Drinking-water is conveniently provided through two distinct networks of pipelines: the first is for drinking-water and carries water directly from desalination plants; the second carries water for other domestic purposes and carries brackish water. Expansion to cover the entire country is being progressively carried out. In addition, there are sanitation facilities which are adequately maintained.

(v) *Water and sustainable urban development*

Water is supplied to urban areas for domestic and industrial purposes mainly by means of desalination plants. Future demand is continuously planned for in the national water policy, and the utmost care is taken to ascertain its sustainability.

(vi) *Water for sustainable food production and rural development*

In view of the limited water sources allocated to the agricultural sector, development of rural areas has modest priority and the private sector has responsibility for it. Although the agricultural sector in Kuwait consumes more than 60% of all water resources, the country continues to depend mainly on food imports, and accordingly there are no plans for self-sufficiency in food.

(vii) *Impact of climate change on water resources*

This programme area does not appear in the national water policy. However, scientists and professionals are currently participating in international meetings.

(f) *Lebanon*

(i) *Integrated water resources development and management*

Despite the apparent abundance of water sources in Lebanon and the comparatively high seasonal rainfall, water continues to be a crucial resource. There are three basic types of water development and management projects in Lebanon: (a) projects developed and managed by the Government; (b) projects developed and maintained by the Government but managed by the private sector; and (c) projects developed and managed by the private sector. Therefore, national integrated development and management is vague.

(ii) *Water resources assessment*

In the absence of an updated national water policy, a reliable and comprehensive water resources assessment is not available. The prevailing situation in Lebanon impedes planning for a national water policy whose implementation would be feasible.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

For the same reasons mentioned above, water resources are inadequately protected. The domestic water network is deteriorating and the irrigation system is ill-maintained.

(iv) *Drinking-water supply and sanitation*

The situation with regard to the drinking-water supply and sanitation facilities remains crucial, and the country lacks the relevant infrastructures. Although relevant plans have been drawn up, their implementation has yet to be effected. In view of the complexity of the technical problems associated with the old drinking-water supply network and treatment plants, which have remained unchanged or inadequately maintained for a considerable length of time, along with the multiplicity of municipal water authorities, the problem of the drinking-water supply and sanitation will continue to deteriorate unless serious and urgent measures are agreed upon and taken. With respect to sanitation, although a considerably high percentage of the domestic waste disposal systems are connected to the public sewage system, the treatment plants are not functioning adequately.

(v) *Water and sustainable urban development*

This issue is the subject of a great deal of activity at the national level, and the utmost effort is being made in order to maintain an acceptable level of daily life, which is imperative for all economic activities. However, the above-mentioned constraints and problems still prevail in the cities.

(vi) *Water for sustainable food production and rural development*

The majority of food production is currently provided by the private sector, which depends mainly on dated agricultural projects. National irrigation projects have been suspended for the time being. This situation reflects negatively on food security and sustainability. In addition, the complexity of the technical problems associated with the prevailing irrigation systems, along with the multiplicity of agricultural and irrigation authorities, constitute major constraints facing the promotion of this sector.

(vii) *Impact of climate change on water resources*

This programme area is not currently the subject of any activity in Lebanon.

(g) *Oman*

(i) *Integrated water resources development and management*

With the establishment of the Ministry of Water Resources in 1990, integrated water resources development and management is now more possible than ever. However, they are currently applied to some basins and for certain purposes. Some examples are newly constructed recharge dams, exploitation of groundwater at coastal basins (al-Batina) and protection zones, particularly for water for domestic purposes. In addition, the issuance of laws and regulations constitutes a complementary and integral part of the development and management of water resources in the country. The Aflag water system is considered an ideal example of water management.

(ii) *Water resources assessment*

A national groundwater inventory project is currently in progress. A database and various sets of hydrogeological maps are being prepared, and surface water is being evaluated. The monitoring system is being strengthened, and observation stations are being established.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

Although surface water and groundwater are threatened with depletion and pollution, adequate plans have been devised, and laws and regulations concerning the protection of these water resources are strictly enforced. Aquatic ecosystems are currently protected.

(iv) *Drinking-water supply and sanitation*

The water policy currently in force includes programmes for the provision of drinking-water supplies and sanitary facilities. These programmes are progressively implemented according to a pre-set geographical distribution scheme. More than 90%

of urban centres and about 50% of rural areas are connected to safe drinking-water. As for sanitation facilities, it is believed that these are available to all urban centres and about 40% of rural areas.

(v) *Water and sustainable urban development*

Appropriate plans and projects for provision of water for domestic and industrial purposes are being implemented in urban areas within the framework of the prevailing national development programme. These projects are therefore given high priority. As indicated above, urban areas enjoy almost full services as regards water supplies and sanitary facilities.

(vi) *Water for sustainable food production and rural development*

The Government is currently encouraging the public sector to expand land reclamation and intensive agriculture by providing various sorts of incentives and selling land at nominal prices. However, sustainability of food production is constrained only by the water shortage.

(vii) *Impact of climate change on water resources*

There is no activity with regard to this programme area except for some drought-related activities.

(h) *Qatar*

(i) *Integrated water resources development and management*

In the absence of a national water policy, integrated water resources development and management seems to be vague. Furthermore, owing to the continued deterioration of the groundwater basins, the gap between available water resources and demand is being bridged by increased levels of desalinated water, reuse of treated wastewater, and negotiations to import water from the Islamic Republic of Iran. The decrees issued for water utilization are considered the main tools for water management.

(ii) *Water resources assessment*

This programme area is not being systematically implemented, nor is it thought to be updated. All efforts are oriented towards development of non-conventional water resources, owing mainly to the extreme shortage in groundwater potentialities.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

Deterioration of water resources as regards quantity seems to be unavoidable. Estimates indicate that the water supply will be completely depleted by the year 2000 if exploitation continues at the prevailing rates. Water quality is also being continuously threatened. Therefore, this programme area has been given a low profile.

(iv) *Drinking-water supply and sanitation*

This programme area is perhaps the only issue that has received national interest and effort. Drinking-water is provided from desalination plants, and sanitary facilities are considered adequate. The cost of drinking-water is greatly subsidized by the Government.

(v) *Water and sustainable urban development*

As mentioned above, this programme area is given utmost priority in the national economic programmes as a crucial means of supporting the majority of the urban population, and to maintain current economic and industrial activities.

(vi) *Water for sustainable food production and rural development*

This programme area does not constitute an important issue in the Government's plans. The country depends to a great extent on food imports, and food security therefore seems to be out of reach.

(vii) *Impact of climate change on water resources*

This programme area is not currently receiving any consideration.

(i) *Saudi Arabia*

(i) *Integrated water resources development and management*

A comprehensive and updated water strategy is currently in force. Development of water projects are implemented according to plans and programmes. Management is normally restricted to water basins or sub-basins. There is an institutional framework which adequately supports these activities. Therefore, this programme area is well under way.

(ii) *Water resources assessment*

Assessment of water resources in Saudi Arabia is continually updated, owing mainly to the availability of a well-established and intensive monitoring system and observation network, the introduction of a database and the GIS, and other technical support tools. Accordingly, the activities and means of implementation pertaining to this programme area are in line with those outlined in Agenda 21.

(iii) *Protection of water resources, water supply and aquatic ecosystems*

Serious measures are under consideration to mitigate the impact of the current water deterioration problem. Nevertheless some serious problems persist. Laws and regulations pertaining to the protection of water resources play an important role in controlling attitudes and patterns of agricultural and industrial activities.

(iv) *Drinking-water supply and sanitation*

This programme area is continuously under consideration, and plans to provide adequate water supplies and sanitary facilities have been devised. These facilities are not available throughout the country, but relevant projects will be executed progressively. It is currently believed that almost all urban centres have access to adequate drinking-water supplies and sanitary services, and about 50% of rural areas have adequate drinking-water and 40% have adequate sanitary services.

(v) *Water and sustainable urban development*

Major urban areas enjoy water sustainability for at least domestic and industrial purposes. A considerable effort is being made to satisfy all water needs in these areas even if transfer of water from remote areas proves to be the only solution.

(vi) *Water for sustainable food production and rural development*

In view of the water shortage, this programme area is constrained, and rural development is not always feasible. Accordingly, food security is not adequately maintained, and the country will continue to depend partially on food imports, which does not constitute a major handicap.

(vii) *Impact of climate change on water resources*

There is no activity in this programme area with the exception of activities related to water conservation in drought-prone areas.

(j) *Syrian Arab Republic*

(i) *Integrated water resources development and management*

A national water policy is foreseen, and water development projects have been developed within the context of the current five-year plans and programmes.

Integrated water resources development and management is conducted at the level of individual closed basins (Euphrates, Al-Assy, Damascus) through central authorities for each individual basin. The absence of water agreements with riparian countries precludes the establishment of a long-term national water policy. A National Water Research Centre is being established. Meanwhile, within the activities of this programme area, the country is adequately dealing with eventual flood and drought phenomena through the construction of dams at relevant sites. Artificial groundwater recharge and treatment and reuse of wastewater are also receiving considerable attention. The country possesses high capabilities in public awareness through local community committees and professional syndicates. These issues are considered valuable tools leading to appropriate integration of the development and management of water resources.

(ii) *Water resources assessment*

Despite the importance of water resources assessment and need to achieve it at the national level, it has been conducted at various occasions and only for individual water basins. The establishment of a database and the use of models are being promoted. The monitoring network in surface-water and groundwater basins is being expanded. In general, this programme area is well acknowledged, and activities are being initiated.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

Deterioration of both surface water and groundwater is considered a serious problem. This is due mainly to the prevalence of inadequate wastewater and irrigation drainage systems. Serious efforts are directed towards the protection of these sources through the establishment of specialized institutions and an increase in national capacity and reuse of wastewater. The newly established Ministry of Environment is giving particular emphasis to this programme area. In this regard, the Ministry has issued standards for industrial wastewater disposed of in the sewage network. Standards for safe drinking-water have also been issued. The water quality monitoring system is being promoted. The "polluter pays" principle is being applied, and protection zones are being identified. Major industrial factories are obligated to establish local waste treatment units.

(iv) *Drinking-water supply and sanitation*

This programme area receives priority in the national water programmes. However, deficiencies in financial resources may impede extension of these facilities to cover all localities. In addition, the prevalence of closed basins makes transfer of water a major constraint. About 90% of urban centres currently have safe drinking-water, and about 75% have sanitary services, while in rural areas the numbers drop to about 70% and 60% respectively.

(v) *Water and sustainable urban development*

National water development plans include a basic consideration for the development of urban areas, which are home to the main economic and industrial activities. Achievement of these goals is currently constrained by a shortage of water and financial resources and wastewater network resources. However, the construction of a new wastewater treatment plant in Damascus is nearly completed, and a similar one in Aleppo is under way. In addition, artificial groundwater recharge in Damascus is being implemented to supply additional drinking-water to the city.

(vi) *Water for sustainable food production and rural development*

Food security remains a primary target in national economic plans. Some 140 dams have been constructed at various water basins since 1968. Major efforts are being oriented toward rural development; however, this is constrained by: absence of water agreements with riparian countries; groundwater deterioration; and insufficient financial resources. The rural councils are actively contributing to the development of rural areas through integrated management of each individual basin.

(vii) *Impact of climate change on water resources*

A study on the impact of climate change, based on the assumptions made by the United Nations in respect of the rise of the water temperature by 1.5°C to 3°C and the sea-water level by 0.6 m to 1 m, has been carried out in the coastal areas of the country. The results indicate that, if the assumptions are valid, salt water will intrude into the coastal aquifers, which will render the groundwater unsuitable for irrigation.

(k) *United Arab Emirates*

(i) *Integrated water resources development and management*

In the absence of a long-term national water policy, along with the multiplicity of water authorities with conflicting functions, appropriate integration of water resources development and management is apparently vague. Therefore, this issue should be reconsidered from a scientific viewpoint, and activities pertaining to this programme area should be activated.

(ii) *Water resources assessment*

Assessment of both surface water and groundwater resources is being conducted at the sectoral level. Current efforts in this regard still need intensification. However, the country operates a network of observation stations for collection of various hydrological, meteorological, and groundwater data, which are transferred to computer programs for water resources assessment.

(iii) *Protection of water resources, water quality and aquatic ecosystems*

Owing to widespread efforts in respect of treatment and reuse of wastewater at the national level, water pollution has been greatly reduced. In addition, with the establishment of the Federal Environmental Agency (FEA) in Dubai, concentrated water protection activities will be promoted and activated. Regular campaigns are being carried out to create awareness among water users about water protection and conservation.

(iv) *Drinking-water supply and sanitation*

Both issues are given top priority in the national development programmes. Adequate drinking-water is provided by plants that desalinate both salt and brackish water. Sanitation facilities aim at reuse after third category treatment. Therefore, this programme area is well in harmony with that of Agenda 21.

(v) *Water for sustainable urban development*

Intensive efforts are being made in respect of all urban areas in the United Arab Emirates, and accordingly sustainable development is being appropriately achieved. This may be due mainly to the decentralization policy prevailing in the United Arab Emirates, which gives more attention to urban areas.

(vi) *Water for sustainable food production and rural development*

Despite the continuous support of the Government for the private sector with respect to rural development, the chances for achieving food security remain doubtful, owing mainly to the severe shortage of national water resources. However, intensive activity in respect of reuse of wastewater has enabled the United Arab Emirates to plant more than 20 million palm trees, which is a record.

(vii) *Impact of climate change on water resources*

There is no activity related to this programme area, with the exception of studies into the use of brackish water in agriculture.

(l) *Yemen*

(i) *Integrated water resources development and management*

The implementation of the national water policy that has been recently prepared remains unlikely without considerable financial support. Although water development projects are being implemented at a modest rate, water management is inadequately integrated. Most of the water development projects are driven or motivated by sectoral demands, while the resource management responsibility is fragmented among numerous sector users instead of being consolidated into a single national management entity which can integrate the development activities with socio-economic development. However, the mandate of the proposed National Water Resources Authority (NWRA), which is expected to be functional by 1996, considers this particular programme area as its main task.

(ii) *Water resources assessment*

Assessment of water resources in Yemen is being conducted only sporadically. Although plans for WRA do exist, their implementation remains constrained by the scarcity of both technical and financial resources. It is hoped, however, that the establishment of the NWRA will provide the institutional framework to enable a comprehensive WRA.

(iii) *Protection of water resources, water quality and aquatic ecosystem*

Owing to the prevailing scarcity of water resources, surface water and groundwater basins are continuously subjected to both quantitative and qualitative deterioration. The taking of measures to protect these resources is constrained by financial problems. Owing mainly to the prevailing tendency of sectoral entities to focus on development and use while ignoring management, the water degradation problem will persist and probably augment. A serious new hazard is now emerging as a result of the disposal of the water by-product of the newly discovered oil field in Hadramawt into the groundwater basin in Masila.

(iv) *Drinking-water supply and sanitation*

There are serious problems associated with this programme area. The country lacks adequate infrastructures for drinking-water supplies and sanitation projects, which require intensive efforts and financial support. The proportion of the population with access to piped drinking-water probably does not exceed 30% to 40% of the total population. A similar percentage of the population has public sanitary facilities. Furthermore, owing to the continued leakage from the inadequate sanitary network into the fractured drinking-water pipeline, waterborne diseases prevail, and this is believed to be the main reason behind the high mortality rate among children.

(v) *Water and sustainable urban development*

Although numerous activities are being carried out under this programme area, the multiplicity of problems related to the water shortage coupled with financial constraints impede the achievement of sustainable urban development. The current level of water supplies and sanitation facilities in urban areas is considerably low compared with those targeted in Agenda 21.

(vi) *Water for sustainable food production and rural development*

In view of the limited surface water resources, along with the continuous deterioration of groundwater basins, rural development is insufficient to support food security. Therefore, in this programme area Yemen is still behind the anticipated goals.

(vii) *Impact of climate change on water resources*

A newly established project to conduct research on climate change is being sponsored in Yemen by the Government of the Netherlands. In 1995, the Environmental Protection Council organized a workshop on the various impacts of climate changes, including those on water resources.

E. CONCLUSIONS AND RECOMMENDATIONS

1. *Conclusions*

Chapter 18 of Agenda 21 focuses specifically on the protection of water resources and the water supply through the application of integrated approaches to the development, management and use of these resources. The chapter includes seven programme areas, described in terms of basis for action, objectives, activities and means of implementation. It gives comprehensive coverage of major water resources issues which are crucial to the appropriate conservation, development and sustainability of those resources for the various types of use.

The status of available water resources in the ESCWA region indicates a number of constraints and challenges to the provision of water supplies to satisfy projected requirements. While some countries are suffering from an extreme shortage of water resources, others are approaching the same predicament. The major water resources constraints and challenges in the ESCWA region have been described for each country, and serious action and objective, economical water development and management plans and programmes should be considered as early as possible.

The review of the general features of the national water strategy and policy of each country in the ESCWA region reflects the principal indicators and general features of the extent to which the programme areas have been incorporated into these water strategies. However, it should be recalled that most of the readily available national water policies predate Agenda 21. This does not necessarily imply that previously endorsed water policies must be reformulated; however, Agenda 21 can still be used to fill gaps and promote the scope of those policies. It has been shown that some countries in the region are taking action in accordance with the programme areas listed in chapter 18 of Agenda 21. Others either have a water policy and plans but are unable to implement them or have not endeavoured to formulate a water policy at the national level. The extent to which each programme area of chapter 18 of Agenda 21 is reflected in the national water strategies and policies has been shown, and considerable variation has been revealed in respect of the extent to which these programme areas are being implemented in the ESCWA region.

A specific evaluation has been presented of the status of each ESCWA member country with regard to the implications of the various programme areas. In general, with the exception of the programme area pertaining to the impacts of global climate change on water resources, all countries are fully or partially addressing the issues in the various programme areas, although the scopes and levels of implementation differ.

2. *Recommendations*

Recommendations for strengthening incorporation of the objectives, activities and means of implementation of the various programme areas included in chapter 18 of Agenda 21 into the national water plans and economic development programmes of the countries in the ESCWA region are addressed to both international and regional organizations as well as to the countries themselves, including the water researchers and planners.

(a) *Recommendations addressed to international and regional organizations*

(i) *Technical assistance for the formulation of a national water policy*

As foreseen, some countries have had technical difficulties in formulating and/or updating their national water policies. Therefore, the international and regional organizations are requested to provide such assistance to these countries by assigning a number of qualified consultants.

(ii) *Financial assistance*

Agenda 21 includes a clause regarding the estimated annual cost of implementing the activities of each programme area. The funds are to be provided from the international community as grants or on concessional terms; however, the status of these funds is vague. Therefore, the international organizations in the region are requested to follow up this matter for the purpose of allocating relevant financial assistance, specifically to the countries suffering financial deficiencies.

(iii) *Follow-up*

The international and regional organizations are requested to continue following up the implementation of the various components of Agenda 21 by organizing periodic seminars and ad hoc meetings in order to detect any eventual technical constraint that may impede the progress of activities.

(iv) *Training courses*

Agenda 21 is composed of programme areas broken down into terms of objectives, activities and means of implementation; however, in practice these should be elaborated and detailed, particularly with respect to human resources building. Therefore, the international and regional organizations are requested to organize and sponsor ad hoc training courses in line with the main components of each programme area. In this regard, a roving mission composed of highly qualified instructors can give on-site training in each country that may request it; in this way, the training can be assured of reaching the greatest number of individuals.

(v) *Dissemination of Agenda 21*

It is apparent that the distribution of Agenda 21 has been confined to very few offices in the region. Accordingly, its contents are inadequately known to all sectors of professionals, planners and decision makers. Therefore, the concerned international organization is requested to effect wider dissemination of the document, including ministries, national authorities, municipalities and research institutions.

(b) *Recommendations addressed to the countries in the ESCWA region*

(i) *Water master plans*

All countries in the region are urged to update their national water policies or formulate one. Alternative scenarios should be developed in order to account for eventual climate changes and unforeseen water risks that may result from changes in environmental, social, political or technological conditions.

(ii) *Water development versus management*

Water development is not always the sole rescue from a water shortage. However, non-structural water management should be integrated with structural water development. This is due to the fact that the integrated approach to water development and management is the most appropriate technique for alleviating water resources constraints. Therefore, all countries are urged to manage their readily developed water resources adequately by reducing water losses, adopting low-rate consumptive tools in irrigation and industry, and maintaining water-supply and sanitary networks.

(iii) *Water agreements between riparian countries*

Governments are urged to seek all possible political approaches with neighbouring countries which share the same water source in order to reach a clear and well-defined water agreement.

(iv) *Water resources assessment*

This programme area should be given top priority in any national water policy, since water resources assessment constitutes the basic information for any water development and management plan.

(v) *Avoidance of multiplicity of water authorities*

A multiplicity of water authorities with overlapping or conflicting functions is a major impediment to efficient water management. Therefore, all countries should endeavour to avoid such multiplicity by assigning the responsibilities of water development and management to one specific authority or ministry.

(vi) *Environmental strategy*

The role of environmental institutions is becoming a leading issue for water decision makers. Therefore, parallel to a national water strategy, the formulation of national environmental strategy is now more imperative than ever. This is due to the fact that the various water sources are continuously deteriorating in quality, which in turn will render their utilization risky to all sorts of life.

(vii) *Public awareness and participation of non-governmental organizations*

This issue is the most effective tool for adequate water conservation. Therefore, with active public participation, all endeavours towards conservation and rational utilization of water resources will be more fruitful. The involvement of non-governmental organizations should be encouraged.

(viii) *Human resources development and capacity-building*

Implicit in virtually all programme areas pertaining to water resources and related matters is the need for progressive enhancement of the institutional framework and the training of personnel.

(c) *Recommendations addressed to water researchers and planners*

Within the context of the water resources section of Agenda 21, the main goal has been specifically identified as the protection of the quality and supply of freshwater resources through the application of integrated approaches to the development, management and use of water resources. In this regard, a set of measures should be considered to account for the important physical, economic, social and cultural linkages within the system being developed and managed. In order to achieve these linkages adequately, four major problem areas are particularly recommended (UNESCO, 1991):

(a) Incorporating the environmental, social and cultural consequences of water resources projects into the early stages of project planning. This includes a systematic assessment of environmental impacts;

(b) Integrating watershed land management with surface water and groundwater resources development in order to deal effectively with important land-water linkages in river and groundwater basins, particularly in respect of quantity and quality;

(c) Allocating water rationally among competing users in the context of efficiency, equity, sustainability and order objectives. This implies placing emphasis on the demand side in water resources management in order to balance the demand for and supply of water;

(d) Achieving effective implementation of national project plans, including the involvement of local people in planning and implementation. In the case of riparian countries, high authorities and top decision makers, in cooperation with researchers and planners, are to be involved in the planning and implementation processes, within the prevailing water agreements. This will enable better integration of upstream management with downstream water development.

REFERENCES

ACSAD, AFESD and KFAED, Proceedings of the Seminar on Water Resources and Utilization in the Arab Region, Kuwait, 1986.

ACSAD, Evaluation of Present Situation of Water Resources in the Arab Region, Damascus, 1993.

ALECSO, Proceedings of the Fifth Meeting of the IHP Arab Permanent Committee, Cairo, 1992.

ALECSO, Water Security Programme in the Arab Region, Tunis, 1992.

ALECSO, Arab Journal of Science, vol. 21, 1993.

Bahrain Centre for Studies and Research, Water Resources Development, Bahrain, 1992.

Bahrain, Country Report, ESCWA EGM, Amman, 1995.

Egypt, Country Report, ESCWA EGM, Amman, 1995.

Egypt, National Water Master Planning in Egypt, Cairo, 1995.

Egypt, Statistical Yearbook, Cairo, 1992.

ESCWA, Progress Achieved in the Implementation of the Mar del Plata Action Plan in the ESCWA Region, Amman, 1991.

FAO, Mission report on irrigation of sub-sector revision in the Syrian Arab Republic, 1993.

Iraq, Country Report, ESCWA EGM, Amman, 1995.

Jordan, national water master plan of Jordan, vol. 1, 1977.

Jordan, Water Quality Improvement and Conservation Project, Amman, 1995.

Jordan, National Environment Strategy for Jordan, Amman, 1991.

Jordan, Country Report, ESCWA EGM, Amman, 1995.

League of Arab States, Economic Report, 1990.

Lebanon, Country Report, ESCWA EGM, Amman, 1995.

Syrian Arab Republic, Country Report, ESCWA EGM, Amman, 1995.

United Arab Emirates, Union Law No. 21, Abu Dhabi, 1981.

United Arab Emirates, Country Report, ESCWA EGM, Amman, 1995.

UNESCO, Statistical Yearbook, Paris, 1990.

UNESCO/ROSTAS, Water Resources Assessment in the Arab Region, Cairo, 1988.

UNESCO/ROSTAS, Groundwater Protection in the Arab Region, Cairo, 1995.

UNESCO, Oman, Mission report on rational use of water resources in Oman, Paris, 1993.

UNESCO, Approaches to Integrated Water Resources Management in Humid, Tropical and Arid and Semi-arid Zones in Developing Countries, TDN, Paris, 1991.

United Nations, Report of the United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, June 1992.

Yemen, water resources management and economic development, vol. 1, Sana'a, 1992.

Yemen, Country Report, ESCWA EGM, Amman, 1995.

III. METHODOLOGIES FOR WATER SECTOR PLANNING

A. General observations

The continuously increasing demand for water and the rapidly diminishing water supplies makes rational water sector planning imperative. Water sector planning should be carried out within the context of national development goals and objectives. The planning process must recognize that the development in the water sector and other sectors is interdependent and mutually supporting, in such a way as to achieve integrated water management at the national level in accordance with the respective programme areas and objectives of Agenda 21.

The planning process should proceed with a good understanding of national development goals, sectoral objectives, and planning horizons. The sectoral review should be carried out with specific objectives to generate information and data needed for the planning exercise. Alternative strategies should be formulated and tested to determine the best option for attaining the sectoral objectives. The selected strategy should clearly spell out the policies, programmes and projects. The financial requirements to implement the plan should be assessed to test the viability of the plan within the context of macroeconomic budgetary constraints.

Water sector planning requires an enormous amount of data which can be translated into supply and demand. The scarcity of reliable data in the ESCWA region about these supply and demand variables may not facilitate efficient water sector planning.

B. Methodology for water sector planning

A substantive knowledge of all aspects of the water sector at the national level is a prerequisite for water planning. Once basic information is developed within a systematic framework, comprehensive planning is possible. Such knowledge can be achieved through acquisition of the already compiled basic data on water, land and manpower resources, in addition to the new data to be collected after establishment of a minimum required monitoring network throughout the country. This will furnish an initial database and thus permit substantive resource assessment.

In other words, water planning at the national level is only possible if the following questions can be answered (1):

(a) How much water is available in the short, medium, and long term?

(b) What are the present uses and the future demands in the same ranges?

(c) To what extent may the available and potential water resources satisfy these demands for all sectors?

This supply and demand approach for planning formulation may lead to the proposal of certain measures to cope with the prevailing situation such as:

(a) Exploring new sources to be exploited;

(b) Reallocating resources among various users;

(c) Controlling per capita and/or irrigation consumption rates and water demand in general;

(d) Conducting feasibility studies on the basis of these findings to ascertain possible alternative strategies.

The first two above activities have some social and political impact which must be carefully dealt with in the master planning. The third activity embodies financial and institutional arrangements.

In line with the above, the overall work plan for water master planning is presented below (see charts I to VIII).

The work plan should be as comprehensive as possible in order to include all envisaged activities to achieve the following:

(a) A comprehensive water database;

(b) A sound monitoring system;

(c) An assessment of the available resources (water, land and manpower);

(d) Water use/demand projections;

(e) Formulation of a plan in accordance with the above.

It is worth noting here that the reliability of the plan formulated is totally dependent on the availability of water sector data, and their adequacy and reliability. Therefore, the work plan will focus on data acquisition. Sound cooperation between public and private institutions active in the water sector at the national level is required during the planning process. In addition, it must be kept in mind that water planning should not be rigid, and should permit modifications and revisions in line with the availability of more data and/or the overall changes in socio-economic conditions at the national level. This means that the final product of the work is a National Water

Master Plan based on the available water sector data and socio-economic aspects prevailing during the formulation of the master plan.

In order to develop a water sector plan that is consistent with the overall national development plan, the following activities should be undertaken (2):

(a) Review of national development goals and objectives;

(b) Development of sectoral objectives and setting of preliminary growth targets to achieve national development goals and objectives;

(c) Carrying out of sectoral review, collecting relevant data and information, and revising growth targets;

(d) Defining planning horizons and making future projections about the sector's development;

(e) Describing and analysing alternative strategies for achieving planned targets for the sector;

(f) Formulating and analysing programmes to be carried out to achieve the sector's targets and objectives;

(g) Assessing financial requirements to implement the projects and programmes, including the yearly financial plan for the plan period and possible sources of financing.

Although the above sequence of various activities provides a logical framework to prepare the sector plan, it does not mean that there can be no deviation from the suggested sequence. The sequence only suggests that the information generated by one component can serve as an input to initiate and organize the work for the next component. The planning process can proceed simultaneously on more than one component, because the suggested components are interrelated and interact.

What follows is a brief review of each of the above required activities.

(a) *National development goals*

The term "planning" generally refers to the process of allocating scarce resources in a manner that will maximize the achievement of selected objectives. The development goals and objectives are most frequently defined in terms of high economic growth, better income distribution, less inflation, and high employment level.

(b) *Sectoral objectives and growth targets*

In order to accomplish the national development goals, the economy is divided into various economic sectors, and objectives and growth targets are set for each sector. There is a distinction between an objective and the target; the latter may be defined as the quantitative transformation of the former. The sectoral growth targets are generally rationalized on the basis of intersectoral relationships, the relative importance of a particular sector, and the potential availability of physical and financial resources.

(c) *Diagnostic surveys and sectoral review*

The diagnostic surveys and sectoral review studies to be carried out in support of water sector planning should collect and generate the following data and information:

(a) Data acquisition, analysis and review of the available literature;

(b) Assessment of conventional (surface water and groundwater) and non-conventional water resources in terms of availability and reliability in quantity and quality;

(c) Identification of water-consuming sectors, water requirements and projection of water demand;

(d) Determination of the water supply/demand gap at the national level;

(e) Provision of water development projects to bridge the gaps, considering the ongoing and planned water projects and scheduling of their financing;

(f) Cost-benefit analysis and feasibility studies considering the prevailing socio-economic conditions;

(g) Survey of water losses and/or water use efficiencies in various water-consuming sectors and provision for possible water conservation measures including water legislation;

(h) Identification of environmental impact of water management practices;

(i) Capacity-building infrastructures including institutional arrangements for water resources management, administration and execution of the master plan.

(d) *Planning horizon and future projections*

The planning exercise can be carried out for the planning horizon, which could be either short-term (annual plan), or medium-term (five-year plan), or long-term (10 years or longer plan). In most of the ESCWA member countries, medium-term planning is a common planning horizon. The medium-term plans can be reviewed periodically and adjusted to reflect changes in overall economics over time.

(e) *Alternative strategies*

In order to achieve an objective, or a target, or both, a development strategy is needed. The development strategy may be defined as a framework that consists of different policies, programmes, projects, and measures which help to attain a particular objective.

The selection of a particular strategy is mainly guided by the nature of the objective; therefore, before adopting a particular strategy, its usefulness must be examined and compared with other possible strategies within the context of the time horizon.

(f) *Programmes for water resources development projects and policy formulation*

The next step is to prepare a detailed programme of policies and projects which is consistent with the overall development strategy. In the whole planning process, policy-making is a relatively complex and difficult task. Policy reforms introduced in one sector can easily influence the performance of other sectors. Therefore, before a policy is implemented, it is important to analyse its possible economic effects on other sectors of the economy. The projects proposed can be viewed as another variant of the policy. Sometimes projects are conceived and prepared in support of the policies formulated to achieve sector objectives. As such, the project can be viewed as an action measure to implement a policy.

(g) *Financial assessments*

The financial resources required to implement the plan during the planning horizon have to be assessed. Financial requirements should be projected over the planning period to identify the amount needed to implement plan activities and development projects in each year to facilitate annual updating of the sectoral budget, if needed, and to make intersectoral comparisons in terms of funds needed and development projects to be implemented. In the ESCWA region in general, financial resources are scarce; hence it is important to identify the possible sources of funding for each activity defined in the plan. In addition, financial requirements should be examined against the national budget within the context of the socio-economic development goals and priorities.

GUIDELINES FOR DIAGNOSTIC SURVEYS AND SECTORAL REVIEWS (3)

In order to work out a National Water Master Plan (NWMP), the following are the subjects of the main diagnostic surveys which have to be carried out:

1. Data acquisition and inputs.
2. Water resources monitoring.
3. Water resources assessment in quantity and quality including non-conventional resources.
4. Socio-economic and environmental analysis.
5. Water use and demand projections.
6. Water legislation and water rights inventory and assessment.
7. Institutional set-ups involved in each of the above activities.

These diagnostic surveys and their envisaged outputs, as described in the following charts, would lead to the formulation of a National Water Plan, with water use strategy based on adopted national water policy as well as the establishment of a Water Resources Database.

The components of the outlined diagnostic surveys are interrelated (see chart VIII).

CHART I. ACTIVITY I: DATA ACQUISITION, ANALYSIS AND INPUT

Sub-activity	Output
Collection and analysis of data, reports, maps, aerial photos, satellite imageries (hydrology, meteorology, hydrogeology, geology, topography)	Creation of a comprehensive water database with nationwide coverage
Identification of computer facilities users, hard and software, methodology and manpower involved	Standardization of water data collection, processing, analysis, storage and retrieval
Inspection of data flow mechanisms	Computerized data flow system
Review and appraisal of adequacy and reliability of water data with relevance to water master planning	
Establishment of a comprehensive water data bank	Water data periodic dissemination

CHART II. ACTIVITY II: WATER RESOURCES MONITORING

Sub-activity	Output
Description of existing monitoring systems for surface and groundwater (instrumentation, network density, operation and maintenance)	Report on current monitoring methods
Design of new system network, data collection and processing	Proposal for physical extension of monitoring system
Identification of efficient monitoring system requirements (instrumentation, manpower, workshops)	Proposal for institutional set-up to maintain and operate the system
Final design, tender documents for station rehabilitation and construction of new stations	Construction of minimum required observation stations

CHART III. ACTIVITY III: SURFACE WATER ASSESSMENT

Sub-activity	Output
Identification of institutions, manpower involved, previous studies, available surface water, major surface water structures	
Review, assessment and evaluation of relevant literature and available surface water data	Surface Water Resources Report
Field survey to check existing surface water gauging stations Construction of relevant thematic surface water maps onto earlier prepared base maps Analysis and interpretation of surface water data and writing of technical reports	- Hydrology (rainfall, runoff, evaporation, sediment loads, water quality); - Present and potential use of surface water resources; - Proposal of action programmes: • Further studies; • Surface water development projects; • Surface water legislation, administration and monitoring; - Annexes and maps

CHART IV. ACTIVITY IV: GROUNDWATER ASSESSMENT

Sub-activity	Output
Identification of institutions, previous studies, available groundwater data, drilling activities	
Inventory, evaluation and appraisal of relevant literature and records and of hydrogeological set-up in each basin within the country	Groundwater Resources Report
Conducting complementary studies (geophysics, pumping test, simulation modelling) as needed Construction of relevant thematic groundwater maps onto earlier prepared base maps Analysis and interpretation of groundwater data and writing of technical reports	- Geologic set-up - Hydrogeology - Groundwater quality - Constraints and problems in the field of groundwater development, management and administration - Proposal of action programmes: • Further investigations; • Legislation; • Control measures; - Annexes and maps

CHART V. ACTIVITY V: SOCIO-ECONOMIC SURVEY

Sub-activity	Output
Identification of major factors governing socio-economic development and prospects; delineation of the various development regions and population centres	Report on: Aspects of regional development; - Presentation of regional structures and their socio-economic properties
Cost-benefit analyses of major projects envisaged in the development plans (with special attention to water availability on a national scale)	- Criteria for project priorities (in the light of projected water demand and local water availability)
Interpretation and analysis of socio-economic data and report writing	- Description of major development projects and identification of their priorities

CHART VI. ACTIVITY VI: WATER USE AND DEMAND

Sub-activity	Output
Determination of per capita, irrigation (per ha) and industrial water demand. Estimation of present and future water use and demand in line with socio-economic prospects, up to certain planning horizons	Report on: - Domestic/industrial water demand; - Present water consumption and projected demand; - Net and gross irrigation water demand, irrigated acreages, total usages (present, projected)
Description of the existing public and private water supply systems (sources, consumption centres, institutional set-up, O&M [operation and management] mechanisms)	- Existing water supply system
Description of waste disposal/treatment facilities (institutional set-up, O&M mechanisms, possibilities of water reuse, identification of protection areas)	- Sewage disposal and treatment plants - Water pollution and control measures for environmental protection
Overall assessment	- Description of major agricultural projects with regard to long-term water availability - Action proposals for water resources allocation to meet water requirements

CHART VII. ACTIVITY VII: WATER LEGISLATION

Sub-activity	Output
Identification of existing water use systems, allocations, traditional practices and water rights	
Assessment and evaluation of registered water rights, their constraints, problems and possibilities for improvement	
Review of the existing institutional set-up for water resources management from a legal point of view	Setting up of rules, water code and regulations to conserve, manage and administer the national water resources within the framework of the Master Plan

CHART VII. *(continued)*

Sub-activity	Output
Drafting of water legislation, water code, regulations and appropriate protection measures	Proposing a draft legal process and procedures to be adopted by the public and private sectors

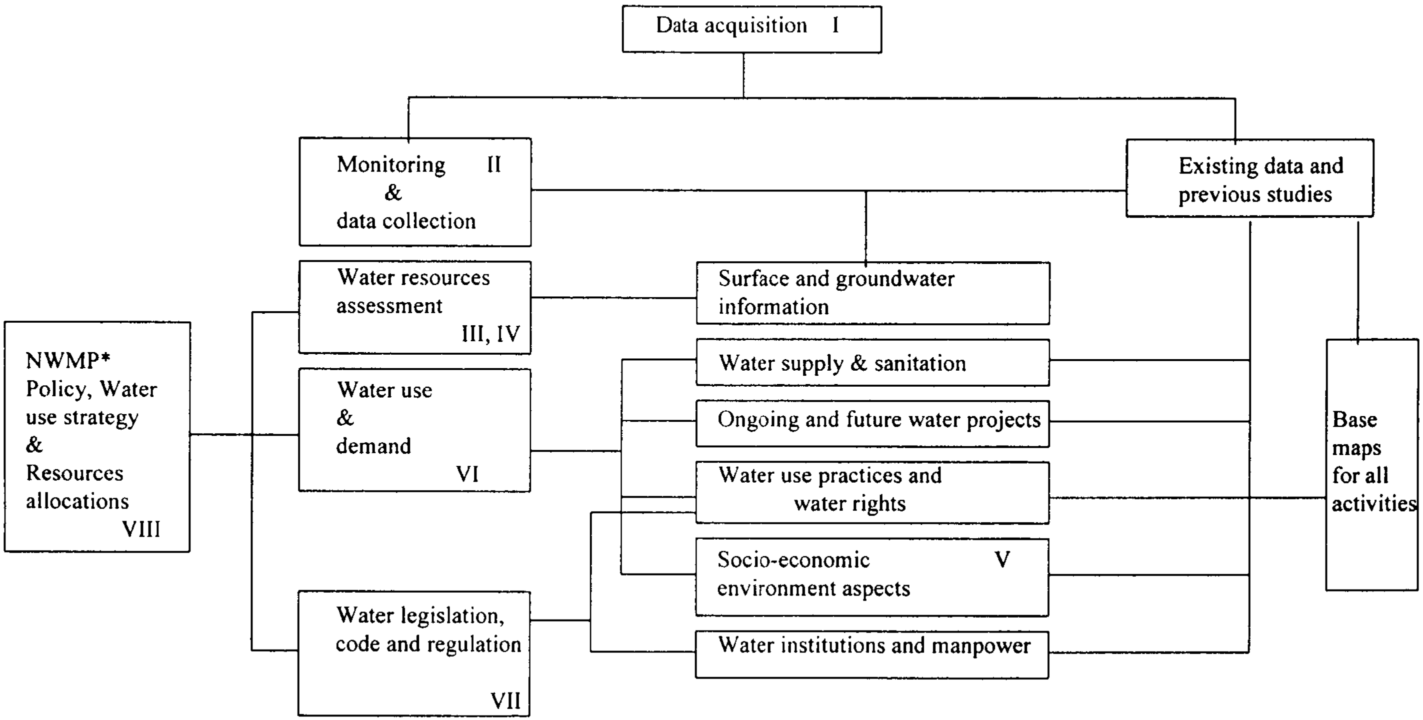
C. PATTERNS OF WATER RESOURCES PLANNING AND UTILIZATION IN THE ESCWA REGION

In reviewing the available literature pertaining to water resources development plans and conservation in the ESCWA region, it can be noted that the patterns of these plans vary from one country to another. They rely on many factors related to prevailing hydrologic and hydrogeologic set-ups, the overall socio-economic conditions, the objectives and goals identified, and the planning horizons.

Table 1 shows the various activities considered for water resources planning purposes in the region. It can be concluded that surface water impoundment for both water storage and/or flood control is the most common practice for water planning in addition to the continuous conventional exploitation of surface and groundwater resources. Appreciable efforts have been made to develop surface water resources at the national level. A number of surface water reservoirs have been built, while plans for new projects are being carried out. Iraq, the Syrian Arab Republic, Jordan, Yemen and Saudi Arabia have been the active member States in this respect during the past two decades. The Iraqi total storage capacity of the existing and future reservoirs (when completed) is estimated to be 95,000 MCM/a (4). About 15 reservoirs had been constructed in Jordan by 1988; the total capacity of these dams is about 126 MCM (4). A number of dam sites with a potential total storage capacity of about 387 MCM were identified in different localities in the country; studies on and construction of some of these structures are under way. In the Syrian Arab Republic, about 125 dams were recently constructed, including the major Euphrates dam of which the storage capacity is 14.1 BCM. Currently, construction work is being carried out at 23 sites in the areas of the Yarmouk, Orontes, Al-Badiya, Euphrates and Al-Khabour basins. About 199 small and large dams were constructed during the last decade in Saudi Arabia, with an estimated total storage capacity of 750 MCM. These dams are mainly for making use of flood waters for irrigation, livestock and/or artificial groundwater recharge (5).

Because of their limited water resources and the rapidly decreasing quantity and quality of the water, many oil-producing countries in the region have turned to the sea for their freshwater supply; considerable progress in desalination activities has been achieved in recent years. In Bahrain, additional desalination units were designed to

CHART VIII. INTERRELATIONSHIP OF THE MAIN ACTIVITIES FOR WATER SECTOR PLANNING



* National Water Master Plan.
Note: I-VIII denote activities mentioned in charts I-VIII.

produce 50 MCM/a so as to have a total production of 125 MCM/a in 1998 (6). In Kuwait, more desalination plants were constructed, raising the total production capacity to 365 MCM/a (7). Six new plants were constructed in Saudi Arabia, bringing the total installed capacity of the Kingdom to 657 MCM/a (7). In Oman, additional units were installed to increase the freshwater production capacity to 41 MCM/a (8). In Qatar, the expansion of some existing stations, with a designed capacity of 96 MCM/a, was completed in 1986. The total production of desalination water in the United Arab Emirates has reached 264 MCM/a (7).

Treating wastewater effluent, a non-conventional means of augmenting water supplies, has become an important developmental activity in the region. Wastewater reuse has been practised by some ESCWA member States for a considerable period of time; however, its application has been limited, and plans have only recently been formulated for large-scale development of this non-conventional supply source. Lack of knowledge about the long-term effects of treated sewage effluent used for various purposes and the availability of other water resources has prevented the reuse of treated wastewater on a wider scale; however, the development of new technologies and the rising cost of desalinating water have led to a higher, more substantial rate of wastewater reuse in the ESCWA region during the past decade. Jordan, the Gulf Cooperation Council States and Egypt have practised wastewater reuse in agriculture and public gardening. The treated wastewater production is presently rated at about 1,290 MCM/a, and it is planned to produce an additional 1,140 MCM/a for Bahrain, Egypt and Jordan by the year 2000 (5).

Considerable attention was given to water-saving measures in water resources development plans in the region in recent years. Such measures were related to irrigation or agricultural water use and drinking-water supply schemes. In general, irrigation and agricultural water-use projects have received a lot of attention in ESCWA member States in recent years, particularly in Iraq, Egypt, the Syrian Arab Republic, Jordan, Saudi Arabia and Oman; major projects have been executed extensively in Jordan and Saudi Arabia, while rehabilitation of the existing irrigation-drainage networks in Iraq and Egypt is progressing well. In the Syrian Arab Republic, several irrigation projects and parallel dam construction activities are also in progress. Studies to use treated drainage water are being considered in Iraq and Egypt, where the reused drainage water amounted to 12.168 BCM in 1989 (9). The oil-producing countries, in particular Oman, Saudi Arabia and Iraq, are proceeding with plans to increase agricultural production through the implementation of modern and efficient irrigation-drainage projects, to become as self-sufficient in food production as the available water resources will allow.

All ESCWA member countries have undertaken drinking-water supply projects aimed at improving the living standards of their populations. Most of the member States' national development plans have included a target date for the year 2000 to secure a safe and adequate water supply for the total population within the region. In recent years, the GCC countries have carried out several drinking-water supply and sanitation projects. In Bahrain, Kuwait, the United Arab Emirates and Qatar, 100% of the urban areas are supplied with piped water. The water supply projects vary from one country to another according to the water supply source, relying on surface water resources in Egypt (the Nile River), in Iraq (Tigris and Euphrates rivers) and equally on surface water and groundwater in the Syrian Arab Republic (Euphrates, Orontes and Al-Khabour rivers). The rest of the ESCWA member States depend largely on groundwater for their water supply. This source is not reliable, as it is a depletable source which deteriorates in quality when over-pumped, as a result of the increased water demand in large cities such as Amman, Aden, Riyadh and Sana'a. Sources are also frequently distant from inhabited areas. There is poor-quality groundwater in the United Arab Emirates, Bahrain, Qatar and Kuwait; brackish groundwater is blended with desalinated water to provide adequate water supplies to these Gulf States.

D. NOTES ON WATER SECTOR PLANNING IN SOME ESCWA MEMBER COUNTRIES

What follows is a brief description of water sector planning methodologies and patterns in some ESCWA member States:

(a) *Water resources planning and utilization in Egypt*

A Water Master Plan project (UNDP/EGY-73/024) was launched in January 1977. The project was executed by the International Bank for Reconstruction and Development and financed by UNDP, with the Ministry of Irrigation acting as cooperating agency. The project was begun in October 1977 and the first phase was completed in December 1981; the second phase commenced in January 1982 and was completed in 1987. A third phase of the project was still operating during 1995. The Water Master Plan contains a detailed and exhaustive statement of the water management and development needs of the country including descriptions, reviews, analyses, plans and recommendations for water-related projects. It also includes investments and implementation schedules, production targets, cost-benefit analysis and water resources distribution plans (10).

The first part of the project involved the preparation and evaluation of development plans in which the water supply and demand were matched, while the second was concerned with supporting studies and analysis.

<u>Part 1: planning methodology</u>

(a) Develop the agricultural sector. Three alternative planning methodologies were studied:

(i) Evaluate the available water supply, as well as present and new projects. Compute the water requirements for other users and deduct these figures from the available water resources totals. The remainder was for agricultural development to the year 2000, distributed at five-year intervals;

(ii) Determine the water requirements for all users including the agricultural sector (with an annual growth rate of 4.9%, including 1.9% for new lands development);

(iii) Determine the staging of new water-supply development projects (including the Upper Nile conservation projects) to satisfy water demand;

(iv) Determine water requirements, as in (ii) above, but with a 3% rate of growth in the agricultural sector, 0.5% of which must be for new lands development.

(b) Supply the growing demand for municipal, industrial and all other users.

(c) Evaluate and compare plans on the basis of the effective use of available water, economic performance in the agricultural sector, capital investment required, social and environmental impact and energy requirements.

Part 2: supporting studies

These studies are related to the following: cost analysis of the water supply and land development projects, and cash-flow expenditure during the planning period; water requirements to support agricultural development and economic evaluation for these projects; water demand and cost analysis for municipal and industrial uses, as well as wastewater quality investigations and treatment for possible reuse in agriculture; determination of the operation, maintenance and replacement costs for Nile River regulation, irrigation and drainage systems; and finally, the establishment of a database and development of an agro-economic model.

The Water Master Plan concluded that if the Upper Nile conservation project were completed, about 11.5 BCM of additional water would be available after 20 years (first alternative). This amount would be enough for developing an additional 2.7 million feddan, and there would be a remaining 1.8 BCM of water available for land development after the year 2000. As per the second alternative, and if new lands irrigated by the Nile waters were developed at the rate of 180,000 feddan/year, the developed water supply would be fully committed after 1997, and no further development would be possible unless additional water supplies were mobilized. If land development continued at the rate of 50,000 feddan/year, the increased water supply would exceed demand during the planning period. In this case, only the Jonjuli Project (part of the Upper Nile conservation project) would be required up to 1997 (11).

TABLE 1. PATTERNS OF WATER RESOURCES PLANNING IN THE ESCWA REGION

		Egypt	GCC Countries	Iraq	Jordan	Lebanon	Syrian Arab Republic	Yemen
Activity								
Surface water impounding	Storage	X	X	X	X	X	X	X
	. Recharge		X		X			
	Diversion			X	X			X
Irrigation networks	Rehabilitation	X	X	X			X	
	Modernization	X		X	X		X	X
Reuse	Drainage water	X	X	X				
	Treated waste effluent	X	X		X		X	X
Desalination								
Efficient utilization	Irrigation	X	X	X	X		X	X
	Industry	X		X	X		X	
	Domestic	X	X		X		X	
Groundwater		X	X	X	X	X	X	X
Water transference		X		X	X		X	
Water quality control		X	X	X		X	X	
Technology applications		X	X	X	X		X	
Water legislation			X	X	X		X	X

The Water Master Plan project guarantees that there will be significant amounts of water used for agriculture independent of the supply-demand balance for the Nile. These will be drawn from the ground-water resources of the New Valley in the Oasis areas, the shore lands along Lake Nasser, and treated waste-water in the Greater Cairo area.

The drought conditions prevailing in the eastern coastal regions of Africa, the halted Upper Nile water conservation projects and government plans to increase the cultivated areas in Egypt at a rate of 150,000 feddan annually have all led the Egyptian Government to reconsider its water use policy. Much progress has been made in Egypt's use of its national water resources. Conjunctive use of surface water, groundwater, drainage and treated wastewaters has been successfully practised to cope with both the drought conditions, which lasted from 1979/80 to 1987/88, and the halting of water-conservation projects. These projects are expected to feed the High Dam Lake at a rate of 7,500 MCM/year in their first phase, rising to 8,900 MCM/year upon completion. The groundwater resources available in the eastern and western deserts and in Sinai provide about 2,700 MCM/year, expected to increase to 4,900 MCM/year after development. Treated sewage and industrial wastewater currently contribute a total volume of about 1,400 MCM/year, and are expected to reach 2,200 MCM/year by the year 2000. Drainage-water reuse was practised at a rate of about 3,470 MCM/year during the five-year period 1987-1992, and may reach 6,500 MCM/year by the year 2000. A digital model was created in 1983 which simulates the changes that may occur in the quantity and quality of drainage waters over time after improving the drainage networks, increasing the volume of reusable drainage water for irrigation, changing the crop pattern and cultivating short-span crops. This model was intended to be used as a tool to make appropriate decisions for future development and to optimize reuse of the available drainage water and record its limitations, taking all necessary precautions so as not to affect soil and crop productivity negatively (12).

The strategy to utilize the potential groundwater resources in the Nile Delta and Valley, eastern and western deserts and in Sinai is mainly designed to achieve the following goals:

(a) Provide domestic water supplies;

(b) Irrigate newly reclaimed lands at the peripheries of the Nile Delta and Valley;

(c) Improve the efficiency of agricultural production and the existing irrigation networks.

The concerned government authorities have adopted a short-term water-use policy to overcome the Nile water shortage by:

(a) Using the largest possible quantity of groundwater, agricultural drainage water and sewage drainage for irrigation;

(b) Rationalizing water in all fields and reducing withdrawal discharges from the High Dam Lake;

(c) Taking into account the possibility of consecutive years of continuous shortage in the Nile supply, the withdrawal would be as follows:

(i) When the lake storage is 60-65 BCM by the end of July, withdrawal is to be reduced by 10%;

(ii) When the lake storage is 50 BCM or less by the end of July, withdrawal is to be reduced by 20%.

(b) *Water resources planning and utilization in Jordan (13)*

The organizational framework of Jordan's water sector has evolved over the years to suit various requirements at different times. Until July 1987, the water sector was managed by two independent authorities: the Jordan Valley Authority (JVA) and the Water Authority of Jordan (WAJ). JVA was responsible for irrigation and development in the Jordan Valley, while WAJ was concerned with water supply, sewerage and water resources. In 1987, the two authorities were brought together under one Ministry of Water and Irrigation (MWI). The final organizational structure of the new Ministry is still under discussion.

Surface water impounding activities are progressing well in Jordan. Most of them originate from the Yarmouk and Zarqa rivers, which provide most of the irrigation water for the Jordan Valley. Present surface water consumption is currently estimated at 336 MCM. Plans to make use of desert flash flood water through small dams (for aquifer recharge, local irrigation and livestock) have been implemented. There are plans to make use of storm run-off water, and of flood water available during the rainy season. Water impounded by dams or retention reservoirs is used for domestic, industrial, irrigation and livestock purposes. Modern irrigation systems started in the Jordan Valley with the completion of the King Abdullah Canal in 1965 and the construction of the King Talal Dam on the Zarqa River in 1979. Great progress has been achieved in many parts of the country in modernizing irrigation techniques designed to conserve the country's water resources. In general, non-conventional and limited conventional irrigation methods are presently applied in Jordan because the Government has been well aware of the need for rational water resources planning. Many developments have taken place since the implementation of the National Water Master Plan in 1977: the King Talal Dam has been used only for irrigation, but additional limited groundwater resources have been identified. Sewage network and treatment activities are under way.

The Government in Jordan has also begun to develop rain-water harvesting practices. Desert pools have been rehabilitated or constructed, and flood-water spreading has been undertaken. Artificial groundwater recharge using flood water has been practised in different localities (Shueib and Khalidiya dams) and, as of 1989, was under way in others (the Sewage, Al-Abyed, Jurdaneh, and the Azraq and Jafer basins).

Groundwater sources in Jordan have been extensively exploited for municipal and industrial purposes. Most of these sources are currently being extracted to or beyond the limits of reliable aquifer yields. They are presently used for municipal, industrial and agricultural purposes. It is estimated that about 354 MCM of this water is currently being utilized in different localities in Jordan, resulting in the overpumping or depletion of Jordan's main aquifers at a rate of about 94 MCM (1989 estimates). Fossil groundwater constitutes most of the stored quantity of available groundwater in Jordan. The main potential for increased production lies within the fossil aquifer or the Disi Basin in southern Jordan. Appreciable amounts of brackish groundwater are available in Jordan, particularly in the Rift Valley and desert areas.

The construction of sewerage facilities has rapidly increased since 1984. With the creation of WAJ, 11 treatment plants were constructed and another 22 plants were planned and designed for urban and rural areas. Approximately 84% should be served by 2015. It is estimated that the production of treated effluent which can be used for irrigation will reach 116 MCM in the year 2005 and 165 MCM in 2015. Experimental irrigation using treated effluent has been applied in some areas of Jordan.

In the last 10 years, water pollution has become a very sensitive subject among local and international agencies because of the environmental problems it produces. In Jordan, several governmental organizations are responsible for the control of water pollution for surface water bodies such as the King Talal Dam (KTD), and for groundwater basins which may have direct contact with sewage effluent or contaminated water. Chemical and bacterial analyses are mainly carried out by the MWI, Ministry of Health, Royal Scientific Society (RSS), Jordan University and Municipality of Greater Amman laboratories. The MWI is responsible for the routine monitoring of water resources quality, while the other agencies are responsible for ensuring that the water quality meets WHO drinking-water standards.

Other measures, such as improving skilled manpower capabilities, applying computers in water science, establishing a comprehensive water sector database, and establishing a regional centre for isotope analysis and interpretation in cooperation with the International Atomic Energy Agency, have been undertaken by the water-related institutions in Jordan.

(c) *Experience of the Gulf Cooperation Council member States in water sector planning*

Because of their limited water resources and an overdraft situation which has resulted in reduced quantity and quality, many of the GCC countries have turned to the sea for their freshwater supply. Considerable progress in desalination activities has been made in recent years, as noted above. The Gulf States are generally considered world leaders in non-conventional water-resources production, particularly in desalinating sea water and/or brackish groundwater. During the last decade, substantial progress has been made in desalination techniques, improving skilled manpower capabilities to maintain and operate desalination plants, and the progressive cost reduction of desalination per unit volume of water produced. In addition, treated sewage effluent reuse is widely practised in the Gulf States for restricted irrigation or public gardening. Non-conventional water resources production in the GCC States has contributed substantially to meeting the countries' domestic, industrial and, to a certain extent, irrigation water requirements. The national water resources (primarily groundwater) in some member States are no longer potable and can hardly even be used to irrigate certain saline-water-tolerant crops, owing to excessive water-quality deterioration and sea water intrusion into the coastal aquifers. Treated sewage effluent, which normally provides about 60 to 70% of domestic water supply, has helped to maintain agricultural production in some areas in the Gulf States.

In general, the concerned government authorities in the GCC member States have considered the following measures to facilitate water planning:

(a) Construction of additional desalination plants to meet the growing water demands;

(b) Promotion of surface water impoundings to make use of the flash floods for storage and/or artificial groundwater recharge;

(c) Enhancement of wastewater reuse for restricted agriculture;

(d) Implementation of groundwater exploration, management and conservation projects;

(e) Modernization of irrigation schemes together with efficiently operating, maintaining and development of the conventional or traditional (falaj and springs) irrigation schemes.

In Bahrain, as elsewhere in the Gulf area, a long-term water resources development policy is to produce distilled sea water and blend it with brackish groundwater to bring the quality up to acceptable drinking-water standards. Water production in desalination plants was increased from 5 MCM in 1975 to 63 MCM in

1991 and is planned to reach 125 MCM/year by 1998 (14). A team of national experts in Bahrain recently prepared a work plan for water sector planning and development. The proposed plan will be implemented in three main phases (15).

(a) The first phase (Diagnostic Studies), which will include review and collection of the previous studies and data, water resources assessment and potential water use, for various sectors, water demands and projections, and the establishment of water resources database;

(b) The second phase (Preventive and Control Measures), which will include studies related to water problems and formulation of alternative strategies to overcome the problems prevailing by the use of simulation modelling techniques;

(c) The third phase (Operational Phase), which will include the implementation of the master plan formulated, follow up of the execution of the proposed projects in coordination with the concerned authorities, and evaluation of the impact of these projects as well as continuous review and updating of the water master plan.

In Oman, a National Water Resources Master Plan was completed by the end of 1991. The Master Plan was aimed at the following:

(a) Strengthening of the institutional and legal framework to provide effective management of water resources in the interests of the Sultanate's long-term development;

(b) Giving priority to domestic and industrial water supplies, by using desalinated sea water, despite the high cost, to augment agricultural water uses;

(c) Managing of domestic water demand and improving the efficiency of agricultural water uses;

(d) Restricting agricultural development in line with the available resources and reducing agriculture in areas where resources are presently overexploited;

(e) Controlling development of non-renewable water resources;

(f) Augmenting the resources wherever possible.

(d) *Water Resources Plans and Policies in Yemen*

As in other parts of the region, the demand for water is rapidly increasing in Yemen. The water demands are mainly met from the groundwater. The available information indicates that the groundwater resources have been severely overexploited, and in most cases, exploitation has exceeded the economic pumping depth. The Government of Yemen has made the development of this sector a priority in an effort to overcome the water scarcity problem. The planned growth rate for the sector was 25% during the Second Five-Year Plan (1982-1986), the highest among all the sectors. For the Third Five-Year Plan (1987-1991), the planned growth rate is 15%, which is the second highest after the oil sector (80%). The changing patterns of water demand, the tight budgetary constraints, and the lack of intersectoral coordination suggests the need for more comprehensive and rational sectoral planning (16).

There is a growing awareness that sustainable economic development requires efficient and effective management of the country's scarce water resources. At the same time, it is widely recognized that it is a difficult task to accomplish, given that water is traditionally considered as a free commodity, and given the decentralized political structures in many of the more seriously affected parts of Yemen. Despite these difficulties, the Government has already initiated appropriate action. In this context, the Government has under consideration a new water law designed to provide for the licensing of new wells and for a more orderly set of arrangements for water abstractions. Moreover, to improve the institutional framework for water resources development and management, a proposal to integrate various water-related functions under one government institution is receiving serious consideration.

In order to improve water sector planning in Yemen, the Government established a High Council for Water (HWC). The activities of the HWC are being supported by a Technical Secretariat (TS). The TS has been entrusted with the task of preparing a National Water Master Plan (NWMP) for the country. The TS has collected and processed a great deal of statistical data and information required for water sector planning. A number of sector review and research studies were initiated to assess the prevailing water sector status in the country. The TS is supposed to collaborate and coordinate with different national and regional institutions to review the nature and extent of their databases in an effort to develop a national database needed for the preparation of the NWMP. However, in recent years, a number of water projects in Yemen have collected and processed a great deal of water resources statistics. These databases were incorporated into the national database to support water sector planning at the national level.

In order to develop an efficient TS for the Council, a major project, funded by UNDP, was implemented (1988-1992). The project, "Assistance to the Technical Secretariat of the High Council for Water" (YEM/88/001), has generated a substantial amount of information in support of planning for water resources management. The final report of the project consists of 10 volumes that address the following issues:

(a) Water resources management in the context of national economic development;

(b) Legal and institutional issues related to water resources use and development;

(c) Assessment of available water resources and their present and future uses;

(d) Analysis of present and future regional water requirements;

(e) Status and future development of water supply and sanitation;

(f) Assessment of present and future environmental issues;

(g) Two case-studies for the development of water resources management plans (Sana'a basin and Tihama).

In view of the different studies carried out under the auspices of the project, it was concluded that there is a water crisis in Yemen. There is insufficient water to meet the increasing water demands. Water levels have already declined below the economic pumping levels in many basins in the country. In addition, the fragmented nature of the water sector's responsibility—together with the absence of an appropriate legislative and policy framework—has worsened the prevailing water crisis in Yemen. It is imperative for the concerned government authorities to undertake the necessary efforts and measures to achieve an equilibrium between net water withdrawals and renewable water availability and to identify how much the rate of groundwater mining is to be permitted. The country also needs to gear its efforts towards the formulation and implementation of a water management plan for water resources conservation and optimal water allocations among various users. The implementation of the formulated plan has to be entrusted to an efficient institution responsible on a country-wide scale and supported by the enforcement of appropriate legislation to control water supply-demand variables. For this purpose, the Government is in the process of creating a national water resources authority (NWRA) that will be solely responsible for planning and management of water resources in the country, including national policy-making on water resources. The main target of the strategy is to curb excessive demands through technical and demand management measures, and to search for new sources of water. The Government is presently pursuing an economic and administrative reform agenda. The organization of an institutional framework for rational decision-making, by creating NWRA, is an important element of this agenda. A five-year economic development plan is currently under preparation. In general, the government policy seems to be consistent with the objectives and activities of Agenda 21. However, at this stage, it is difficult to predict to what extent and how vigorously these objectives and activities will be pursued (17).

REFERENCES*

1. Water Policy Initiatives for Yemen, Recommendations by CID Water Team, CID Yemen report 052-1980-1.

2. Proceedings of the Seminar on: "Database systems for water resources planning in the Republic of Yemen", Sana'a, 2-4 October 1990.

3. Based on the author's own experience as a team leader for the preparation of Jordan's "National Water Master Plan" and as a project manager (CTA) for the project YEM/88/001 "Preparation of National Water Master Plan of Yemen", October 1988.

4. Economic and Social Commission for Western Asia. "Water Resources Planning, Management, Use and Conservation in the ESCWA Region" (E/ESCWA/NR/1993/21), December 1993, pp. 38-42.

5. Economic and Social Commission for Western Asia. "Progress achieved in the implementation of the Mar del Plata Action Plan in the ESCWA Region" (E/ESCWA/ENR/1992/5), October 1991.

6. Bahrain Country Paper, "Water resources plan for the year 2000" (Arabic), presented at the Fifth Meeting of the IHP Permanent Arab Committee, Cairo, 9-11 November 1992.

7. Arab Planning Institute. "Water crisis in the Arab World" (Arabic), Kuwait, June 1993.

8. E/ESCWA/ENR/1992/5, and "The Role of Water Resources Management in Combating Desertification in Oman" (E/ESCWA/ENR/1993/2), January 1993.

9. Economic and Social Commission for Western Asia. "Water resources planning in Egypt: Issues ahead to the year 2000". Meeting on Water Security, Damascus, 13-16 November 1989 (E/ESCWA/NR/89/WG.3/WP.8).

10. E/ESCWA/NR/WG.3/WP.8, E/ESCWA/ENR/1992/5, and "Integrated water resources management and planning in the ESCWA region", M. Abu Zeid, October 1993.

---

* Issued as submitted.

11. Fahmi, Sarwat. Ministry of Public Works and Water Resources, Egypt. "Water resources management, development and utilization in Egypt" (E/ESCWA/NR/1993/WG.1/8), December 1993.

12. Fahmi, Sarwat. Ministry of Public Works and Water Resources, Egypt. "National Water Master Planning Egyptian Prospective", March 1995.

13. E/ESCWA/ENR/5, and Jordan National paper on "Jordan Water Sector" by Hazim Al-Naser and Z. Elias, Ministry of Water and Irrigation, presented at the Regional Symposium on Water Use and Conservation, Amman (E/ESCWA/NR/1993/WG.1/4), December 1993.

14. Mubarak Aman, "Bahrain Water Plan up to Year 2000", presented at *Fifth Meeting of the IHP Permanent Arab Committee* (Arabic), Cairo, 9-11 November 1992.

15. Bahrain Research and Investigations Centre, "Integrated Water Resources Management in Bahrain" (Arabic), No. Data, p.10.

16. UNDP/DESD. "Water Resources Management and Economic Development". Final report, vol. I. Project YEM/88/001, December 1992.

17. Direct consultation with government officials during staff member's mission undertaken to Yemen, August 1995.

IV. ESTABLISHMENT OF A REGIONAL WATER TRAINING NETWORK IN THE ESCWA REGION*

by

Ghanem Hassawy

A. BACKGROUND

Water shortages in the ESCWA region are becoming a development constraint seriously impending the economic growth of many countries. Most of these countries are located in arid zones where annual rainfall is scanty and evapo-transpiration is enormous, resulting in very scarce water resources. These resources have been assessed recently (1992) by ALECSO for all Arab countries. ALECSO reached the conclusion that "there are serious current shortages in many of these countries and [there will be] potential crises in almost all countries of the region by the year 2030." To many experts, it is not only the issue of scarcity but also the mismanagement of these resources, as a result of considerable deficiencies in qualified human resources, that should equally cause great concern.

ESCWA is considered a pioneer in addressing this critical situation within its members and was wise in selecting the key issue of "manpower development" as the theme of its current efforts. Human resources development has been recognized as essential for achieving sustainable water resources management. Alerts (1991) has concluded that "training and education have proven to be day capacity-building instruments which support long-term development strategies."

The need for manpower development (MDP) was recognized by the international community much earlier: the Mar del Plata Action Plan in 1977, the New Delhi Statement in 1990, the Delft declaration in 1991, the Dublin Statement of the International Conference on Water and Environment in 1992, and in Agenda 21 from the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil in 1992.

ESCWA interest in manpower development in the water sector was thus a direct response to recommendations from United Nations and regional meetings as well as surveys and studies conducted by ESCWA itself.

In the period 1985 to 1989, ESCWA was actively involved in organizing regional surveys, publishing technical reports and holding expert group meetings.

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* In the preparation of this document, Mr. Ghanem Hassawy served as a consultant to the Economic and Social Commission for Western Asia (ESCWA).

Based on these surveys and studies, a report was published in 1987 on "Development of Manpower, Education and Training in the Water Sector in Western Asia" (E/ESCWA/NR/85/14). That report ascertained, without any doubt, the need for regional cooperation and manpower development programmes in the water sector of the ESCWA member countries. The findings of this report, together with many country reports, were discussed in an expert group meeting held during the period 5 to 8 June 1989 in Amman. The main recommendations of the meeting are the following:

(a) ESCWA was requested to:

(i) Continue its manpower surveys in the region;
(ii) Survey available education and training institutes;
(iii) Survey the curricula and syllabi of these institutes;
(iv) Encourage subregional cooperation;

(b) To prepare a project document for the establishment of a regional network in two phases, namely: Phase I, which is a preparatory stage covering the four recommendations mentioned above; and Phase II, which is an executive phase depending on the findings of Phase I;

(c) To secure the financial resources necessary to accomplish these activities from potential financing agencies in the region and abroad;

(d) To create preliminary contacts with the countries of the region that have already established good training centres, with the aim of sharing these resources with countries that are in need of them. Similar contacts should be established with regional and international training centres;

(e) To establish a technical advisory committee to assist ESCWA in the establishment of the network and in drawing its action plan;

(f) To shoulder the secretariat business of the network during its establishment stage.

These efforts have been mentioned in an ESCWA report that included a study of four selected countries of the region during the period 23 December 1992 to 10 January 1993. The recommendations of this report supported the idea of the network and followed in many aspects the recommendations of the 1989 expert group meeting.

In the light of the above findings and conclusions, ESCWA investigated various forms of regional cooperation and different modules. It has been concluded that the only open option is the networking approach, which is flexible in accommodating financial and political constraints. Hence, a form of organizational structure was suggested, and a project document was prepared (E/ESCWA/NR/1993/WG.1/WP.5).

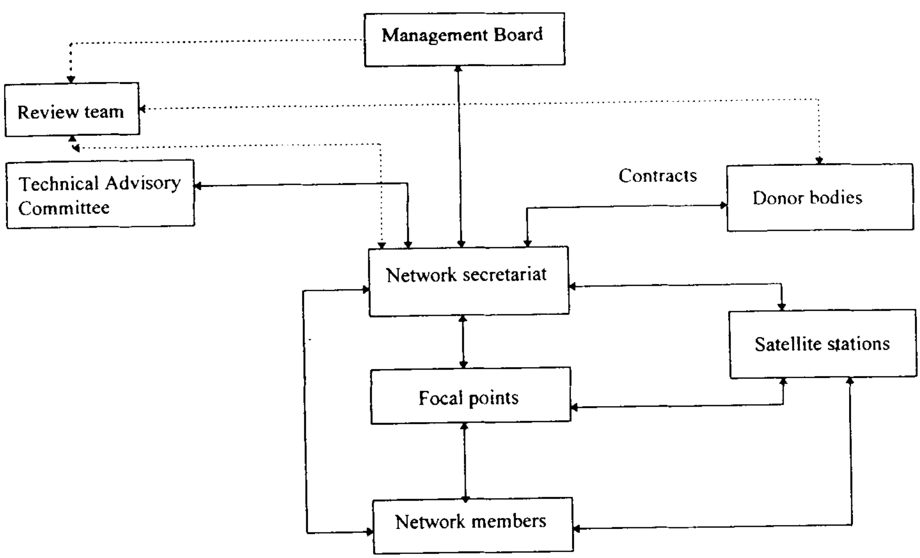
The organizational structure of the network, its immediate and development objectives, its input and output and its activities, are specified in the following sections.

B. ORGANIZATIONAL STRUCTURE OF THE NETWORK

The Network of the Water Sector (NOWS) is established as an independent, autonomous and an inter-institutional regional entity. The organizational structure of the Network is made of the following bodies (see figure 1):

(a) The Network secretariat (headquarters);
(b) The Network members (general body);
(c) The Management Board;
(d) Satellite stations;
(e) The focal points;
(f) The Technical Advisory Committee;
(g) The donor bodies.

Figure 1. Organizational structure of the Network



1. *The Network secretariat*

The functions of the Network secretariat include:

(a) Initiating and preparing the short-, medium- and long-term plans of action of the Network;

(b) Supervising the implementation of the approved plan of action;

(c) Securing sufficient financial resources from donor bodies to meet the implementation requirements of the approved plan of action;

(d) Drafting financial and administrative rules, regulations and procedures to be approved by the Management Board;

(e) Running the day-to-day business of the Network;

(f) Maintaining close contacts with the focal points, Satellite Stations, the Network members, the Management Board, the Advisory Committee and the donor bodies;

(g) Expanding Network membership and donor bodies;

(h) Establishing an effective database relevant to the needs of the Network and its different entities;

(i) Preparing and submitting database reports and budgets to the Management Board.

The Network secretariat will be located, for the time being, at ESCWA headquarters. The office would be run by a minimum number of permanent staff, possibly comprising a coordinator, assistant administrator and a secretary. At the initial preparatory stage, ESCWA staff members will be expected to shoulder their responsibility. At a later stage of the project, the secretariat may be moved to one of the volunteering member countries where the budget of the above core staff could be reduced significantly.

The following facilities will be required:

(a) Furnished office space (two rooms) and supplies;

(b) Modern communication and data processing facilities (personal computer with a laser printer, xeroxing m/c, telephones, fax and telex).

The Network coordinator should be a highly qualified and efficient person. The functions of the coordinator include the following:

(a) Assuming full responsibility as the chief executive of the Network;
(b) Ensuring that the Network is performing its functions smoothly and efficiently;
(c) Mobilizing financial resources for the Network plan of action.

2. *The Network members*

The Network membership will be open to educational institutions (such as universities and technical colleges), research institutes, the employer sector (public or private), professional associations, and regional organizations (such as ACSAD and ROSTAS). This means that several bodies from the same country could be members of the Network. The Network members meet in a general assembly once every two years following a biennial congress centring around a selected topic related to the functions of the Network. The assembly and the congress venue should be rotated among the ESCWA member countries.

The main functions of the general assembly are:

(a) Approving any changes in the by-laws;

(b) Approving the initiation of new satellite stations;

(c) Approving the general policy and themes of any new plans for the Network;

(d) Approving the general report of the Management Board;

(e) Electing the president and vice-president of the Network;

(f) Approving the selection of the focal points;

(g) Approving any changes in the composition or venue of the secretariat.

The cost of the biannual meeting is expected to be met by the member institutes.

3. *The Management Board*

The Management Board is made up of all the focal points and the coordinator of the Network, who will act as its convener. The president of the general assembly of the Network is also the chairman of the Board.

The functions of the Board include the following:

(a) Reviewing, amending and approving the annual budget and reports of the Network;

(b) Reviewing and approving the Network's financial and administrative rules and regulations;

(c) Reviewing and commenting on changes in the by-laws or creation of a new satellite station and submit its views to the general assembly of the Network;

(d) Approving admission of new members to the Network;

(e) Assisting the secretariat in performing its duties more effectively.

The Board should meet once each year. However, it may delegate some of its powers to a smaller executive committee made up of the president, the vice-president and the coordinator. In urgent situations, the Board's views may be obtained through fast mail or by fax. The cost of Board meetings could be covered from members' fees.

4. *The satellite stations*

These are offshoots of the central secretariat, linking similar activities in neighbouring countries and forming subregional networks. The focal persons from these countries form the executive committee for the specific satellite station.

5. *The focal points*

These are contact points representing each of the member countries of ESCWA, preferably elected from educational institutions or research centres. On obtaining the blessing of the general assembly of NOWS, a senior will be delegated by his institute as the contact person. Each contact person will become a member of the Management Board. The functions of the contact person (point) include:

(a) Ensuring the full participation of his country in the Network's plans of action;

(b) Acting as a liaison officer for the Network secretariat in his country;

(c) Keeping good contacts with the Network members in the country;

(d) Serving as an active member in the activities of the satellite station involving his country;

(e) Serving as a member of the Management Board.

6. *The Technical Advisory Committee*

This Committee is made up of a number of outstanding experts from the ESCWA member countries selected according to their merits. They will serve as an ad hoc committee assisting the secretariat in the following tasks:

(a) Preparing the Network's plan of action and formulating the work programmes;

(b) Advising the secretariat and the Management Board on technical issues related to the implementation of the plan of action;

(c) Reporting on the progress of the various work programmes and suggesting possible modifications that may improve the effectiveness of these programmes.

7. *The donor bodies*

These are the financial backers of the Network; they could be development banks, international bodies, or individual countries. The secretariat should keep close contacts with these bodies and invite them to various activities, such as the biennial meeting.

C. DEVELOPMENT OBJECTIVES

Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with protection of the natural ecosystem. This form of management requires well-trained and qualified personnel. Hence the main development objectives will include:

(a) Producing high quality, well-trained and qualified personnel in all levels of the water sector capable of managing the scarce water resources in the region in an effective holistic manner;

(b) Promoting regional cooperation in all issues pertaining to water resources, especially shared resources and problems;

(c) Enhancing national appreciation of water as an economic good that has economic value in all of its competing uses.

D. IMMEDIATE OBJECTIVES

The immediate objectives of the Network are the following:

(a) To provide up-to-date information and statistics on the manpower situation in the water sector, including education and training institutes and their capabilities;

(b) To assess the regional and national needs for capacity-building, education and training requirements in the water sector and prepare and execute a plan of action to meet these requirements;

(c) To create effective linkages between R and D centres, education and training institutes, the corresponding industries, and professional societies;

(d) To create effective linkages between the entities in (c) above and their counterparts in the different ESCWA member countries as well as the corresponding advanced bodies abroad;

(e) To establish effective regional and national capabilities for building databases and documentation centres and for exchanging technical information;

(f) To initiate publications and public awareness programmes.

E. OUTPUTS

The output of the project will include the following:

Phase I

(a) A series of reports on the establishment of the Network;

(b) A series of reports on the national and regional surveys, the assessment of needs and the short-term, medium-term and long-term action plans;

(c) A series of reports on the training courses, the symposium contents and the proceedings of the biennial congress.

Phase II

(d) Packages of modern curricula for teaching and training purposes;

(e) Progress reports on the staff development programme;

(f) Progress reports on the scheme for improving teaching and training facilities;

(g) Published booklets on the annual programmes for short courses and workshops and the contents of these programmes;

(h) Proceedings of symposia and congresses;

(i) Progress reports on linkages;

(j) A series of reports on assessment, evaluation, classification and accreditation schemes;

(k) Regular technical, popular and informative publications.

F. NETWORK ACTIVITIES

In the first two years (Phase I), the Network activities will concentrate on the following:

(a) Establishing the Network's organizational structure, namely:

(i) Selection of the technical Advisory Committee;

(ii) Selection of focal points and focal persons;

(iii) Creation of active contacts with donor bodies to secure necessary funds for Phase I and potential funds for Phase II;

(iv) Accepting applications for membership in the Network;

(v) Selection of the first Management Board and the convening of its annual meeting.

(b) Surveying and assessing needs, leading ultimately to the preparation of the short-term (Phase II), medium-term and long-term action plan;

(c) Executing technical activities, if funds become available. These activities could include:

(i) A regional symposium focusing on the objectives of the Network, held at the end of the first year just before or after the first Management Board meeting;

(ii) The first biennial congress and the first general assembly of the members to be held by the end of the second year, just before the commencement of Phase II;

(iii) Three training courses attended by at least one participant from each of the member countries. The courses could be selected from available courses in the region, i.e. the Training Centre of the MPWWR in Egypt, ACSAD programmes or the Training Centre of the Water Authority in Jordan.

To minimize the cost of Phase I, it is expected that, except for a secretary, the secretarial work of the Network will be shouldered by regular ESCWA staff members. In technical and specialized issues they will be assisted by the Technical Advisory Committee.

If financial backing becomes promising, a full-time coordinator should be appointed by the end of Phase I. Tentative activities for Phase II may include:

(a) Short training courses and workshops;

(b) A staff development programme;

(c) Preparation and distribution of model curricula and training material;

(d) Improving teaching and training facilities;

(e) Promoting R and D, linkage schemes (between the institutes in the ESCWA region themselves and renowned institutes abroad);

(f) Integrating education and training institutes with the needs of the corresponding industries;

(g) Introducing evaluation and assessment systems for the educational institutions and training institutes (such as accreditation and external examiners systems);

(h) Promoting the ability of professional societies to protect professional and technical practices by introducing the system of chartership and licensing for all levels of practitioners;

(i) Building and updating databases and information dissemination systems.

G. INPUT

1. *Governmental participation*

The contribution of each Government would include, but would not necessarily be limited to, the following:

(a) Designating a competent institute to act as a focal point for the project in the respective country. The focal point should designate a senior and highly qualified person to serve as the focal person for the country. The focal person would be fully aware of the project's development and ensure the fulfilment of all governmental obligations to the project in due time;

(b) Facilitating and encouraging the membership of interested institutes in the Network;

(c) Facilitating the payment of the membership fees by the members within the country (the annual membership fee for each member institute is US$ 2,000. This could be increased or decreased according to future developments).

2. *ESCWA participation*

The contribution of ESCWA would include, but would not be limited to, the following:

(a) Shouldering the secretariat work of the Network during the preparatory stage (Phase I);

(b) Supervising the progress of the Network during Phase II.

3. *Funding agencies' contributions*

Funding agencies are expected to provide funds as follows:

Preparatory stage (Phase I)	US$ 358,000
Initial stage (Phase II)	US$ 1,195,000
Total	US$ 1,553,000

Details of the various components were spelled out and clearly identified in the project budget.

H. PREPARATION OF THE WORK PLAN

A detailed work plan for the implementation of the project will be prepared by the secretariat, assisted by the technical advisory committee in consultation with the focal persons. This will be done at the start of the project and will be updated periodically.

I. PREPARATION OF A FRAMEWORK FOR THE EFFECTIVE PARTICIPATION OF NATIONAL AND INTERNATIONAL STAFF IN THE PROJECT

The activities necessary to produce the indicated output and to achieve the immediate objectives of the project will be carried out jointly by the national and international staff to whom the task is assigned. The respective roles of national and international staff will be determined by their superiors at the beginning of the project through mutual discussions and agreement and will be set out in a framework for the effective participation of national and international staff in the project. This framework will be reviewed, if necessary. The respective roles of national and international staff shall be in accordance with the established concept and specific purpose of technical cooperation.

J. Development support communication

ESCWA and other participating agencies and organizations will distribute reports and data and exchange information collected on the subject of the project.

K. Institutional framework

As the executing agency, ESCWA will be the primary institution concerned with the implementation of project activities. The project coordinator and any project personnel or consultant recruited to implement the project will be based at ESCWA headquarters.

The project will be executed under the supervision of and in accordance with the regular administrative procedures of ESCWA, the executing agency.

All activities to be carried out within the framework of the project will be reviewed by the participating ESCWA member countries, the principle donor countries, financial institutions, and a consultants' advisory group. Where appropriate, suggestions and advice will be forwarded by them directly to ESCWA, the executing agency for the project.

Participating countries not members of ESCWA are requested to support the project either through a direct contribution or through the services of experts who will study specific problems, provide equipment and, by special arrangement, obtain access to the technical information needed for the implementation of the project.

L. Project review, reporting and evaluation

1. *Tripartite monitoring review*

The project will be subject to periodic review by ESCWA, in accordance with ESCWA policies and procedures for monitoring projects and programmes.

2. *Progress and terminal reports*

The project coordinator, in consultation with experts, consultants and focal points of the project, will submit periodic reports during the implementation of the project, as well as a terminal report.

3. *Evaluation*

The project will be subject to evaluation in accordance with the policies and procedures established for this purpose by the financing agencies. The organization, terms of reference and timing of the evaluation will be decided upon after consultation between the Network secretariat, the financing agencies and ESCWA, as the executing agency.

M. FURTHER ESCWA EFFORTS

The idea of establishing the Regional Water Training Network was well received and supported by the representatives of most ESCWA member countries (ESCWA report, 1992-1993). As a follow-up, ESCWA organized a mission to four representative countries (Egypt, Jordan, Saudi Arabia and the Syrian Arab Republic) in 1993 to update the previous surveys and to seek support for the Network project. The mission was successful in meeting most of its objectives. In 1994, ESCWA convened an expert group meeting in Amman which decided to take practical steps to establish the Regional Water Training Network.

Accordingly, an ESCWA consultant was asked to prepare a technical report, with the following objectives:

(a) To select certain institutes in some ESCWA member countries to be the first focal points of the Network;

(b) To make an assessment of the functions and performance of the selected institutes;

(c) To formulate training programmes for 1995 that would be executed in cooperation with the selected institutes.

Having received the consultant's technical report, ESCWA held a meeting in September 1995, attended by substantive ESCWA staff and the consultants to discuss the contents and the technical aspects of the report. It was agreed to hold an expert group meeting (EGM) on the proposed Regional Water Training Network and the consultant's technical report. The date of EGM was tentatively set for 15 and 16 November 1995 in Amman. Invitation letters were sent to each of the training centres that had been selected as candidates from the five ESCWA member countries to take part in the proposed Network and to be involved in the initial planning phase of the Network.

REFERENCES

1. United Nations Water Conference, Mar del Plata Action Plan, Mar de Plata, Argentina, 14-25 March 1977.

2. Expert Group Meeting on Manpower Development in the Water Sector in the ESCWA Region, Amman, Jordan, 5-8 June 1989 (E/ESCWA/NR/1990/I), in Arabic.

3. "Prelude to the Establishment of a Regional Water Training Network in the ESCWA Region" (E/ESCWA/NR/89/WG.1/WP.4), 30 June 1989.

4. "Working Paper on a Review of Manpower Development, Education and Training in the Water Sector in Western Asia" (E/ESCWA/NR/89/WG.1/WP.2), 28 May 1989.

5. United Nations Economic and Social Commission for Western Asia. *Development of Manpower, Education and Training in the Water Sector in Western Asia* (E/ESCWA/NR/85/14), August 1987.

6. "Project Profile, Solar Energy Based Herders Settlements" (E/ESCWA/NR/88/15), September 1988.

7. "Detail Programme for the Preparation of Arab Water Security Plan", ALECSO, Tunis, 1922 (in Arabic).

8. "Arab Physics Education Network (ARAPEN)", UNESCO/ROSTAS, Cairo, Egypt, 1990.

9. "Training in Water Resources Exploration, Development and Management", UNESCO/ROSTAS, Cairo, Egypt, 1991.

10. Daghestani F., "Concept Paper in the Arab Network for Science and Technology Management Training (ASTMT)", UNESCO/ROSTAS, Cairo, Egypt, March 1992.

11. Salih, A.M.A., "Education Needs for Efficient Water Use and Conservation", *ROSTAS Bulletin*, Issue No. 23, January 1991.

12. Salih, A.M.A., "Pre-Feasibility Study on Development of Engineering Education in Arab States", UNESCO/ROSTAS, Cairo, Egypt, June 1992.

13. Nash, J.E. and others, "The Education of Hydrologists", Report of an IAHS/UNESCO Panel on Hydrological Education. *Hydrological Science Journal*, vol. 15, No. 6, December 1990.

14. "Sustainable Water Resources Management in Arid Countries", Special issue, IWRA/*Canadian Journal of Development Studies*, 1992.

15. Alaerts, G.J., "Training and Education for Capacity Building in Water Sector", Proceedings of the UNDP Symposium on "A Strategy for Water Sector Capacity Building", Delft, 3-5 June 1991 (IHE Report, series 24).

16. *The Delft Declaration*, UNDP Symposium, Delft, 3-5 June 1991.

17. United Nations. The Dublin Statement and Report of the Conference, International Conference on Water and the Environment: Development Issues for the 21st Century, 26-31 January 1992, Dublin.

18. "Special Issue on International Drinking-Water Supply and Sanitation Decade", Water International, vol. 16, No. 3, September 1991.

19. "Mediterranean Network for Water", 2nd Mediterranean Conference on Water, 28-30 October 1992, Rome.

20. "The African Network of Centres and Programs for Training and Research on Science and Technology Planning and Management", 1992.

21. "The African Water Resources Network (AWRN): Regional Coordination Unit," *Information Bulletin*, WRC, Cairo, Egypt, November 1992.

22. Abayazid, O.M., "An Estimate of the Needs of Engineers and Technicians in the Arab Region up to the Year 2000", *UNESCO/ROSTAS Bulletin*, vol. XII, Nos. 1, 2, 3 and 4, 1984.

23. Banks, R.B., "The Asian Institute of Technology, a Regional Postgraduate School of Engineering and Applied Sciences", *Proceedings of the International Symposium on Postgraduate Engineering Education of Developing Countries*, UNESCO, Paris, 1979.

24. "Opportunities in the Hydrologic Sciences", *National Advisory Press*, Washington, D.C., 1991.

25. Regional Symposium on Water Use and Conservation, 28 November - 2 December 1993, Amman, Jordan (E/ESCWA/NR/1993/WG.1/WP.5), 14 November 1993.

V. ASSESSMENT OF WATER QUALITY IN THE ESCWA REGION (INTEGRATED MANAGEMENT OF WATER QUALITY AND QUANTITY IN THE ESCWA REGION)

Introduction

Water is the most important molecule on Earth, the only known planet where water exists in liquid form. Due to its versatile characteristics and great chemical activity, water functions in nature as a unifying agent of the ecosystem and life-support systems and it must be equitably shared among all those living in a particular water basin. In other words, water plays a pivotal role in many physical, chemical and biological processes regulating our planets, where man's activity is now inseparable in its effects from natural events. With all those different roles and functions, water is linked to many sectors; among these are health, agriculture, energy, industry, transportation and recreation.

In the last two decades, significant environmental changes have been witnessed. The lack of interdisciplinary approaches has impeded the necessary scientific understanding. Water-related problems in the ESCWA region have been met mainly by an impact-thinking approach. Research on water quality and its impact on environment has to a large extent been problem-driven and effect-oriented. The water resources researchers have been pushed by reality rather than being pulled by the desire to understand the overall water system to solve problems stemming from the accumulated results of past misuse which is now threatening the sustainability of water resources. At present, a whole range of perturbations are operating in parallel, all affecting the same hydrologic process in different ways: rapid population growth forcing Governments to intensify the use of land and water; delayed responses to water quality deterioration and pollutants already discharged into water bodies or soil; the continuing release of exhaust into the atmosphere, resulting in acid rivers; and the ongoing discharge of wastewater into the water bodies. To make matters worse, all these perturbations exacerbate each other.

In the ESCWA region, as was stressed by the Preparatory Committee for the United Nations Conference on Environment and Development, there is a need for a strategy to address water-related problems by considering the integrated water resources management approach. However, it is worth mentioning that in its conventional meaning, integrated water management involves an integration of all water uses and all water-dependent sectors. As land use, besides being water-dependent, is also water-impacting, water management will have to be integrated with land use. The land/water integration should include environmental protection of both uplands and downlands so that the fertile lowlands are protected from degradation under silt flows and floods emerging from water-driven degradation of the slopes in the upland basin. The natural unit for such integration is the watershed.

A. FACTORS ASSOCIATED WITH THE PROCESS OF WATER QUALITY ASSESSMENT

One of the major topics which should be studied in depth, and of direct relation to the integrated water resources management, is the assessment of water quality. The assessment of water quality includes the monitoring of water characteristics (physical, chemical and biological) to achieve adequate national water quality standards. Closely related to water quality monitoring are two other activities: water quality surveying and surveillance.

There are many operations involved in the process of the assessment of water quality. These operations include: objectives (such as hydrological factors, water use, economic development and policies); preliminary surveys (short- or long-term); monitoring design (selection of types of pollutants and station location); field monitoring operations; hydrological monitoring; laboratory activities; data quality control; data storage and reporting; data interpretation; and water management.

In the light of the available information on water quality monitoring in the region, it could safely be said that there is a direct need for the design and implementation of a water quality assessment programme in which the water quality monitoring operations are clearly defined. Of course, the type of water source to be studied, be it rivers, lakes and reservoirs or groundwater, has great bearing on the selection of survey and monitoring options as well as the eventual use or uses intended. Water quality monitoring is an important component of water quality assessment which refers to the evaluation of the physical, chemical and biological nature of water in relation to intended uses.

B. PURPOSE OF THE PAPER

The present paper focuses on different aspects related to integrated management of water quality and quantity. In the ESCWA region, there are also important facts as regards the linkage between water quality, availability, environment and socio-economic development. These facts include:

(a) An increasing lack of water of acceptable quality, which is influenced by growing water demand resulting from population growth and increasing per capita demand;

(b) The growing problem of deteriorating water quality resulting from water pollution, which reduces the usability of water;

(c) The important environmental linkages between land use and water in terms of land use impacts on water and water impacts on land.

In this paper it is intended to introduce the understanding of the integrated management of freshwater quality- and quantity-related problems existing in the region (availability and usability); water quality assessment and its deterioration; and pollution problems and their role in environmental degradation. Therefore, the need arises to address crucial issues related to the water criteria, standards and guidelines adopted by each ESCWA member State. Consequently, a better assessment of the nature of the water quality problem will be presented, and accordingly, proper recommendations can be made.

A. WATER AVAILABILITY AND USABILITY IN THE ESCWA REGION

1. *Water availability*

Most of the ESCWA region is characterized by a precarious water situation. Population growth and economic development have overwhelmed traditional water management practices, and water scarcity and mounting pollution are faced to varying degrees throughout the region. Issues of efficiency, allocation, and water quality must be urgently addressed if the problem is to be effectively managed. It is now known that annual per capita average of renewable supplies in the region has fallen by about 80%, from 3,436 cubic metres per capita (in 1966) to 667 cubic metres (projected in 2025) (8). These levels are far below the levels of other major regions of the world. In several ESCWA member countries, renewable freshwater will barely cover basic human needs into the next century. In addition, 35% of renewable supplies are provided by rivers flowing from outside the region, and these rivers are vulnerable to abstraction by upstream riparian countries. Within the ESCWA region, rivers and aquifers crossing national borders invariably involve complex issues of resource management. Accordingly, in most of the ESCWA member countries, the cost of maintaining water quality and controlling pollution will rise steeply, and expensive desalinated brackish/sea water, besides the treated wastewater, will be relied upon to augment the water supply.

To study the current status of water quality in the ESCWA region, water quantity related issues such as available water, pattern of utilization and rate of population growth should be taken into consideration. Hence, the most relevant problems to be addressed are mainly water shortage and water quality.

From different studies of water availability in the ESCWA region, broad categories of per capita availability of water were established and are given below:

Country	Water available 1,000 Mm^3/yr	Persons/Mm^3/yr 1990-2000	Water withdrawal km^3/yr	Percentage of available water	Municipal and Industry (percentage)
Egypt	55.5	948-1,183	54.0	97	12
Iraq	100.0	189-262	42.8	43	8
Jordan	0.9	3,508-5,005	0.8	89	35
Lebanon	3.8	705-785	0.8	21	15
Oman	2.0	777-1,129	0.4	22	6
Saudi Arabia	2.2	6,421-9,236	2.3	106	6
Syrian Arab Republic	5.5	2,280-3,246	3.3	61	17
Yemen	2.5	4,635-6,540	3.4	129	7

\+ Measurements of water scarcity in persons per million cubic metre per year:
100 - 500 = water management problems.

\+ 500 - 1,000 = water stress with large investments required.

\+ >1,000 = water scarcity with significant adjustment required.

\+ TOTAL Renewable Water Resources =
Internal renewable water resources + inflows from other countries less outflow to other countries.
>1,000 = Absolute water scarcity.

Reference (1).

The above data suggest that most of the countries are facing water scarcity conditions. A more drastic picture emerges from the study of the so-called "water poverty line", which showed that, among the countries of the ESCWA region, only Iraq, Lebanon, Oman and the Syrian Arab Republic fall above the line:

CATEGORIES OF GLOBAL PER CAPITA AVAILABILITY OF WATER
(1986)

Category	Per capita availability (cm/yr)
Very low	1,000 or less
Low	1,000 - 5,000
Medium	5,000 - 10,000
High	10,000 and above

Reference (2).

2. *Water usability*

Recent studies and surveys predict that per capita water availability will progressively decline, reaching below the minimum needed by the end of this century. This may be attributed to various factors, such as a high rate of population growth, the misuse of some important water resources, leading to their depletion and water quality degradation, water wastage and reliance on highly consumptive methods in irrigation and in some industries. A significant water consumer is the agriculture sector, which in many countries of the region consumes more than 80% of the available water.

The seriousness of this situation is attributed to the fact that most of the irrigation methods used in the ESCWA region lead to water losses estimated at between 50% and 80%. The following table indicates percentages of water use for different purposes:

PATTERN OF WATER USE ACCORDING TO SOCIO-ECONOMIC SECTORS IN THE ESCWA REGION (1992)*

Country	Percentage sectoral distribution		
	Domestic	Industry	Agriculture
Bahrain	32	3	64
Egypt	7	5	88
Iraq	3	5	92
Jordan	29	6	65
Kuwait	35	4	61
Lebanon	11	4	85
Oman	3	3	94
Qatar	-	-	-
Saudi Arabia	45	8	47
Syrian Arab Republic	7	10	83
United Arab Emirates	38	a/	62
Yemen	5	2	93

Source: All figures are from reference (2).

* The global figures are 8:25:67 for 1990 (9).

a/ Included in the figure for domestic.

Another problem to be considered is the serious loss owing to the inefficient use of domestic and urban water and to the improper maintenance and inefficient operation of the storage and distribution systems. However, the changing pattern of development in the ESCWA member countries, with greater emphasis being placed on industry, is bound to affect the relative allocation of water among the various users.

3. *Integrated approach to water resources management in terms of quality and quantity*

The widespread problems of water shortages, inadequate management tools, pollution and water and land degradation call into question the appropriateness and adequacy of the planning and integrated management tools being used in the ESCWA region. The following points, which cut across regional and national boundaries, could be mentioned:[1]

(a) In most countries the economic and legal tools for conserving the quantity and quality of water through the control of water abstraction/demand and the discharge of wastes into water bodies are either weak or non-existent; if they are available, the capacity to implement them is not available. Economic incentives and disincentives are not properly applied to manage demand because it has not been fully accepted that water is an economic good, and that the resources consumed in making it accessible should be fully paid for by the beneficiaries. This leads to excessive demand for water and wastefulness in meeting domestic, municipal, industrial and irrigation needs;

(b) The need has been recognized, where the water shortage situation is more serious, to mobilize additional water from non-conventional sources such as the drainage water, treated wastewater and saline water, and treated sea water. However, this is not being realized fast enough, owing to the economic, technical, social and cultural barriers that have to be overcome;

(c) Allocation of water under conditions of scarcity between upstream and downstream users within national boundaries often leads to irrational use of resources and might lead to mismanagement of the source. However, when the water is transboundary, the principles for allocating to meet current and future needs must be acceptable to all the riparian countries. The situation with regard to the sharing of the Nile, Jordan, Tigris and Euphrates waters among the riparian countries provide clear examples;

(d) The institutional set-ups for planning and managing water resources are many and varied. They also have different levels of adequacy and effectiveness. Common shortcomings include:

(i) The absence in many countries of an overall authority to give central direction to the utilization and conservation of water resources;

(ii) Duplication and overlapping of functions, leading to inefficient use of scarce resources;

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[1] Based on previous ESCWA studies, reports and missions to different ESCWA member countries.

(iii) Ineffective linkages between water agencies and their sector ministries, and ineffective linkages between sector ministries and the agencies dealing with overall national development planning and finance;

(iv) Lack of mechanisms for integrating land and water resources planning and management in spite of the fact that it is recognized as desirable;

(v) Absence of clearly designated and mandated agencies to deal with transboundary water issues in countries where river or groundwater basins are shared with other countries;

(vi) The importance of water to the sustainability of the region and to socio-economic development is not reflected in the institutions. The decision-making processes at various levels of Government have not been able to incorporate water as a key factor in decision-making (3);

(e) A particular problem is how to address water resources assessment. In spite of the recommendation in the Mar del Plata Action Plan to increase the basic data networks so as to provide adequate background data for water resources planning and management, the development has in fact taken the opposite direction, and stations have been closed down in response to economic difficulties. There is therefore a need to develop approximation methods based on various types of proxy data.

B. WATER QUALITY MANAGEMENT

1. *The nature of the water quality problem*

As indicated in section A, water quality and quantity management is inseparable. Water resources cannot be fully described without knowledge of the quality characteristics. The quality of water resources is assessed from their physical, chemical and biological constituents. The latter may originate naturally from the environment (e.g. soils and geological formation), or from wastes discharged as a result of agricultural, human settlements and industrial activities. They are introduced either from point sources (mostly industrial), which are manageable, or from non-point sources (mainly agricultural), in which case management is more difficult.

The concentration of the constituents simply expresses the state of the water in physical, chemical and biological terms. Quality can only be discussed meaningfully when it is related to a use. In such cases, guidelines on the concentrations of various constituents that should not be exceeded so as not to impair the water for a particular use must be known. The human activities that have an impact on water quality in the ESCWA region are discussed in subsequent paragraphs.

Population increase, with its concomitant urbanization, has resulted in a dramatic rise in urban dwellers in most countries of the region. This, in most instances, has not been accompanied by the necessary increase in domestic and urban wastewater treatment facilities. In fact, the old practice of discharging wastewater into surface waters has continued in a number of major cities of the region. This must be contrasted with the growing demand for safe drinking-water and sanitation services, resulting in increased amounts of wastewater that must be treated. Thus, the limited finances available for the services needed are usually directed towards safe drinking-water supplies, and the result is the overloading of the sewer system and the inability of the wastewater treatment plants to cope with increased loads. The data given in the table below show clearly the high level of safe drinking-water and sanitation services provided in some countries of the region, whether in urban or rural areas. However, information on wastewater treatment plants and their capacities have been given in previous ESCWA studies and papers. In Egypt, for example, the water and sewage systems are seriously overstressed, and some surveys have shown the sewers in many parts of the major cities to be extremely overloaded and impossible to maintain efficiently. Street flooding by sewage from broken and clogged lines is common.

POPULATION (PERCENTAGE) WITH ACCESS TO SAFE DRINKING-WATER AND SANITATION IN SELECTED COUNTRIES OF THE ESCWA REGION (1988)

Country	Safe drinking-water		Sanitation services	
	Urban	Rural	Urban	Rural
Egypt	96	82	100	34
Iraq	100	72	92	55
Jordan	100	98	100	100
Oman	87	42	100	34
Saudi Arabia	100	74	100	30
Syrian Arab Republic	91	68	72	55
Yemen[a/]	100	48	66	-

Source: Reference (2).

a/ Figures are for the former Yemen Arab Republic.

Not only have the rise of industry and the rapid industrialization that have taken place in the region in the last three decades increased the demand for freshwater, but the poor control exercised over industrial water discharge and the type of technologies used have resulted in serious surface water pollution owing to discharge of industrial wastewater and toxic substances. Even the well-established petroleum industry has not been immune from such practices.

Another aspect of the deteriorating water quality is that of water-related health problems. These can be either biological, due to pathogen-contaminated waters, or chemical, due to toxic materials. Both urban and rural areas in the region are subject to serious health risks from wastewater. The high level of biological contamination of surface water seems to be common in most countries, and it is a matter of great concern because it reflects on the quality of life in the region.

2. *Sources of water quality deterioration*

Water quality is deteriorating all over the region in various ways, reducing the usability of water. Information and data obtained in the last two years have indicated that water quality deterioration in the ESCWA region is attributed to the following:

(a) Pathogenic agents from faecal discharge, probable to become more severe as population increases more rapidly than wastewater collection and effective treatment are implemented;

(b) Organic pollution from the same sources, consuming the oxygen in the receiving water bodies, with consequential effects on biological life;

(c) Salinization, primarily by poorly managed irrigation systems in the region, one of the primary water quality problems in overexploited coastal aquifers; and as a result groundwater mining activities;

(d) Nitrate pollution of aquifers from surplus fertilizers and from human activities in particular shallow aquifers;

(e) Eutrophication caused by increasing levels of nutrients, normally phosphate but sometimes nitrate;

(f) Heavy metals, of which only a small fraction has yet leached into water bodies, but the amount may increase owing to rain acidification;

(g) Pesticides, in the use of which there has been an exponential rise during the last two decades, but the contamination resulting from their use remains poorly documented owing to analytical difficulties;

(h) Industrial organic substances such as solvents, chlorinated hydrocarbons and polycyclic aromatic hydrocarbons from air exhausts, dump-site leakage, and wastewater;

(i) Acidifying substances released in air exhausts as inorganic acids and causing acidification of aquifers, rivers and lakes in poorly buffered areas, such as those with sandstone and crystalline rocks, and associated with increases in dissolved aluminium and some other metals;

(j) River sediment loads which have increased considerably through erosion accelerated by man, causing enormous turbidity problems locally, and in general disrupting the natural biological processes in rivers and coastal areas.

Human activities in the region have also taken their toll on the natural hydrologic regimes, with various direct effects on water bodies: salinization of rivers, lakes and soils; salt intrusion into coastal aquifers; and reduced dilution and self-purification capacity of rivers (2)(3)(4).

3. *Water quality/pollution related issues*

In the light of the developments of the last three decades, the laws and regulations which were effective half a century ago have become completely ineffective. The authorities responsible for water control have continued to operate along traditional lines with marginal changes brought about on an ad hoc basis. These authorities concerned themselves mainly with the supply of adequately treated water with a minimum level of safety, mainly with respect to the absence of pathogenic contaminants. Their role *vis-à-vis* the misuse of water sources was limited to the discharge of raw domestic wastes. Hardly any control was exercised concerning the discharge of industrial effluents or of inadequately treated wastewater. The question of the deterioration of the main water resources, surface waters or groundwaters, owing to agricultural drainage or the contamination arising from toxic agrochemicals, was seldom considered (8).

The situation is further complicated by the fact that in many countries of the region responsibilities for water resources are divided among various governmental and public departments with, in some cases, no central authority responsible for all aspects of the water sector. Thus, there seems to be no single body responsible for water quality management. Water quality issues are dealt with on an ad hoc basis by the different ministries. Water authorities as such mainly handle water distribution systems and treatment, such as disinfection of water supplies, if needed. The low level of technical competence and the inadequate training, made it difficult for the water authorities to tackle the problems arising from water resource deterioration in most countries of the region. However, recent interest in environmental issues and especially in the impact of development on the environment, has led to greater attention being paid, in most countries of the region, to the question of water resources pollution. Consequently, this is expected to lead to the enactment of environmental quality standards, important among which are those related to water quality (6)(8).

So far, responsible authorities in the region have accepted international standards, specifically the World Health Organization (WHO) standards in most cases. This must be viewed with caution because of the important differences and peculiarities of the region and the ESCWA member countries with respect to most environmental problems, not least among them are the climatic and soil conditions. To this must be added the socio-economic and environmental requirements for sustainable development in the region. All this must lead to an emphasis on the need for an endogenous water system built upon a clearly stated national and regional water policy. Water quality, in all its aspects, can only be considered rationally within the framework of a system that recognizes the realities of the water situation as part of the socio-economic and geopolitic milieus of the region.

The situation may be summarized in the following terms:

(a) Legislation has not developed sufficiently to meet the level of technological advancement achieved in many of the socio-economic sectors;

(b) There is no national policy on water quality that can serve as the basis for water quality standards;

(c) The organizational set-up is not adequate to handle the demand for the quantity and quality of water required by a rapidly growing and advancing society.

The situation of legislation and institutions related to water quantity and quality on a country-by-country basis will be published in an ESCWA technical publication by the end of 1995. The information presented in that publication will be gathered, as far as possible, from contributions by the countries concerned to ESCWA and other regional and international meetings and organizations as well as from published documents of these organizations.

4. *Regional and subregional cooperation*

The Gulf Cooperation Council (GCC) has included water resources among its priorities and has issued some important decisions on water conservation for its members. The specialized committees of the GCC have also worked on some studies and reports concerning various aspects related to water; of interest among them is a guide for drinking-water standards. Interest in the well-being of the aquatic quality of the Gulf led in 1978 to a regional convention for the protection of the Gulf environment joined by all the countries surrounding it, viz., the countries of the GCC, Iraq and the Islamic Republic of Iran. The convention dealt with wide-ranging issues related to industrial and oil pollution, aquatic life, discharge of municipal and industrial wastewater, and the environmental impact of engineering and mining projects in the coastal regions.

Efforts to formulate similar programmes for the Red Sea and the Gulf of Aden have yet to materialize. However, the Mediterranean Sea environment has been the centre of great interest, as reflected by the various activities in which some countries of the ESCWA region are directly involved. No similar activities could be recorded in the case of shared international rivers or common aquifers. However, an activity in which the countries of the region are involved which is expected to be of great promise is the Inter-Islamic Network for Water Resources Development and Management.

There are regional and international organizations with direct interest in water affairs in the ESCWA region. The cross-section of such institutions covering a wide range of activities on the country, regional, subregional, and interregional levels shows clearly the priority allotted to water resources and water quality problems. Among the many activities of these organizations, water quality features prominently. It is hoped that the proposed regional water committee would soon see the light and take a leading role in coordinating regional activities in such areas as water quality standards and legislation as well as in laying the grounds for regional cooperation in all water issues (3)(5).

5. *Drinking-water supply guidelines in the ESCWA region*

WHO, as well as other organizations, is taking an active role in developing guidelines to describe water quality to satisfy economic and consumer health considerations. These guidelines highlight the importance of analytical monitoring of drinking-water quality to avoid ingestion of pollutants such as chemicals and bacteria. In 1984, WHO introduced Drinking-Water Quality Guidelines (three volumes), superseding both the European Standards and International Standards for Drinking-Water which had been in existence for over a decade. The main reason for replacing the previous standards for drinking-water quality was the desirability of adopting a risk-benefit approach to the national standards criteria, standards and regulations. Adoption of two stringent drinking-water standards could limit the availability of water supplies that met those standards. Hence the WHO guidelines for drinking-water quality were set instead of WHO standards for use by countries as a basis for the development of their own national standards, which if properly implemented would ensure the safety of the drinking-water supply.

It was emphasized on many occasions that the WHO guidelines are not standards in themselves but represent recommended levels for water constituents and contaminations. Therefore, many of the ESCWA member countries have set their guidelines in line with the WHO guidelines for drinking water quality. These guidelines highlight the continuous need and importance of analytical monitoring of drinking-water quality to avoid ingestion of pollutants such as chemicals and bacteria. This prompts the necessity for water quality follow-up in the laboratories.

In the ESCWA region, drinking-water quality has received great attention in recent times, owing not only to the rise in demand but also to the degradation of the usual sources of public water. Every effort should be directed to achieve a drinking-water quality as high as practicable. Protection of water supplies from contamination is the first line of defence. Source protection is almost invariably the best method of ensuring safe drinking-water and is to be preferred to treating a contaminated water supply to render it suitable for consumption (4)(6).

6. *Water quality guidelines for irrigation*

Water used for agriculture depends on its quality and adequacy for irrigation. Using lower quality water results in adapting careful planning to ensure that the quality of available water is put in the best use. Such planning is taking into consideration soil and crops in selecting alternatives to cope with potential water quality related problems that might reduce production under prevailing water quality use. Water characteristics usually influence its suitability for specific use. In irrigation water, emphasis is mainly placed on chemical and physical characteristics and rarely are other factors considered important. In this regard, river water loaded with sediment loads is useful in irrigation but unacceptable for municipal use without proper treatment.

Of the total amount of water used by the ESCWA region, 70% to 80% is used for agriculture. The so-called green revolution of the 1970s and in developing countries, including ESCWA member countries, brought several million hectares of land under cultivation by irrigation. Irrigated agriculture plays an important role in producing food in the region. Water used for irrigation often contains some salts which may sometimes be necessary for the growth of the crop. Often low-saline water in irrigation systems may cause soil permeability problems. Therefore, whether a particular source of water is good for irrigating a particular type of crop in a specific type of soil is determined by the amounts and types of salts present in the water.

Generally, the problems resulting from use of poor quality water for irrigation are salinity, permeability, toxicity and other effects. There have been a number of different water quality guidelines related to irrigated agriculture, each of which was useful to cover certain aspects but none has been entirely satisfactory because of the wide variability in the field conditions. The Food and Agriculture Organization of the United Nations (FAO) developed guidelines for interpretation of water quality which relied heavily on previous ones but were modified to give more practical procedures for evaluating and managing water quality related problems of irrigated agriculture.

As previously mentioned, irrigation is one of the main agricultural consumers of water in the ESCWA region. Poor quality water may affect irrigated crops by causing accumulation of salts in the root zone, by causing loss of permeability of the soil due to excess sodium or calcium leaching or by containing pathogens or contaminants which are directly toxic to plants. When the presence of pesticides or pathogenic organisms in irrigation water does not affect plant growth and in turn affects the acceptability of the agricultural product, FAO guidelines, adapted in the ESCWA member countries, take into account such characteristics as crop tolerance for salinity, sodium concentration and phytotoxic elements. Sodium in irrigation water (Jordan and the Syrian Arab Republic) can adversely affect soil structure and reduce the rate at which water moves into the soil. However, water quality guidelines in the ESCWA region may be considerably adjusted (Egypt, Iraq and the Syrian Arab Republic) due to different annual application rates of irrigation water (7).

C. CONCLUSIONS AND RECOMMENDATIONS

The countries of the ESCWA region, with their high rate of population growth, almost explosive urbanization, and rapid industrialization, coupled with serious overdraft conditions of their water resources and unsolved problems of shared water basins among riparian countries, have had to deal with a rapid sequence of water quality issues over a short period of time, compared with over a century and a half that the developed industrialized countries have taken to confront the sort of problems currently afflicting the region. Thus, situations have arisen in many ESCWA member countries in which more advanced pollution issues appeared before control over traditional pollution sources had been successfully achieved. The people of the region know that they must give the highest priority to ensuring a satisfactory supply of "good" quality water so essential to their sustainable development. Therefore, with their water-poor region, they must exercise the greatest care in sustaining their water resources both quantitatively and qualitatively. The question of water quantity control is a pivotal one that requires quick action to devise the most effective water action plan involving not only the much needed modern legislation but also viable management and organization.

There is currently a focus on many regional plans and policies prepared on the water resources of the region. The issue of water quality was considered to be one of the three priority issues identified for action in the region. The inadequacy of water quality monitoring in the region, together with the institutional incapabilities and the lack of legal and regulatory prowess, was duly identified. These observations were frequently recorded in many regional and national gatherings on water resources in the ESCWA region. The problem of deterioration and depletion of water resources was identified as being of the highest priority among the environmental constraints in the region. A strategic objective of the regional plan is water quality improvement and efficient water use, which comes under one of the main goals of sustainable development.

An analysis of water resources problems identified the following problem areas to be of greatest concern:

(a) Water shortages resulting from inefficient use;

(b) Deterioration of water quality;
(c) Ineffective public- and private-sector water resources management.

The following strategic objective components were defined:

(a) Increase effective use of water;
(b) Enhance water quality;
(c) Improve water management.

The Bureau for Near East of the United States, Japan, the European Union and several individual European countries have shown great interest in the water-related problems of the region. Water quality has featured prominently in all of them. It is hoped that such international concern will be reflected in greater regional and international cooperation in this viable area of development.

Water shortage and water quality problems characterize the ESCWA region. In general, the countries of the region have many issues in common pertaining to water:

(a) The increased deterioration of water quality and degradation of water resources, coupled with explosive urbanization, rapid industrialization, and uncontrolled expansion of irrigation and indiscriminate use of agrochemicals in agriculture;

(b) The diversity of institutions and authorities in charge of water affairs in most countries of the region, and the absence of a well-defined water policy and national water plan;

(c) The inadequacy of the current legislation or sometimes its absence in confronting the problems of water quality, and the ineffective enforcement of the existing regulations;

(d) Water quality standards are almost outdated; those which are being instituted are either international guidelines or foreign standards and therefore do not necessarily reflect the local and regional requirements;

(e) Regional cooperation has been limited to certain areas of immediate concern, while such issues as common water basins and problems related to shared water sources have not received the necessary level and degree of attention. The call for the formation of a regional water resources body has not been effectively answered.

In the light of the information presented in previous sections, a number of observations in the form of recommendations may be tentatively made:

(a) Water quality must feature prominently in any water policy or plans at the national and regional levels;

(b) A water quality assessment strategy must be formulated and effectively enacted at the national level and it should include regional components to reflect the commonality of many of the problems;

(c) Integrated water legislation should include water conservation and water quality matters dealt with in accordance with the requirements of national and regional sustainable development;

(d) Water quality standards should be made in the light of internationally acknowledged guidelines, and in congruence with the national needs of the various socio-economic sectors and their sustainable development;

(e) Regional cooperation on water resources should consider the problem of water quality in the region among its first priorities, and ESCWA should assist in drawing a regional plan of action on water resources that includes:

(i) An information network on water quality issues;

(ii) Cooperation in formulating water quality standards, possibly through the production of guidelines specially designed to correspond to the water situation and needs of the countries and of the region as a whole;

(iii) Training programmes to upgrade personnel working in the water sector, and in matters of water quality control in particular;

(iv) Model legislation for water quality control to be used as guides in the formulation of national laws and regulations;

(v) Model water management system to assist Governments in the region in the establishment of more effective water institutions;

(vi) A regional strategy for water quality assessment, including water quality monitoring, benefiting from the experience of the Global Environment Monitoring System (GEMS).

REFERENCES

1. World Bank. Technical Paper No. 2, pp. 1&2.

2. United States Agency for International Development, Bureau for the Near East, "Water Resources Action Plan for the Near East", Washington, 1993.

3. ESCWA, "Proceedings of the Ad Hoc Expert Group Meeting on Water Security in the ESCWA Region", Damascus, November 1989 (E/ESCWA/NR/1990/3).

4. WHO/UNEP, "Assessment of Freshwater Quality", 1988.

5. F.I. Kanbour, "Appropriate industrial pollution standards for Arab countries", UNEP Regional Office for West Asia, Manama, 1989 (in Arabic).

6. WHO/EMRO/CEHA, selected presentations, "Regional Seminar on Drinking Water Quality", 20-24 May 1991, Nicosia, Cyprus (CEHA Document No. TLM-3).

7. FAO, "Water Quality for Agriculture", Rome, 1995 (FAO Irrigation and Drainage Paper 29, Rev.1).

8. World Bank, "A Strategy for Managing Water in the Middle East and North Africa", Washington, D.C., 1994.

VI. GROUNDWATER QUALITY CONTROL IN THE ESCWA REGION

by

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Introduction

Assessment and control of the quality of water resources is an essential task for securing water supplies in the ESCWA region in view of the following:

(a) Freshwater resources are exploited to a large extent in most countries of the region;

(b) Extensive exploitation and contamination have caused a deterioration of water quality in many areas;

(c) The increasing water demand necessitates the use of water resources with marginal quality (such as brackish water and non-conventional water resources).

In view of this situation, the work programme of ESCWA includes the preparation of contributions to the "Assessment of water resources quality in the ESCWA region". The present paper has been prepared as a contribution to the general task of assessing the quality of water resources and developing strategies for conservation of groundwater quality in the ESCWA region.

The paper comprises:

(a) A review of regional features of groundwater quality;

(b) An outline of hydrochemical conditions in selected hydrogeological provinces, based on a review of relevant literature and a summary evaluation of available groundwater quality data;

(c) A summary of information of the main sources of groundwater salinity and of groundwater quality deterioration in the region;

(d) Considerations of necessities and options for conservation of water quality in exploited and exploitable aquifers, including aspects of:

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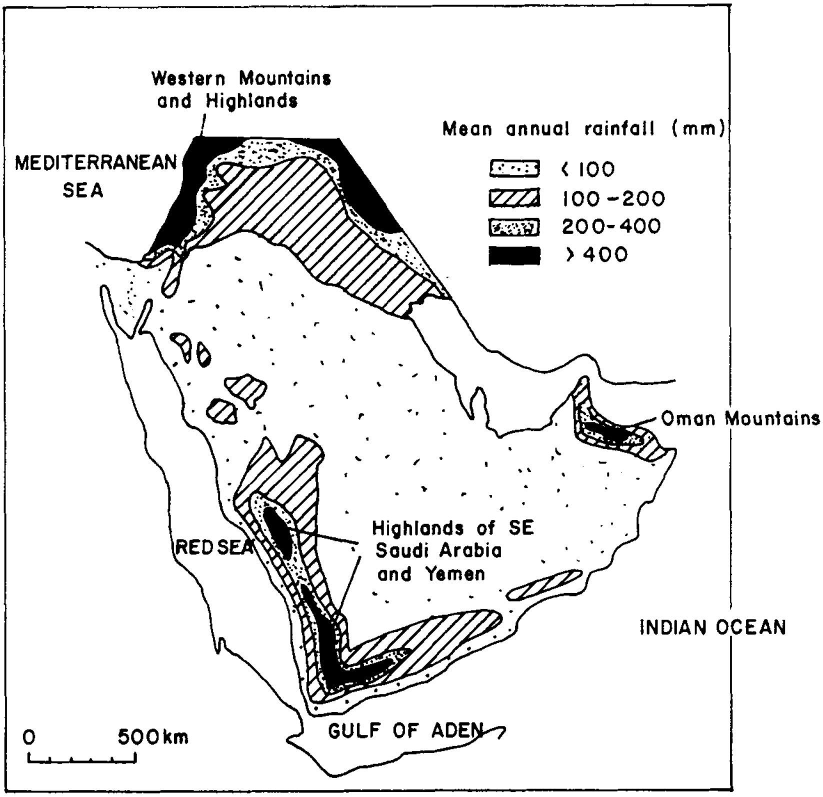
(i) Groundwater protection against intrusion of brackish or saline water;
(ii) Groundwater protection against contamination from the surface;
(iii) Related investigations and monitoring programmes.

A. REGIONAL FEATURES OF GROUNDWATER QUALITY

1. *Groundwater salinity in different hydrogeological provinces*

The ESCWA region is situated predominantly in zones with a semi-arid to arid climate. Sub-humid climate conditions extend over the western highlands and mountain ranges of Jordan, the Syrian Arab Republic and Lebanon with a Mediterranean climate and over mountain ranges at the south-eastern and south-western fringes of the Arabian Peninsula in south-western Saudi Arabia, Yemen and Oman, which receive a limited amount of monsoonal rainfall with a mean annual precipitation of 200-600 mm (figure 1).

Figure 1. Mean annual rainfall in the ESCWA region



Source: United Nations (1982).

The ESCWA region coincides with the geological structure of the Arabian Platform, a huge plate of the Earth's crust which was attached to the African Plate until the opening of the Red Sea rift structure during the Late Cretaceous to the Tertiary Period. The Arabian Platform comprises two major geological provinces: the Arabian Shield, composed of Precambrian crystalline rocks, and the Arabian Shelf, which is covered by a thick sequence of sedimentary rocks.

The distribution of natural groundwater salinity in the ESCWA member countries appears, in a regional view, related to geological and morphological-climatic features: more humid climate conditions favour the formation of fresh groundwater resources; the geochemical reactivity of soil and rock material is a dominant factor for the concentration of dissolved substances in the groundwater; morphological features influence run-off and infiltration characteristics.

Groundwater with low salinity extends over wide parts of the western mountain ranges, where the Mediterranean sub-humid climate and karstic aquifers create relatively favourable recharge conditions, and over the highlands and the western escarpment in Yemen.

In most of the semi-arid to arid areas covering the steppe (Badyie) in the northern Arab countries and most of the Arabian Peninsula, the groundwater salinity reaches from >1,000 to several thousand mg/l of total dissolved solids (TDS). This general increase of groundwater salinity towards the more arid regions is certainly, to a large extent, related to the climatic conditions: increasing aridity is accompanied by decreasing recharge and an increasing impact of evaporative processes.

Some areas of the ESCWA region with very low rainfall contain groundwater resources with adequate or marginal quality for domestic use or irrigation. These occurrences of fresh groundwater are related to recharge during previous periods with more humid climate or to recent recharge in extended wadi systems (Wagner 1995).

Lerner et al. (1990:24) defined areas with similar climatic, geologic and soil conditions as hydrogeological provinces. This concept can be applied to the ESCWA member countries, on a regional scale, considering the lithologic characteristics of major aquifers and morphologic-climatic zones. In different hydrogeological provinces, particular groundwater quality characteristics can be found.

Some of the main hydrogeologic provinces of the region and their characteristics are listed schematically in table 1.

TABLE 1. SELECTED HYDROGEOLOGICAL PROVINCES OF THE ESCWA REGION

Hydrogeologic province	Major aquifers	Climate	Groundwater type acc. to salinity
Western highlands and mountains, Jordan, Syrian Arab Republic, Lebanon	Karstic limestones and dolomited	Sub-humid	Mainly fresh
Badyie and Hamad	Fissured carbonate aquifers	Semi-arid	Brackish, fresh in limited areas
Basalt area, Jordan and Syrian Arab Republic	Fissured basalt	Semi-arid to sub-humid	Mainly fresh
Sandstone area in Jordan and Saudi Arabia	Sandstone	Prevailingly arid	Fossil fresh groundwater
Carbonate aquifers in Saudi Arabia and the Gulf area	Fissured or karstic carbonate aquifers	Prevailingly arid	Mainly brackish
Arabian Shield	Unconsolidated wadi aquifers	Arid, semi-arid in mountain areas	Fresh to brackish
Western highlands and escarpment in Yemen	Limestone, sandstone, volcanics	Semi-arid to sub-humid	Fresh to slightly brackish
Oman Mountains	Ophiolites carbonate rocks	Semi-arid	Low yielding freshwater aquifers. Fresh to brackish
Coastal areas	Unconsolidated coastal aquifers	Semi-arid to arid	Brackish to saline, freshwater lenses

2. *Hydrochemical aspects*

The main natural sources of substances dissolved in the groundwater in the ESCWA region are:

(a) Atmospheric inputs: substances dissolved in infiltrating rainwater;

(b) Pedogenic inputs: substances dissolved through interaction of biogenic CO_2 with soil material and water; salts dissolved from the soil zone;

(c) Laithogenic inputs: substances dissolved from rock material in the saturated and unsaturated zone.

Processes that increase the groundwater salinity are:

(a) Enrichment of salts through evapo-transpiration;

(b) Intrusion of brackish or saline water from surface-water bodies (sea water, *sabkhas*) or from adjacent aquifers or aquitards.

Anion concentrations in rain water (table 2) are in the following order of magnitude (figure 2, Salameh et al. 1991):

Cl 5-25 mg/l
SO_4 4-50 mg/l
HCO_3 20-60 mg/l

High contents of dust particles can create SO_4 and HCO_3 concentrations of more than 100 mg/l in atmospheric deposition.

During the recharge process, the ion contents from atmospheric deposition are generally increased: HCO_3 and equivalent cations are dissolved through interaction of CO_2, which is produced by biological activity in the soil zone, with carbonate and silicate minerals, and Cl and SO_4 contents are enriched through evapo-transpiration.

Infiltrating surface water run-off (indirect recharge) usually also supplies concentrations of dissolved substances increased in comparison to rainwater through pedogenic HCO_3 contents enrichment by evapo-transpiration and dissolution of salt accumulations which occur at the surface or in the soil zone.

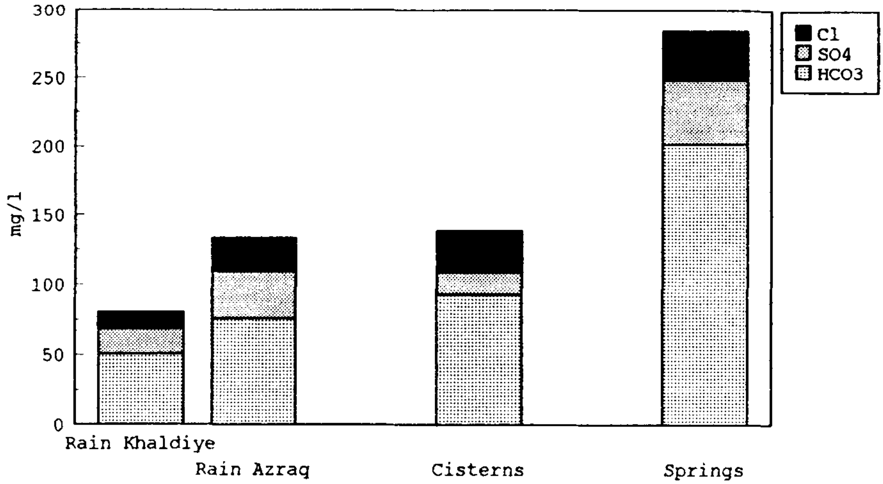
TABLE 2. AVERAGE CONCENTRATIONS OF MAJOR IONS IN RAINWATER IN SELECTED AREAS

	Jordan Khalidiye	Jordan Azraq	Central Syrian Arab Republic	Northern United Arab Emirates
El. conductivity	165	273	120	70-350
Total diss. solids			70	
Ca	23.3	34.9	18	20
Mg	2.1	34.9	1	1-5
Na	5.4	18.5	2	5-20
K	3.1	2.3	1	
Cl	11.9	23.7	6	5-50
SO_4	18.0	33.7	20	10-50
HCO_3	50.6	75.9	40	20-60

Electrical conductivity in $-\mu S/cm$, ions in mg/l.

After information from Salameh et al. 1991, Droubi 1983, and United Arab Emirates Ministry of Electricity and Water.

Figure 2. Anion concentrations in rainwater and fresh recharge, northern Jordan



Source: Salameh et al. 1991, Rimawi and Udluft 1985.

During longer water retention periods in the aquifer, a further increase in anion concentrations from lithogenic components can occur:

(a) Increase in Cl and SO_4 concentrations through dissolution of evaporite (gypsum) layers and salts;

(b) Increase in HCO_3 concentrations through interaction of dissolved CO_2 with carbonate or silicate minerals or through oxidation of organic matter.

The concentrations of lithogenic components are largely controlled by the geochemical composition of the rock formations with which the groundwater comes into contact. On the Arabian Shelf, the groundwater quality is influenced by the following main lithological types of aquifers and aquitards:

(a) Carbonate aquifers: limestones, dolomites, chalk;

(b) Siliceous aquifers: sandstones, volcanic rocks;

(c) Aquifers with sulfitic layers: carbonate rocks, sandstones or semi-consolidated Pleistocene basin deposits with gypsum or anhydride intercalations;

(d) Aquitards of marine origin with dispersed salts and pyrite;

(e) Unconsolidated or semi-consolidated Pleistocene to recent aquifers in wadis, basins and coastal areas with varying geochemical rock types.

The classification of groundwater according to quality characteristics is generally based on contents of dissolved solids. The major aims of groundwater quality classification are:

(a) The assessment of suitability of groundwater use for the domestic supply or for irrigation;

(b) The investigation of the origin of the groundwater and of sources of groundwater salinity.

Criteria for groundwater quality classification regarding natural inorganic components are:

(a) Total salinity and the corresponding Cl concentration;

(b) Standards of major constituent concentration with regard to human consumption (WHO 1993);

(c) Standards for irrigation water based primarily on total salinity (electrical conductivity values) and sodium hazards (exchangeable sodium rations, sodium adsorption ratio, Appelo and Postma 1993:191);

(d) Proportional contents of major ions used for definition of hydrochemical water types.

For regional aspects of groundwater classification, values of total salinity and of anion concentrations can be evaluated. Major cations (alkaline ions: Na, K and earth alkaline ions: Ca, Mg) can have characteristic ranges or proportional contents in a specific aquifer but vary over wide ranges in many cases.

A simplified scheme of the classification of water types by Stuifzand (1991) may serve to define regional hydrochemical characteristics, based on the following categories:

(a) Total salinity and Cl concentration:

	TDS g/l	Cl mg/l
Freshwater	<1.0	<150
Brackish water	1.0-10	150-300
Salt water	>10	>300

(b) Predominant anion and cation contents (proportional contents in meq %):

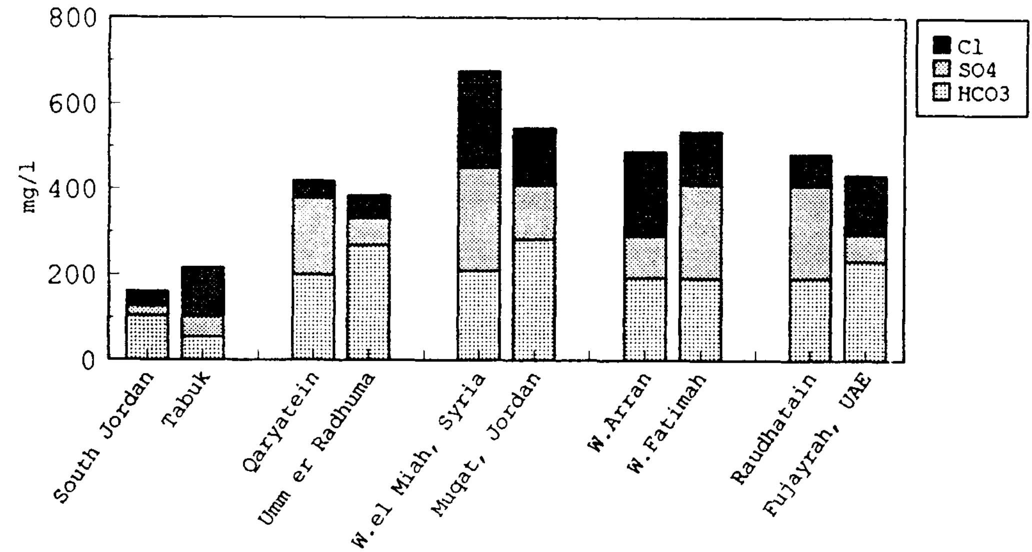
Anions: HCO_3, SO_4, Cl;
Cations: Na+K (alkali ions, generally Na- type water), Ca+Mg (earth alkaline ions, Ca- or Mg-type water).

B. Hydrochemical conditions in selected hydrogeological provinces

1. *Western highlands and mountain ranges in Jordan, Lebanon and the Syrian Arab Republic*

Karstic carbonate aquifers in the western highlands and mountain ranges of Jordan, Lebanon and the Syrian Arab Republic with sub-humid mediterranean climates receive relatively high recharge. The groundwater is prevailingly fresh Ca-HCO_3-type water with a salinity of 250-500 mg/l TDS (figure 3). Dissolved substances are dominated by atmospheric inputs and by dissolution of carbonates with minor enrichment through evapo-transpiration processes. Analyses of water samples collected from cisterns and from springs of very shallow aquifers in the western highlands of Jordan (Rimawi and Udluft 1985) provide indications of the quality of groundwater recharge. Water from cisterns is similar to rainwater in its anion composition with a slight increase in HCO_3 concentration. The effect of dissolution of soil and rock carbonate can be seen in HCO_3 contents of spring water from shallow carbonate aquifers, which are considerably higher than in rainwater (figure 2).

Figure 3. Anion concentrations in low salinity groundwater in arid parts of the ESCWA region



Source: Hobler et al. 1991, United Nations 1982, ACSAD 1983, Otkun 1975, Jado and Hötzl 1984, files of Kuwait Inst. Sci. Research and United Arab Emirates Min. Agric.

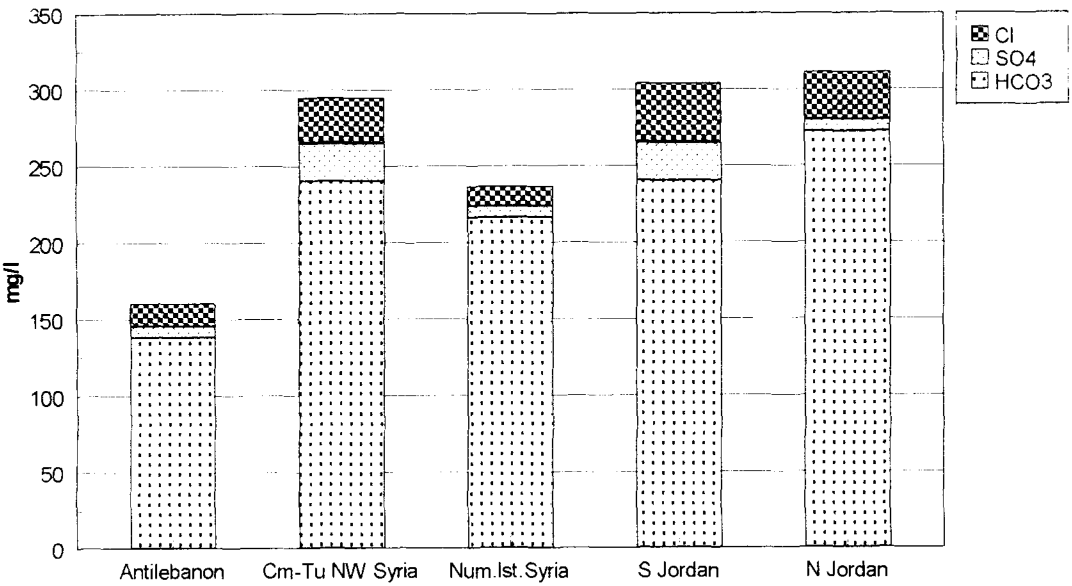
The anion composition of water from some of the large karst springs in the Lebanon and Anti-Lebanon Mountains, such as Ain el Figeh, reflects the origin of the water from atmospheric inputs: Cl and SO_4 concentrations of a few mg/l, and of carbonate dissolution: HCO_3 concentrations around 170 - 200 mg/l.

Groundwater ages in the extensive karst aquifers range from recent to several thousand years. The mean turnover time of groundwater discharging in Ain el Figeh (Anti-Lebanon and the Syrian Arab Republic) has been calculated to about 50 years (Yurtsever 1993).

Most of the groundwater in the Amman-Wadi Sir aquifer of the western highlands in Jordan is apparently several thousand years old (5,000 to 15,000 years), with limited recent direct and indirect recharge (Lloyd 1980, 1981).

Elevated SO_4 concentrations in Mesozoic karst aquifers in the Syrian Arab Republic indicate a lithogenic source of sulphate formed by gypsum layers. Groundwater with elevated SO_4 contents in the Anti-Lebanon (Barada, Hor and Sarda springs) are predominantly recent with ^{14}C value around 50 pmc and tritium levels around 30 T.U. (ACSAD files).

Figure 4. Anion concentrations, karst aquifers, Jordan and the Syrian Arab Republic



2. *Basalt area in Jordan and the Syrian Arab Republic*
(United Nations 1982, Almomani 1995, Katan 1995)

Groundwater in the basalt aquifer of the Hauran area in the Syrian Arab Republic and in northern Jordan is generally characterized by low salinity between 200 and 500 mg/l and groundwater salinity is even less at the higher slopes of Jebel el Arab, with electrical conductivity values of 120 to 350 μS/cm. The low salinity groundwater samples from basalt aquifers vary from HCO_3 to Cl-HCO_3 waters. HCO_3 concentrations are generally <140 mg/l (figure 5).

Figure 5. Anion concentrations, basalt aquifers, Jordan and the Syrian Arab Republic

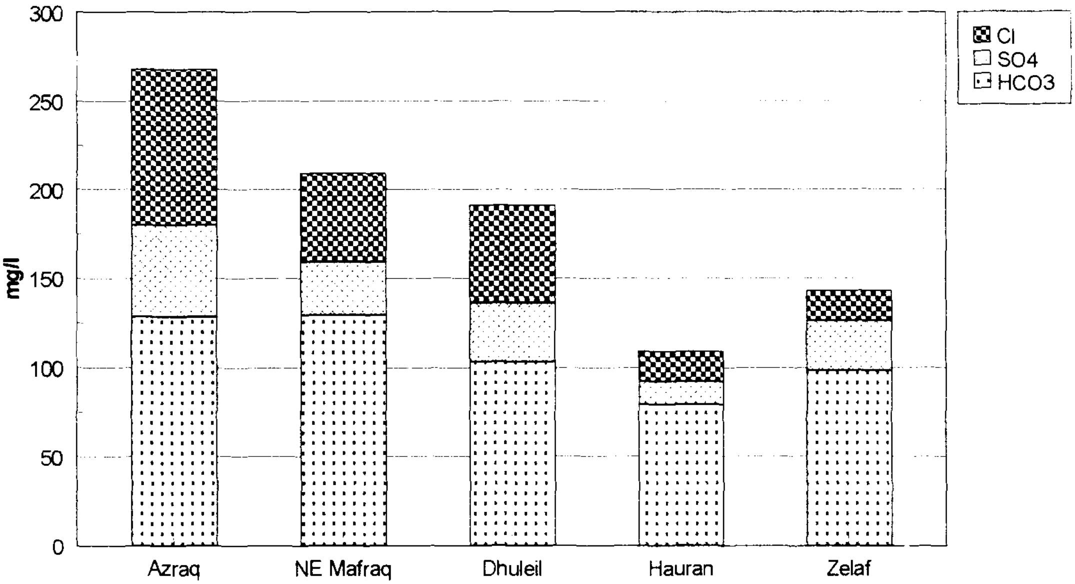


TABLE 3. GENERAL RANGE OF ANION CONCENTRATIONS IN KARSTIFIED CARBONATE AQUIFERS OF THE WESTERN MOUNTAINS AND HIGHLANDS OF JORDAN AND THE SYRIAN ARAB REPUBLIC

	Cl	SO_4	HCO_3
Mesozoic Anti-Lebanon	12-18	2.5-12	123-153
Gypsiferous Mesozoic Anti-Lebanon		29-125	80-146
Cenomanian-Turonian NW Syrian Arab Republic	10-49	4-46	180-400
Jurassic Ansariyeh	10-14	43-570	227-308
Nummulitic Limestone Syrian Arab Republic	11-15	5-10	153-278
Amman-Wadi Sir Jordan	28-50	10-40	180-300

Source: Ponikarov et al. 1967, Bockh et al. 1970, Hobler 1991, Rimawi 1995, ACSAD files.

The relatively high rainfall in the mountain area (mean annual precipitation 400-500 mm) creates a significant amount of groundwater recharge, indicated by numerous, mostly seasonal, springs. The low groundwater salinity can be attributed to short retention periods in siliceous rocks with low geochemical reactivity. In the carbonate-free lithology, only a limited amount of HCO_3 is dissolved through interaction between CO_2 and silica minerals (feldspars). Cation compositions vary from approximately equal proportions of major cations (Ca, Mg, Na+K) in the Syrian part of the basalt area to predominance of Na in the Azraq area. In the direction of groundwater flow towards west and south, groundwater salinities increase to 200-400 mg/l.

3. *Badyie and Hamad*

The hydrogeologic provinces of the Badyie in the Syrian Arab Republic and Jordan and the Hamad region comprise extensive fissured carbonate aquifers: limestones, dolomites, marly limestones and chalk of Cretaceous (Cenomanian-Santonian) and Paleogene (Paleocene-Eocene) age. Groundwater in these aquifers shows the following hydrochemical characteristics (table 4, summarized from ACSAD 1983, Bockh et al. 1970, United Nations 1982, Droubi 1983):

(a) Eocene chalks in the north-western Syrian Arab Republic contain Ca-HCO_3 type water with a total salinity of 200-400 mg/l TDS. The chalks comprise a water table aquifer which is significantly replenished by current recharge;

(b) Groundwater in confined Cretaceous limestone and dolomite aquifers in the north-western Syrian Arab Republic is prevailingly Ca-SO_4 type water with elevated SO_4 concentrations (500-1,300 mg/l) and total salinity up to 3,000 mg/l TDS. The SO_4 content is assumed to originate from a lithogenic source: evaporite layers in Mesozoic rocks in the catchment area;

(c) The Cretaceous and Tertiary fissured carbonate aquifers of the Syrian Arab Republic extend, to some part, over large inland drainage areas situated between the Orontes and Euphrates river basins. In these inland drainage areas, groundwater movement is directed towards closed basins (Sabkhet al Mouh, Jabboul, Matah, Harayeq). In the *sabkha* areas, the carbonate aquifers contain prevailingly Na-Cl-SO_4 type water with a total salinity of up to 8,000 mg/l TDS. The high salinity is caused by enrichment of dissolved substances through evapo-transpiration and dissolution of evaporite layers in Pleistocene basin sediments;

(d) Karstic carbonate aquifers of Cenomanian-Turonian age in the Palmyra area in the central Syrian Arab Republic contain groundwater with a salinity between 900 and 2,500 mg/l TDS (Droubi 1983). In limited areas, in particular at Qaryatein 100 km west of Palmyra and at Arak 30 km east of Palmyra, the karst aquifer comprises groundwater with a salinity of less than 1000 mg/l TDS and the following ranges of anion concentrations (figures 3 and 6):

Cl and SO_4	17-50 mg/l
Na, Ca, Mg	17-70 mg/l
HCO_3	140-270 mg/l

TABLE 4. GENERAL RANGE OF ANION CONCENTRATIONS IN FISSURED CARBONATE AQUIFERS OF THE BADYIE AND HAMAD AREAS

	Cl	SO_4	HCO_3	TDS	Age	Type
Chalk, north-west Syrian Arab Republic	14-41	5-32	140-275	190-400	Modern?	$Ca\text{-}HCO_3$
Up. Cretaceous North Syrian Arab Republic	32-91	25-230	190-400	310-1,300		$Ca\text{-}HCO_3\text{-}SO_4$
Extreme values	520	1,340	340	3,300		$Ca\text{-}SO_4$
Nasriye-Qaryatein	35-7	24-226	116-220	350-450	9,000-25,000	
Ed Daw-Palmyra Qaryatein	24-2,700	48-1,400	116-430	340-3,200	19,000-25,000	
Basin margins	180-440	370-480	110-240	900-1,400	20,000->36,000	
Sawaneh	240-500	250-870	160-350	1,100-2,000	30,000-34,000	
Arak-Soukhne	50-530	130-1,700	67-150	500-2,500	20,000-32,000	$Ca\text{-}Na\text{-}Cl\text{-}SO_4$
Recent groundwater in wadis	150-600	340-1,870	60-150	860-2300	3,800-8,300	
Ed Daw basin flat	660-4,000	130-1,500	120-256	1,900-8,500	6,100-13,600	$Na\text{-}Cl\text{-}SO_4$
Palmyra basin flat	140-2,000	400-1,360	92-256	1,100-4,800	22,000-26,000	$Na\text{-}Cl\text{-}SO_4$
Extreme values, borehole M5	44,500	5,400	460	55,000		
Hamad region Central Hamad region	500-700	500-1,080	127-550	1,500-2,600	23,000-36,000	Na-Cl to Ca-Cl
Et Tenf-Suab	94-350	144-670	146-232	420-1,400	11,000-24,000	
Ruweishid-Muqat	25-67	62-209	262-354	480-868		

Source: ACSAD 1983, Bockh et al. 1970, United Nations 1982, Droubi 1983.

Figure 6a. Cl concentrations in groundwater of the Ed Daw-Palmyra Basin

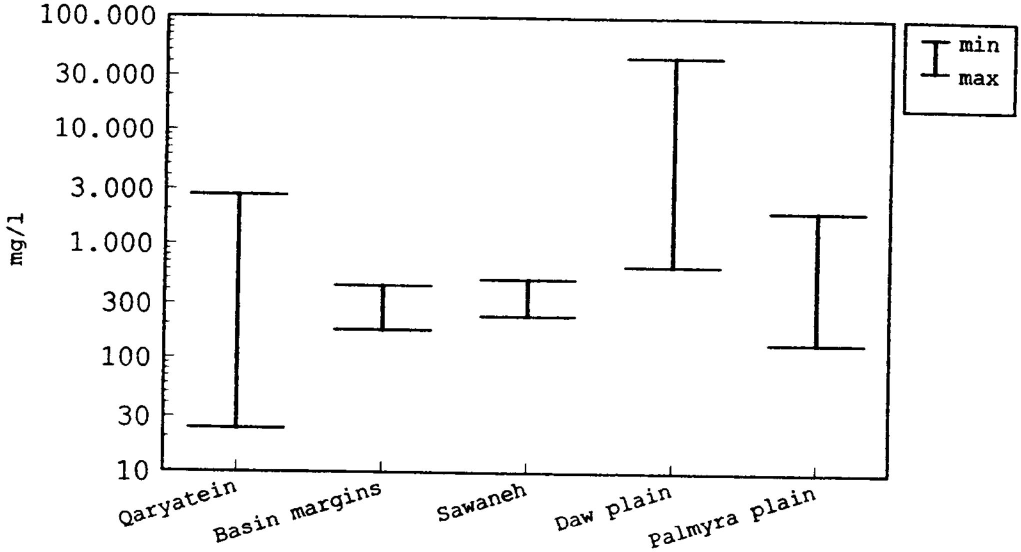
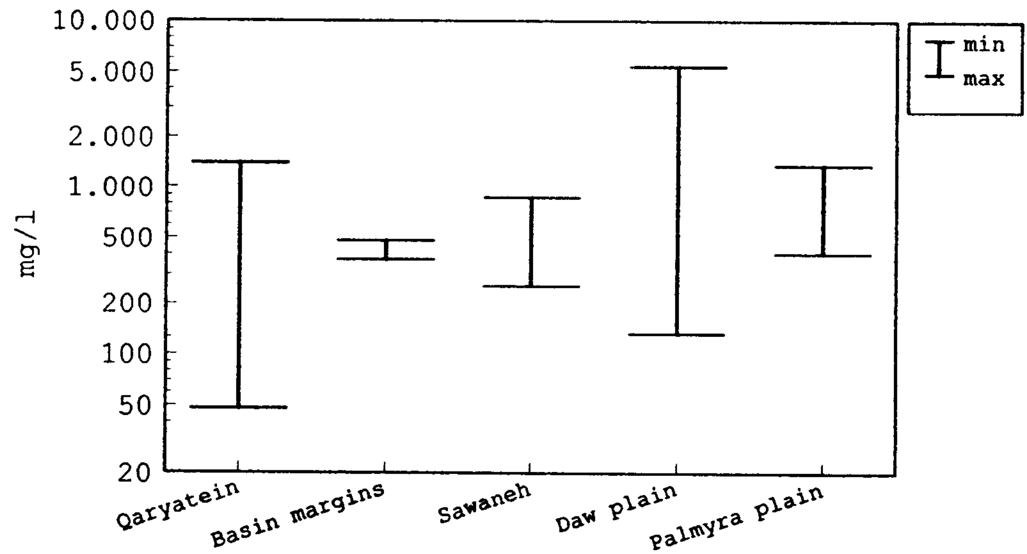


Figure 6b. SO_4 concentrations in groundwater of the Ed Daw-Palmyra Basin



Source: Droubi 1983, ACSAD files.

Groundwater ages are high according to ^{14}C data (20,000 years [Geyh et al. 1994]). The origin of this groundwater has to be sought in recharge events during pluvial periods, while replenishment from present recharge is very low. The low salinity groundwater is obviously related to significant recharge under relatively humid climate conditions. Major ion contents may originate prevailingly from atmospheric inputs and dissolution of rock carbonate under the influence of soil CO_2 with some enrichment of Na and Cl during the recharge process;

(e) The Hamad region comprises a steppe to desert plateau extending from the southern Syrian Arab Republic through north-eastern Jordan and western Iraq into northern Saudi Arabia. The plateau is covered by a sequence of Paleogene to Oligocene limestones, marls, chalk, chert and dolomites, which is underlain by Cretaceous carbonate rocks. The Cretaceous to Tertiary carbonate rock sequence contains a complex fissured aquifer system with generally poor to moderate permeabilities. Groundwater in the central parts of the Hamad region is generally brackish Na-Cl or Ca-Cl type water with Cl and SO_4 concentrations above 500 mg/l. The groundwater is unsuitable for the domestic supply or irrigation but can be used, to some extent, for watering of animals (sheep and camels). Moderate salinities of groundwater, related to indirect recharge in extended wadi systems, are found in the north-eastern to eastern part of the Hamad region (Et Tenf-Sawab area in the Syrian Arab Republic and Iraq, Rutbah area in Iraq) and in the Ruweishid area in the Central Hamad region in Jordan. The groundwater with relatively low salinity in wadi aquifers is generally related to present indirect recharge: infiltration of seasonal or ephemeral wadi run-off. Cl and SO_4 concentrations can be attributed to contents of rainwater concentrated to varying degrees by evapo-transpiration at or near the surface. HCO_3 concentration originate principally from interaction of soil CO_2 with carbonates or silicate minerals.

4. *Sandstone area in Jordan and Saudi Arabia*
(Hobler et al. 1991, ACSAD 1983, Lloyd and Pim 1990, El Naser and Gedeon 1995)

In Paleozoic sandstone aquifers, groundwater with low salinity occurs within and near the outcrop areas of the sandstones, which extend, adjacent to the Precambrian basement of the Arabian Shield, from southern Jordan into the Tabuk, Hail-Buraydah and Wadi Dawasir areas in Saudi Arabia.

The concentrations of Cl and SO_4 are in the range of 20-70 mg/l and not much higher than concentrations in present rainfall (table 5, figure 3). Cl and SO_4 contents probably originate mainly from atmospheric inputs somewhat concentrated through evaporation at or near the surface during the recharge process. HCO_3 concentrations, ranging around 100-130 mg/l, are related, apart from limited atmospheric inputs, to interaction of soil CO_2 with silica minerals or carbonate cement.

The groundwater with low salinity in the Paleozoic sandstone aquifers is attributed to significant past recharge during periods between 10,000 and 30,000 years BP (Lloyd and Pim 1990).

TABLE 5. GENERAL RANGE OF ANION CONCENTRATIONS IN SANDSTONE IN JORDAN AND SAUDI ARABIA

	Cl	SO_4	HCO_3	TDS	
Disi, Jordan	23-43	14-31	80-130	200-250	
Kurnub, Baqqa	32-52	13-24	234-267		535-581
Al Jawf	31-55	48-77	127-139		335-500
Saq, Tabuk	12-137	9-76	37-155		480-840
Wasia, Khureis	170	130	128	602	

Source: Hobler et al. 1991, ACSAD 1983, Lloyd and Pim 1990, Rimawi 1985.

5. *Carbonate aquifers in Saudi Arabia and the Gulf area*

In eastern Saudi Arabia, fissured and karstified carbonate rocks of Upper Cretaceous to Tertiary age form a complex aquifer system comprising aquiferous sections within the Cretaceous Aruma formation, the Tertiary Umm er Radhuma, Rus and Dammam formations and Neogene deposits. It is assumed that the Umm er Radhuma aquifer contains the main quantity of groundwater circulation within this aquifer system and is nourishing most of the natural artesian groundwater outflows in the eastern provinces of Saudi Arabia. The aquifer system receives some recent recharge in the outcrop areas of the Umm er Radhuma Formation, from which groundwater moves in a general eastward to north-eastward direction towards the Euphrates-Gulf depression. At present, large quantities of groundwater are extracted from the aquifer system through boreholes in oasis areas of eastern Saudi Arabia. The Umm er Radhuma Formation constitutes one of Saudi Arabia's most important aquifers. It consists of Paleocene-Eocene limestones and dolomites, which crop out in a 50- to 70-km-wide strip extending in a north-south direction over nearly 1,000 km from the western desert of Iraq through central Saudi Arabia and into Yemen and Oman.

The occurrence of groundwater with a salinity of 380 and 430 mg/l TDS from areas at or near the outcrop of the Umm er Radhuma Formation in Wadi Miyah and Wadi al Batin was reported by Othun (1975). The groundwater salinity generally increases eastward in the direction of the regional groundwater flow, but groundwater with a moderate salinity of 1,500 mg/l TDS is found as far as 200 km east of the outcrop in the Hofuf area (table 6, Bakiewicz et al. 1982). The Umm er Radhuma

Formation constitutes, in the regions downstream of its outcrop, a component of a complex aquifer system of fissured carbonate rocks of the Cretaceous to Tertiary period. It is assumed that the Umm er Radhuma Formation contains the main quantity of groundwater circulating in this aquifer system. The hydrochemical composition of the groundwater changes from bicarbonate near the Umm er Radhuma outcrop area further downstream to calcium sulphate and sodium chloride with increasing salinity. The salinity increase is probably caused by dissolution of evaporite layers in particular in the Rus Formation overlying the Umm er Radhuma Formation (Bakiewicz et al. 1982). The age of the groundwater in the Umm er Radhuma Formation is estimated at 15,000 to 19,000 years (Otkun 1975).

TABLE 6. GENERAL RANGE OF ANION CONCENTRATIONS OF GROUNDWATER FROM THE TERTIARY AQUIFER COMPLEX IN OASES OF EASTERN SAUDI ARABIA

	Cl	SO_4	HCO_3
Al Qatif	570-1,500	430-620	170-195
Hassa	375-500	293-326	186-230
W. el Hiyah	284-1,000	500-780	152-180
Haradh	236-404	216-264	159-183

Source: Jado and Zotl 1984.

Present significant indirect recharge occurs as inflow of surface run-off into karst cavities in the outcrop area of the Umm er Radhuma Formation (Al-Saafin et al. 1990). This actual recharge produces groundwater with a salinity between 1,200 and 1,900 mg/l TDS, the dominant ions being Ca, Na, SO_4 and Cl. The hydrochemical composition of present recharge appears to be different from the composition of fossil groundwater.

Water with varying salt content occurs regionally as well as vertically owing to differences in the geochemical composition of the rock material. Interspersed evaporite layers may account for the exceptionally high water mineralization at some depths. The general pattern and trends of groundwater salinity and hydrochemistry in the carbonate aquifer complex in eastern Saudi Arabia and the Gulf area has been described in a number of reports and publications, e.g. Sen and Al-Dakheel (1986), Pike (1985), FAO (1980), Lloyd et al. (1980), Abderrahman (1990).

6. *Arabian Shield*
(Al-Sayari and Zotl 1978, Lloyd et al. 1980,
Memon et al. 1984, Kotb et al. 1990)

The Arabian Shield, which is composed of Precambrian crystalline and metamorphic rocks, extends over around 770,000 km^2 from southern Jordan over western Saudi Arabia into Yemen. In the northern and western parts of the Shield, average annual rainfall is as low as 50-100 mm. The mountain regions extending parallel to the coast of the Red Sea and the Gulf of Aden in the south-east of the Arabian Peninsula receive more abundant rainfall during the winter and monsoon seasons in December-January and April-May, respectively, averaging around 400 mm per year.

The crystalline rocks of the Shield are, in general, very poor aquifers. The main groundwater resources are contained in alluvial wadi fills, which are recharged primarily through infiltration of run-off during flood flows. The width of major wadis varies from several hundred metres to a few kilometres and the thickness of wadi sediments ranges from a few metres up to about 100 m. The wadi systems on the western slope of the Arabian Shield—west of the water divide—merge into the Red Sea coastal plain (Tihama); the wadi systems directed eastwards or north-eastwards form extensive alluvial fans on the area of the Arabian Shelf. The salinity of groundwater in the alluvial wadi aquifers ranges from 450 mg/l up to 10,000 mg/l.

Generally, the groundwater salinity is low in the upper wadi courses (<1,000 mg/l), where flooding from sporadic rainfall is more frequent than further downstream and which accordingly comprise the major recharge areas of the wadi aquifers. A general increase in groundwater salinity from the upper course towards the lower reaches is observed in most wadi systems, but high local variations of groundwater salinity occur.

Most groundwater in the wadi aquifers are of Na-Cl type. In some wadis, a central freshwater zone of Ca-HCO_3 type is indicated, with higher salinity groundwater of Na-SO_4 type occurring on the edges of the major alluvial thickness (Lloyd et al. 1980).

Wadi systems in the hinterland of Jeddah, directed towards the Red Sea coast (Wadi Khulays, Wadi Usfan and Wadi Fatimah - Wadi Naman) contain extensive aquiferous alluvial covers in parts of their courses. Groundwater salinity in these wadi aquifers ranges from 300-7,500 mg/l (figure 3) and different types of hydrochemical composition prevail in different wadi courses, apparently related to the prevailing lithology of rock outcrops in the catchment area and enrichment by evaporation: Na-Cl type groundwater with moderate salinity to high salinity Na-Cl type groundwater. The elevated salinity may be attributed to dissolution of evaporite layers, evaporative enrichment in *sabkha* areas and impacts of irrigation return flow (Al-Sayari and Zotl 1978).

7. *Coastal areas*

Coastal plains in Western Asia comprise important agricultural areas and a number of urban centres. Coastal plains with irrigated agriculture extend, in particular, along the shores of:

(a) The Mediterranean Sea in the Syrian Arab Republic, Lebanon and the Gaza Strip;

(b) The Red Sea in Saudi Arabia and Yemen;

(c) The Gulf of Oman in Oman and the United Arab Emirates.

The total area irrigated through groundwater extraction in these coastal areas is estimated for 1993 at 170,000 ha (Al-Rifai 1993).

Productive coastal aquifers are composed, in particular, of:

(a) Unconsolidated fluvial or marine sediments of prevailingly Quaternary period, which are recharged mainly through infiltration of flood run-off in wadis entering the coastal plains from their mountainous hinterland;

(b) Carbonate rocks of various ages (Paleozoic to Cretaceous, Middle Cretaceous, Tertiary), which are recharged from rainfall in mountainous catchment areas or which contain fossil groundwater.

Local freshwater lenses sustained by recent recharge occur in permeable formations in some areas of the Gulf coast. Intensive exploitation of groundwater from coastal aquifers, particularly for irrigation, has created widespread problems of declining groundwater levels, depletion of aquifers and salt-water intrusion. The abstraction of groundwater in many coastal plains is several times higher than the present recharge. A large part of the fossil as well as presently renewed groundwater resources in coastal plains is subjected to heavy overexploitation.

Published information on groundwater quality and hydrochemistry in coastal areas on the Mediterranean Sea and the Red Sea can be summarized as follows:

(a) Mediterranean Sea coast (Khair et al. 1992, United Nations 1982, UNDP 1970, Selkhozpromexport 1974): In the coastal plain extending between the Mediterranean Sea coast and the Ansariyeh and Lebanon Mountains in the Syrian Arab Republic and Lebanon, Cenomanian-Turonian limestones and dolomites and, along parts of the Lebanese coast, Eocene-Miocene limestones and dolomites constitute productive aquifers. The carbonate aquifers are, in some areas, overlain by aquiferous Neogene basalts and Neogene-Quaternary sediments. The Cenomanian-Turonian aquifers receive recharge in the sub-humid mountainous hinterland of the coast, the coastal areas acting as major groundwater discharge areas with important springs. The hydrochemical composition in the carbonate aquifers mentioned is characterized by low to moderate salinity and Ca-HCO_3 or Ca-Mg-HCO_3 type water. Directly along the Lebanese coast, Cl type groundwater with slightly elevated salinity indicates an influence of sea-water intrusion. Because of recent intensification of groundwater abstraction in coastal areas of Lebanon, particularly in the Beirut area, extensive areas have been affected by sea-water intrusion. According to Khair et al. (1992), average Cl concentrations in wells in coastal areas of Lebanon rose from 340 mg/l in 1970-1971 to 4,270 mg/l in 1985.

(b) On the Syrian coast, sea-water intrusion has occurred in the Lattakia area and at Hamidiyeh (southern part of the Syrian coast). In the aquifer system of the coastal Akkar plain in the Syrian Arab Republic and Lebanon, which is composed of Cenomanian-Turonian limestones and Quaternary alluvial deposits, groundwater salinity ranges from 100 to 600 mg/l TDS and increases towards the coast to >1,000 mg/l (Agrocomplect 1989, United Nations 1982:102). Well fields near the sea coast may be endangered by salt-water intrusion.

(c) The Gaza Strip comprises a 45-km-long and 5- to 8-km-wide section of the coastal plain. Aquiferous sediments comprise littoral calcareous sands and sandstones. Mean annual rainfall ranges from 300 to 600 mm. Indirect recharge may occur from run-off in three ephemeral streams (Khor Zannoon, Wadi Gaza, Wadi El-Salqah). According to a survey of groundwater quality in the Gaza Strip made in 1967 (El-Nakhal and Himidah 1980), total salinity ranges from 300 to 4,570 mg/l TDS with concentrations of Na between 15 and 125 mg/l and of Cl between 22 and 1,860 mg/l. The groundwater quality of 40% of the samples was adequate for the domestic supply and irrigation; 60% of the samples were unsuitable for the domestic supply and doubtful to unsuitable for irrigation because of elevated salinity. A more recent survey (Zarour et al. 1993) showed that groundwater quality in only 2 of 15 sampled wells was adequate for the domestic supply. The sources of elevated groundwater salinity are assumed to be: movement of saline groundwater from the east and sea-water intrusion, mixing with deeper saline water (WRAP 1994).

(d) The Red Sea coastal plains of Jordan, Saudi Arabia and Yemen receive less than 100 mm of mean annual rainfall. Direct recharge of the aquifers composed of unconsolidated coastal sediments is therefore very limited, indirect recharge is concentrated in narrow strips along wadis receiving ephemeral run-off from the mountainous hinterland where, in particular in south-western Saudi Arabia and in southern Yemen, heavier rainfall occurs.

For the Tihama Quaternary aquifer system of the Wadi Surdud area in Yemen the following hydrogeological conception has been given (van der Gun et al. 1992):

(a) The aquifer system is composed of more or less fan-shaped "groundwater flow domains";

(b) The groundwater flow domains include: recharge zones along streams in the eastern (upper) part of the Tihama, discharge zones in the eastern (lower) part of the Tihama, where natural groundwater discharge occurs through evaporation from salt flats or as submarine outflow, an aquifer zone connecting recharge and discharge zones;

(c) Between the groundwater flow domains, groundwater is almost stagnant;

(d) From relatively narrow recharge zones along stream beds, groundwater flow expands laterally in the more pervious eolian sediments further west into a practically continuous discharge zone at the coast.

The freshwater-bearing Quaternary sedimentary complex reaches a thickness of 200-300 m. Groundwater salinity rises from 400 mg/l TDS in the recharge zones to >2,000 mg/l towards the coast. Near the coast, a "sea-water intrusion wedge" has developed.

Similar hydrochmical conditions exist in the coastal aquifer of the Jizan Plain in Saudi Arabia (Al-Sayari and Zotl 1978): the coastal aquifer contains highly saline groundwater which is overlain by freshwater in channel-like systems analogous to the present drainage pattern and to former wadi systems. The maximum thickness of fresh groundwater is more than 100 m in some wadi areas. Water from surface run-off in wadis has, in general, an electrical conductivity of 300-700 μS/cm and is of $Ca\text{-}HCO_3$ type with relatively high SO_4 concentrations. Groundwater with low electrical conductivity and with a hydrochemical composition similar to surface run-off is found near the wadis and in the foothill areas. With distance from the recharge areas in the foothill wadi areas, groundwater salinity increases up to 4,800 mg/l TDS and the hydrochemical type of the groundwater changes from $Ca\text{-}HCO_3$ to $Na\text{-}HCO_3$ and Na-Cl.

Elevated salinity in the shallow groundwater of the Red Sea coastal plains is attributed to: sea-water intrusion; irrigation return flow; brines ascending in the coastal plain; evaporation in coastal *sabkhas*; and leaching of salt from evaporitic deposits.

C. Main sources of groundwater salinity and groundwater quality deterioration in the ESCWA region

The major quality constraint of groundwater use in Western Asia is its naturally high salinity in wide parts of the region. In the semi-arid to arid zones which predominate in Western Asia, dilution of groundwater with fresh recharge is very limited, and the groundwater salinity is elevated from lithogenic sources and from enrichment of dissolved substances through evaporation.

In addition to these natural groundwater salinity problems, the groundwater quality is threatened in many areas by human activities (table 7). The following activities may be considered major sources of groundwater quality deterioration in Western Asia:

TABLE 7. MAIN SUBSTANCES INTRODUCED INTO GROUNDWATER THROUGH CONTAMINATION FROM THE SURFACE

Source of input	Substances
Irrigation return flow	Cl, SO_4, HCO_3, cations, residues of fertilizers and pesticides
Domestic sewage, untreated disposal or improper disposal of sewerage	N compounds, Cl, SO_4, boron, biological contaminants
Industrial wastewater, untreated release	Major constituents, trace metals, organic contaminants
Leachate of solid waste disposal	As domestic or industrial sewage, depending on the type of waste

(a) Over-exploitation of freshwater aquifers can result in intrusion of brackish water contained in parts of the exploited aquifer or in adjacent aquifers. Increasing salinity may affect any type of groundwater use. Particular hazards of intrusion of brackish or saline water into exploited freshwater aquifers have to be expected in coastal aquifers, in wadi aquifers receiving limited present recharge, and in aquifers with depleting fossil groundwater. The adverse effects of aquifer overexploitation are generally well known (Simmers et al. 1992). Evident problems resulting from overexploitation of aquifers in coastal areas are:

(i) Lowering of groundwater levels and reduction of well yields, with an adverse impact on the cost/benefit ratio of groundwater use for irrigation;

(ii) Deterioration of groundwater quality through intrusion of brackish or saline water induced from the lowering of hydraulic heads in freshwater aquifers;

(b) Infiltration of domestic sewage from unsewered sanitation, leaking sewers or sewage oxidation lagoons can create severe contamination of water supply wells or springs, particularly through contents of bacteria and viruses and elevated N compounds. N contents may exceed drinking water standards in extended parts of affected aquifers. An increase of total salinity and of major ion concentrations, such as Cl and SO_4, caused by sewage contamination may affect the suitability of groundwater use for various purposes. Elevated NO_3 contents in groundwater from shallow aquifers are reported from many locations in Jordan, Lebanon, the Syrian Arab Republic and the Gaza Strip (Bockh et al. 1970, UNDP 1970, Rimawi 1985, Selkhozpromexport 1974);

(c) Irrigation return flow can create an ongoing increase in the salinity of groundwater, affecting its ability to be used for irrigation. Additionally, residues of fertilizers and pesticides in irrigation return flow can endanger drinking-water quality;

(d) Infiltration of untreated industrial wastewater can increase concentrations of various substances above drinking-water quality values: total salinity, major constituents, organic compounds and trace metals. A substantive increase of total salinity and major constituents can also adversely affect the suitability of the groundwater for other uses, e.g. for industrial activities. Trace metals, usually contained in industrial waste- waters, can be adsorbed to a considerable amount in the unsaturated zone; the specific hazard of trace metal contamination of groundwater depends, apart from the contaminant load, on the local hydrogeological conditions. A particular threat to water quality stems from the extensive use of organic solvents (chlorinated hydrocarbons) in modern industrial activities. Recommended maximum concentrations of chlorinated solvents are according to WHO guidelines, e g. 30 μg/l for trichloroethylene and 10 μg/l for perchloroethylene. The low guideline levels of these substances are based on their carcinogenic effects. The chlorinated solvents have a relatively low solubility in water. Contaminations of chlorinated solvents remain therefore in the subsurface mainly in an immiscible phase which has a higher density than water and can therefore penetrate into deeper parts of aquifers, even against upward hydraulic pressure. The solvents can accumulate on top of low-permeability layers and can, since they are very persistent, remain there as long-term contaminants;

(e) Solid waste disposal is an important source of subsurface contaminant load. If waste disposal sites are properly located, constructed and managed, the subsurface contaminant load is likely to be small in volume and low in hazard, unless very hazardous wastes are involved. The actual contamination hazard depends on local factors: the composition of the leachate, the technical construction of the disposal site and the hydrogeological conditions.

D. CONSERVATION OF WATER QUALITY IN EXPLOITED OR EXPLOITABLE AQUIFERS

1. *General considerations*

In order to develop a policy to maintain the groundwater quality in exploited aquifers in the ESCWA region, the following specific regional conditions of groundwater occurrence and groundwater use have to be considered:

(a) Resources of fresh groundwater are restricted to areas with favourable climate conditions and to very limited areas in the dry parts of the region;

(b) A high percentage of the extracted groundwater is used for irrigation (70% to 80% in some countries), and domestic use accounts for up to 25% of total water use in individual States.

(c) Depth-to-groundwater is considerable in wide areas. Significant hazards of groundwater contamination are, under the prevailing climatic conditions, restricted to limited areas: (i) uncovered karst aquifers in semi-humid zones with intensive land use; and (ii) areas where localized groundwater recharge is elevated by natural or man-made reasons (wadis with significant run-off, irrigations areas, and areas where domestic or industrial sewage waters infiltrate into the subsurface);

(d) If contaminants have reached the groundwater, the effects of flushing or dilution of the contaminants by current freshwater recharge are generally low.

In the ESCWA region, groundwater is used primarily for the domestic water supply and for irrigation, agricultural and industrial activities. In view of the sensitivity of drinking-water supplies to water quality changes and the vital importance of safe drinking-water, the first priority for groundwater quality conservation has to be attributed to resources used for the domestic supply:

(a) Wells or springs used for the central piped water supply;

(b) Wells or springs used for the local supply, e.g. in villages;

(c) Groundwater occurrences with drinking-water quality which are potential sources for future domestic supply.

In aquifers exploited for irrigation, acceptable levels of total salinity and Na contents have to be maintained. The industrial water supply generally requires low to moderate levels of total salinity, Cl and hardness (concentration of earth alkaline cations, HCO_3 and SO_4).

Groundwater quality protection policies in the ESCWA member countries should include:

(a) Technical measures to prevent intrusion of brackish or saline water;

(b) Establishment of protection zones to avoid contamination of drinking-water supplies from the surface;

(c) Investigations to obtain the necessary information on hydrogeological and hydrochemical conditions and possible contamination sources;

(d) Groundwater quality monitoring.

2. *Protection against intrusion of brackish or saline water*

Prevention of intrusion of water with higher salinity into freshwater aquifers requires the maintenance of a hydraulic equilibrium between exploited freshwater and brackish saline water which may intrude from adjacent aquiferous horizons or aquifers or from surface-water bodies (saline lakes, *sabkhas* or sea water). Very few technical options are available to prevent the intrusion of the naturally occurring saline or brackish water. Possible measures are part of a groundwater management policy through which overexploitation of aquifers, which leads to aquifer depletion and/or groundwater quality deterioration, is avoided. In many cases, safe groundwater management will require a drastic reduction of groundwater abstraction in areas endangered by salt-water intrusion, an option which is generally not appreciated by groundwater users.

The following measures may, to a limited extent, reduce the dangers of salt-water intrusion into endangered freshwater aquifers:

(a) Optimization of the distribution and the depth of extraction wells. This can generally be achieved only if a detailed knowledge of the hydrogeologic, hydraulic and hydrochemical conditions is available. An efficient design of well fields may have to be supported by groundwater simulation modelling (van der Gun 1992);

(b) Optimization of groundwater extraction may include pumping of brackish or salt water in order to maintain the freshwater-salt water equilibrium. Extraction and desalination of brackish water may be considered under certain hydrogeological conditions. The high costs involved may be balanced by:

(i) A reduction of dangers of intrustion of brackish water into freshwater aquifers;

(ii) Provision of desalinated water;

Efficient hydrologic and economic management of groundwater exploitation and groundwater use will, however, be necessary;

(c) Increase of recharge through artificial infiltration of surface water run-off, e.g. through wadi dams. Wadi dams have been constructed in many parts of Western Asia with the aim of preventing surface run-off into the sea or into depressions where the surface water is, to a large extent, lost by evaporation and, at the same time, to increase the quantity of groundwater recharge. It is highly recommendable to make an overall assessment of the benefits obtainable by this technology, considering investments, technical design, accompanying investigations and quantities of induced recharge;

(d) Build-up of hydraulic barriers to avoid salt-water intrusion. Artificial hydraulic barriers may be considered, in particular, to counteract imminent sea-water intrusion. A major constraint to this technology in Western Asia is the non-availability of the necessary quantities of water which have to be infiltrated. A promising option in some areas may be the infiltration of treated wastewater in coastal areas. This may be feasible if:

(i) Considerable quantities of wastewater with low to moderate salinity are available;

(ii) The hydrogeologic situation allows a cost-efficient infiltration of significant quantities of water in the area of the salt water/freshwater interface, e.g. through infiltration trenches;

Detailed knowledge of hydrogeologic, hydraulic and hydrochemical conditions and supporting groundwater simulation modelling is, in general, required for the design of such measures.

3. *Protection against contamination from the surface*

(a) *Protection of wells (boreholes) used for central water supply*

To design an efficient protection system for production boreholes used for the central water supply, the conception of groundwater protection zones commonly applied in European countries may be adopted with modifications as required according to the regional and local conditions.

The conception of protecting drinking-water sources (boreholes or springs) generally has three categories of groundwater protection (van Waegeningh 1985, DVGW 1975, Adams and Foster 1991):

(a) Protection of water supply wells against direct contamination (immediate protection zone, operational courtyard);

(b) Protection of water supply wells against degradable contaminants, particularly bacteria and viruses (inner protection zone);

(c) Protection of the catchment area of water supply wells against non-degradable and persistent contaminations (outer protection zone).

According to the specific protection requirements of the immediate, inner and outer protection zones, different restrictions on land use apply in each of these zones.

(b) *Protection of local water supply sources (shallow wells, springs, boreholes)*

For local water supply sources, which may consist of single or several supply points with or without a distribution network, the same protection requirements apply, in principle, as for central water supply wells. However, strict protection measures may not be practicable in many locations, and minimum protection requirements have to be defined. The following minimum precautions should be considered:

(a) Protection of water supply sources against direct contamination through adequate well design or spring capturing and delimitation of an operational courtyard;

(b) Abandoning water from shallow wells or springs located within larger settlements and replacing it with wells upstream of the inhabited areas;

(c) Maintaining minimum distances between water supply sources and adsorption pits or other facilities of sewage infiltration;

(d) Limitation of application of fertilizers and pesticides around water supply sources located within irrigation areas.

(c) *Protection of water quality in aquifers potentially used for the water supply*

Most of the important aquifers in Western Asia are intensively exploited. Unused groundwater occurrences, which may provide resources for the future water supply, are limited. Future domestic supplies may, however, rely on groundwater resources which are, at present, used primarily for irrigation. In order to maintain adequate water quality for the domestic supply in vulnerable aquifers within irrigation areas, control and management of groundwater extraction and of land use is required. The main tasks involved are:

(a) Avoiding an increase in salinity and major ion concentrations, which affect the suitability of water use for the domestic supply and irrigation;

(b) Avoiding the introduction of residues of fertilizers and pesticides which may render the water quality inadequate for domestic use.

The danger of increased groundwater salinity in irrigation areas can be reduced through optimization of irrigation practices. No reliable information is available on the impact of fertilizer and pesticide use on groundwater quality for the specific conditions of Western Asia. It appears recommendable to assess related contamination risks through research studies in pilot areas. Particular hazards of groundwater contamination can occur where untreated wastewater is used for irrigation above vulnerable aquifers.

4. *Investigations*

In order to design appropriate measures to maintain groundwater quality that is threatened by salt-water intrusion or contamination from the surface, adequate information on hydrogeological and hydrochemical conditions and possible contamination sources is required. This information must generally include:

(a) Natural groundwater quality and the current state of groundwater quality;

(b) Distribution of groundwater salinity within aquifers or aquifer systems;

(c) Temporal variations of groundwater quality;

(d) Groundwater flow conditions, hydraulic conditions and interrelations between different aquifers.

The following basic information may additionally be required:

(a) For aquifers endangered by salt-water intrusion: quantitative assessments of exploitable groundwater and of groundwater extraction;

(b) For aquifers endangered by contamination from the surface: assessment of land use with particular attention to hazardous activities.

The required information on groundwater quality can be obtained from:

(a) Groundwater quality records, where available;

(b) Surveys of groundwater salinity and hydrochemistry using existing sampling points: shallow wells, springs and boreholes;

(c) Drilling and sampling of investigation boreholes;

(d) Monitoring of groundwater quality at existing observation points or especially constructed observation wells.

5. *Groundwater quality monitoring*

Groundwater quality monitoring is an essential tool for the conservation of the quality of groundwater resources. The main tasks of groundwater quality monitoring in Western Asia will probably be:

(a) The control of intrusion of brackish or saline water into exploited aquifers;

(b) Observation of contamination of vulnerable aquifers through human activities, such as waste disposal or irrigation agriculture.

Accordingly, monitoring networks will generally have to be designed for limited areas where specific problems of groundwater quality are expected. Monitoring programmes may be based on sampling of existing production boreholes, grab sampling from non-pumped wells or the installation of purpose-drilled monitoring boreholes. The type of sampling, parameters to be determined and the spacing of monitoring points has to be defined individually for each monitoring area according to the specific objective, hydrogeological conditions as well as available technical facilities. Programmes for groundwater quality monitoring have been established to a wide extent in Europe and North America. Guidelines and recommendations have also been formulated for groundwater quality monitoring in countries of Latin America (Fosters and Gomes 1989) and the ESCAP region (Bangkok action plan for regional groundwater quality, ESCAP 1991).

The Bangkok Action Plan includes the following recommendations regarding groundwater quality monitoring:

> "The main objective of groundwater quality monitoring is the identification of groundwater quality problems which include coastal saline intrusion, and man-made point source and diffuse source contamination. It is necessary to assess the seriousness and impact on health and the environment, and the economic losses from groundwater contamination. Baseline data are required to define the existing situation and continuous monitoring is needed to assess trends."

The Bangkok Action Plan calls for training of personnel, cooperation among neighbouring countries and applied research in priority topics (ESCAP 1991:6).

The guidelines for Latin American countries include more technical conclusions. The main objectives of groundwater quality monitoring are:

(a) "To provide an early warning of the onset of aquifer contamination or pollution threat to water supply boreholes, or to define the precise distribution of contaminants in an already-polluted aquifer;"

(b) "The surveillance of potable water-supply quality."

> "Traditional methods, such as sampling production borehole discharge or grab sampling from non-pumped boreholes, will often have severe limitations."

> "Many improved sampling techniques have now been developed... but these can be expensive and require importation" (foreign exchange).

> "The necessity for hydrogeological expertise, and for understanding the groundwater flow regime, in the design of monitoring networks and the interpretation and application of monitoring results cannot be overemphasized" (Foster and Gomes 1989:96).

The formulation of general guidelines for groundwater quality monitoring with specific consideration of the conditions of the ESCWA region appears highly recommendable.

REFERENCES*

Abderrahman, W. A., 1990: Effect of groundwater use on the Chemistry of spring water in Al-Hassa oasis. King Abdulaziz Univ. Earth Sci., 3:259-265, Jeddah.

ACSAD, 1983: Studies of the Hamad Basin, Part 1, App. 4 Groundwater Resources. Rep. ACSAD, Damascus (Arabic).

Adams, B. and S.S.D. Foster, 1991: Land surface zoning for groundwater protection, Annual Sympos., 1991. Groundwater pollution and aquifer protection in Europe, Inst. Water Environmental Protection, Paris.

Agrocomplect, 1984-1985: Study and complete design works for the integral development of the Syrian Akkar plain and Bekaa area. Rep. Agrocomplect - Syrian Arab Republic Dir. Land Reclamation, Sofia.

Al-Awadi, A., and A. Mukhopadhyay, 1995: Hydrogeology of the Dammam formation of the Gudair area, Kuwait. Sultanate of Oman Internat. Conf. Water Resources Management in Arid Countries: 428-435, Muscat.

Almomani, M., 1995: Environmental isotope and hydrochemical study of the shallow and deep groundwater in the Azraq basin, Jordan. Internat. Atomic Energy Agency, Isotope Hydrol. Middle East, Vienna.

Al-Rifai, N., 1993: Problem of sea-water intrusion into groundwater coastal aquifers in 10 selected countries of the Near (and Middle) East. FAO Expert consultation sea-water intrusion into coastal aquifers in the Mediterranean Basin and the Near East, Cairo.

Al-Saafin, A.K., T.A. Bader, W. Shehata, H. Hoetzl, S. Wohnlich, and J.G. Zötl, 1990: Groundwater recharge in an arid karst area in Saudi Arabia. Internat. Assoc. Hydrogeol. Selected Pap. Hydrogeol., 1:29-42, Hannover.

Al-Sayari, S.S., and J.G. Zötl (eds.), 1978: Quaternary period in Saudi Arabia, 1: Sedimentological, hydrogeological, hydrochemical, geomorphological and climatological investigations in central and eastern Saudi Arabia, Vienna, New York.

Appelo, C.A.J., and D. Postma, 1993: Geochemistry, groundwater and pollution. Rotterdam.

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* Issued as submitted.

Ashour, M.M., 1985: Study on the changes in the groundwater quality in Gaza Strip. Proc. Second Jordanian Geol. Conf.: 511-530, Amman.

Bakiewicz, W., D.M. Milne, and M. Noori, 1982: Hydrogeology of the Umm Er Radhuma aquifer, Saudi Arabia, with reference to fossil gradients. Quat. Journ. Eng. Geol. London, 15:105-126, London.

Bockh, E. et al. 1970: German geological mission in Syria. Hydrogeological results. Rep. Federal Institute for Geosciences and Natural Resources, Hannover.

Droubi, A., 1983: Study of water resources in the Daw Basin, Part 2, Chapter 6, Hydrochemistry. Rep. ACSAD, Damascus (Arabic).

DVGW, 1975: Richtlinien für Trinkwasserschutzzgebiete, 1. Teil, Schutzgebiete für Grundwasser. Deutscher Verein von Gas- und Wasserfachmännern, Technische Regeln Arbeitsblatt W101, Eschborn.

El Naser, H., and R. Gedeon, 1995: Hydrochemistry and isotopic composition of the Nubian sandstone aquifers of Disi-Mudawwara area/South Jordan. Internat. Atomic Energy Agency, Isotope Hydrol. Middle East, Vienna.

El-Nakhal, H.A.H., and I.H. Himida, 1980: Evaluation of the groundwater quality in the Gaza Strip, Palestine. First Arab Sympos. Water Resources, 2:29-42, ACSAD, Damascus.

ESCAP, 1991: Groundwater quality and monitoring in Asia and the Pacific. United Nations Economic and Social Commission for Asia and the Pacific, Water Resources Series, 70, Bangkok.

FAO, 1979: Survey and evaluation of available data on shared water resources in the Gulf States and the Arabian Peninsula. Food and Agriculture Organization of the United Nations, Rome.

Foster, S., and D.D. Gomes, 1989: Groundwater quality monitoring. CEPIS-ODA BGS-WHO HPE, Lima.

Foster, S.S.D., 1985: Groundwater pollution protection in developing countries. International Contributions to Hydrogeology, 6:167-200, IAH, Hannover.

Geyh, M., H. Bender, R. Rajab, and W. Wagner, 1994: Application of ^{14}C groundwater dating to non-steady systems. Proceedings Internat. Assoc. Hydrol. Sciences, Vienna.

Geyh, M., J. Khouri, R. Rajab, and W. Wagner, 1985: Environmental isotope study in the Hamad region. Geologisches Jahrbuch, C38:3-15, Hannover.

GTZ and NRA, 1977: National Water Master Plan of Jordan. Rep. Agrar- und Hydrotechnik and Federal Institute for Geosciences and Natural Resources, Hannover, Frankfurt, Amman.

Gun, J. van der, W. Elderhorst, and G. Kruseman, 1992: Predicting the long-term impacts of groundwater abstraction from an intensively exploited coastal aquifer. Selected papers on aquifer overexploitation, Internat. Assoc. Hydrogeol. Hydrogeology Selected Papers, 3:303-318, Hannover.

Hobler, M. et al. 1991: Groundwater resources of southern Jordan, vol.1. Rep. Federal Institute for Geosciences and Natural Resources, Hannover.

Jado, A.R., and J.G. Zötl, 1984: Quaternary period in Saudi Arabia, vol. 2: Sedimentological, hydrogeological, hydrochemical, geomorphological, and climatological investigations in western Saudi Arabia, 360 p., Vienna, New York.

Kattan, Z., 1995: Chemical and environmental isotope study of the fissured basaltic aquifer system of Yarmouk Basin (Syrian Arab Republic). Internat. Atomic Energy Agency, Isotope Hydrol. Middle East, Vienna.

Khair, K., F. Haddad and S. Fattouh, 1991: The effects of overexploitation on coastal aquifers in Lebanon, with special reference to saline intrusion. Selected papers on aquifer overexploitation, Internat. Assoc. Hydrogeol. Hydrogeology Selected Paper, 3: 349-362, Hannover.

Khouri, J., 1982: Hydrogeology of the Syrian steppe and adjoining areas. Q.J. eng. Geol. London, 15: 135-154, London.

Kotb, H., M.T. Hussein, and S. Zaidi, 1990: Groundwater quality of Damm area, Saudi Arabia. Journ. King Abdulaziz University. Earth Sci., 3:241-250, Jeddah.

Lerner, N.L., A. Issar, and I. Simmers, 1990: Groundwater recharge. Internat. Contributions to Hydrogeology, 8, 345 p., Hannover.

Lloyd, J.W., P. Fritz, and D. Charlesworth, 1980: A conceptual hydrochemical model for alluvial aquifers on the Saudi Arabian basement shield. International. Atomic Energy Agency, Arid-zone hydrology investigations with isotope techniques, Vienna.

Lloyd, J.W., and R.H. Pim, 1990: The hydrogeology and groundwater resources development of the Cambro-Ordovician sandstone aquifer in Saudi Arabia and Jordan. Journal of Hydrology, 121: 1-20, Amsterdam.

Memon, B.A., A. Kazi, and A.S. Bazuhair, 1984: Hydrogeology of Wadi Al-Yammaniyah, Saudi Arabia. Ground Water, 22, 4:406-411.

Otkun, G., 1975: More about Paleocene karst aquifer in Saudi Arabia. Karst hydrogeology, Internat. Assoc. Hydrogeol. Mem., 12: 25-38, Huntsville.

Otkun, G., 1973: General aspects of Paleocene carbonate aquifer in Saudi Arabia. Internat. Sympos. Development of Groundwater Resources Madras: V. 29-38, Madras.

Ponikarov, V.P. et al. 1967: The geology of Syria, explanatory notes on the geological map of Syria, 1:500.000, Moscow

Pike, J.G., 1985: Groundwater resources and development in the central region of the Arabian Gulf. Mem. 18th Congr. Intrnat. Assoc. Hydrogeol., Cambridge.

Rimawi, O., 1985: Hydrogeochemistry and isotope hydrology of the ground- and surface water in North Jordan (north-north-east of Mafraq, Dhuleil-Hallabat, Azraq-Basin). Thesis Technical Univ. Munich, Munich.

Rimawi, O., and P. Udluft, 1985: Natural Water groups and their origin of the shallow aquifers complex in Azraq-depression/Jordan. Geologisches Jahrbuch, C38:17-38, Hannover.

Salameh, E., and K. Khdier, 1985: Groundwater qualities in Jordan. News Letter Water Research Study Center, 4, Amman.

Salameh, E., O. Rimawi, and I. Abmoghli, 1991: Precipitation water quality in Jordan. University of Jordan Water Research and Study Centre, 16, Amman.

Selkhozpromexport, 1974: Hydrogeological and hydrological surveys and investigations in four areas of Syrian Arab Republic. Rep. Selkhozpromexport-Gruzgiprovodhkoz, Tbilisi.

Sen, Z., and A. Al-Kakheel, 1986: Hydrochemical dacies evolution in Umm Er Radhuma limestone, eastern Saudi Arabia. Ground Water, 24,5:626-635.

Simmers, I., F. Villarroya, and L.F. Rebollo (eds.), 1992: Selected papers on aquifer overexploitation. Internat. Assoc. Hydrogeol. Hydrogeology Selected Papers, 3, Hannover.

Stuyfzand, P.J., 1991: A new hydrochemical classification of water types: principles and application to the coastal-dunes aquifer system of the Netherlands. Hydrogeology of salt-water intrusion, Internat. Contributions Hydrogeol., 11:329-344, Hannover.

United Nations, 1982: Groundwater in the eastern Mediterranean and Western Asia. Natural Resources Water Series, 9, New York.

UNDP, 1970: Liban. Etude des eaux souterraines, rapport technique. United Nations Development Programme, New York.

Waegeningh, H. G. van, 1985: Overview of the protection of groundwater quality. International Contributions to Hydrogeology, 6:159-166, IAH, Hannover.

Wagner, W., 1995: Groundwater with low salinity in the dry regions of Western Asia, hydrochemical aspects. Sultanate of Oman Internat. Conf. Water Resources Management in Arid Countries: 443-449, Muscat.

WHO, 1993: Guidelines for drinking-water quality, 2nd ed., World Health Organization, Geneva.

WRAP, 1994: Palestinian water resources. A rapid interdisciplinary sector review and issues paper. The task force of the water resources action programme, Palestine, Gaza.

Yurtsever, Y, 1993: An overview on the role of isotope applications in water resources and summary of results for groundwater resources in some ESCWA countries. ESCWA Regional Symposium on Water Use and Conservation, Amman.

Zarour, H., J. Isaac, and V. Qumsieh, 1993: Hydrochemical indicators of the severe water crisis in the Gaza Strip. Proc. Internat. Sympos. Water Resources Middle East: 207-228, Urbana.

VII. DEVELOPMENT OF WATER QUALITY INDICES FOR SUSTAINABLE DEVELOPMENT (A CASE-STUDY)

A. Rationale

Chapter 40 of Agenda 21 calls for the development of indicators of sustainable development. In particular, it requests countries at the national level, and international governmental and non-governmental organizations at the international level, to develop the concept of indicators of sustainable development. In its 1995 work programme, the Commission on Sustainable Development (CSD) grouped the desired indicators into four categories, namely economic, social, institutional and environmental.

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

(a) What is important (parameters)?
(b) What is representative (indicators)?
(c) What can be aggregated (indices) and how?
(d) What can be interlinked to describe sustainable development?

The information needs of decision makers are described as a pyramid having the following structure:

(i) Primary data comprises the broad base or foundation information (highly technical);

(ii) Analysed data as the next level (moderately technical - interpreted data);

(iii) Indicators as the third level (slightly technical - indicative data);

(iv) Indices as the last or tip level (slightly technical to mostly descriptive - aggregate data).

The highly aggregated indicators, or indices, which represent the tip of the information pyramid, depend on understanding the linkages among groups of indicators, either within a single cell, or across cells. Aggregating and developing indices reduces the number of indicators and adds analytical and interpretative value to the process. It also increases the value content: in order to design an index, for example, decisions have to be made about how to weigh indicators relative to each other. In sustainable development, with the tensions between environmentalists and advocates of development, countries may differ markedly in their approach to relative weights.

In a study commissioned by UNEP, Bakkes et al. (1994) stressed the need to focus on the quality of environmental subsystems such as soil, water and air. In the water subsystem, Water Pollution Indices (WPI) have the merit of being used independently as excellent tools for the management of water quality. They are extremely useful in compiling and reducing large amounts of data to a simple and single index value which permits communication between technicians and others. In addition, WPI can be used to detect trends, compare different water resources, classify water according to quality, and finally, determine the degrees of success or failure of ongoing national water pollution abatement programmes. Politically, WPI can also be used to justify major expenditures, allocate budgets and communicate technical information to decision makers and the public at large.

The objective of this paper is to analyse, modify and elucidate the methodologies which can be implemented to develop WPI in the ESCWA region. A case-study done on a research basis in Egypt is used to illustrate the applicability of the WPI developed. Steps involving the interlinking of economic, social, institutional and environmental indicators are considered the most critical and difficult aspects of developing indicators. Understanding the linkages among the indicators and ensuring that the sum of these linkages describes a whole process of sustainable development is a multidisciplinary joint effort task that should be developed at a later stage.

B. NECESSITY OF INDICATORS OF SUSTAINABLE DEVELOPMENT IN THE ESCWA REGION

The primary focus of chapter 40 of Agenda 21 and the CSD is to furnish indicators that can provide an important measure with which to evaluate sustainable development processes in a simple and comprehensible manner. Several basic uses of indicators of sustainable development from which ESCWA member countries can profit are the following:

(a) To assist decision makers at the national level in monitoring progress towards sustainable development, in developing policies, in evaluating the effectiveness of these policies and in allocating available resources;

(b) To provide scientists with a tool to further their understanding of the impact of developmental activities on natural phenomena and trend analysis;

(c) To support citizens, either through governmental or non-governmental organizations, by giving them the means to focus their data collection, define their remedial action and plan for their lobbying campaigns;

(d) To supply methods for regional or global assessment by zoning, ranking and comparing uniform national-level indicators. This will help in developing early warning systems for sustainable development and in designing policies that are truly responsive to the needs of countries;

(e) To grant countries the means to facilitate and enhance national reporting to the CSD and other intergovernmental fora;

(f) To provide the international community with specifically designed indicators to interpret and communicate changes in issues such as global climate changes or fish stocks. This will help national decision makers in formulating their policies, including decisions to engage in international, regional or even bilateral negotiation conventions and ratifying agreements;

(g) To provide the local authorities with an instrument to develop policies, monitor performance and raise sustainable development public awareness in their communities.

C. Development of WPI

A WPI can be developed by reducing measurements of two or more water quality variables to a single number or a set of numbers, words or symbols that retain the meaning through a sequence of mathematical manipulations. Conceptually, a WPI is viewed as consisting of two fundamental steps:

(a) Calculation of the sub-indices for the pollution variables used in the index;
(b) Aggregation of the calculated sub-indices into the overall index.

Take, for example, a set of observations for z quality variables, in which X_1 denotes the observed value for the first quality variable, X_2 denotes the observed value for the second quality variable, and X_z denotes the value of z^{th} pollutant variable. Then the set of observations is denoted as (X_1, X_2, X_3, ..., X_z). For each single water quality parameter variable X_z, a sub-index I_z is computed using sub-index function fz (X_z):

$$I_z = fz(X_z) \quad .... \quad (1)$$

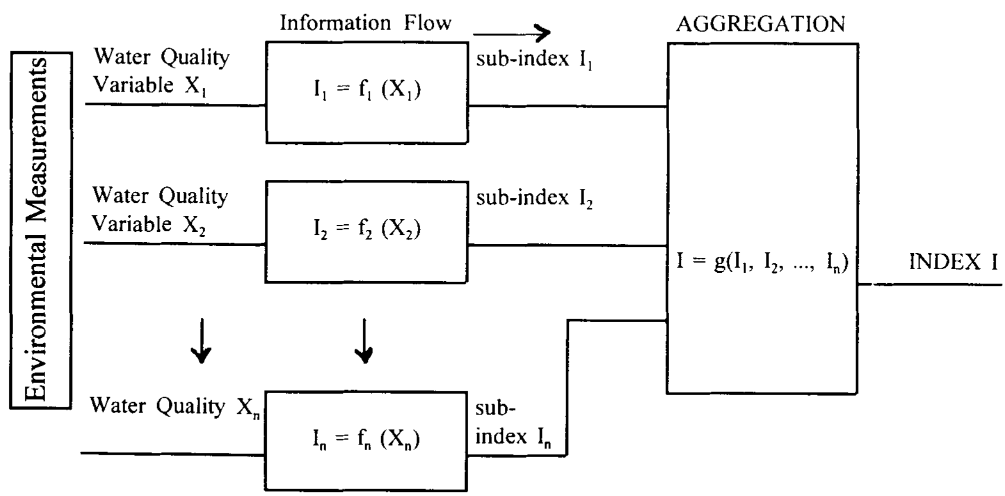
Each sub-index function is intended to represent the environmental characteristics of the particular water quality variable. It may consist of a simple multiplier, or the quality variable raised to a power, or some other functional relationship. Once the sub-indices are calculated, they should be aggregated together in a second mathematical step to form the final index:

$$I = g(I_1,I_2,I_3,...,I_z) \quad .... \quad (2)$$

The aggregation function, equation 2, usually consists either of a summation operation in which individual sub-indices are added together, or a multiplication operation, in which a product is formed from some or all of the sub-indices, or a maximum operator, in which only the maximum sub-index is reported.

The overall process-calculation of sub-indices and aggregation of sub-indices to form the WPI can be presented in the flow diagram illustrated in figure 1. In this process, the information contained in the water quality raw data flows from left to right and is reduced into a more economical form. Some detailed information might be lost during such a process; however, precautions should be taken to avoid or minimize such a loss. If unavoidable, the information loss should be of such a nature that it does not cause the results to be distorted or misinterpreted.

Figure 1. Information flow process in the development of water quality indices



D. SELECTION OF WATER QUALITY PARAMETERS ON WHICH THE INDEX IS BASED

Theoretically, and according to Nemerow (1985), any number of water quality characteristics could make up WPI. However, too large a number would constrain the index use. Therefore, it appears practical to use only those characteristics which are of the greatest significance.

It is very important to hold meetings with the national or local authorities responsible for environmental management to set the criteria applicable for the selection process in each specific area. This step can be followed by the actual selection of water quality characteristics to be incorporated into the WPI. However, the following general criteria controlling the selection process were found to be applicable in almost all cases:

(a) Water pollution parameters that are routinely monitored. It would be pointless to include characteristics that are not generally measured;

(b) Water pollution parameters which represent a potential public health threat, such as indicators for pathogens, carcinogens and toxins;

(c) Water pollution parameters which represent potential non-health related effects, such as damage to aquatic ecology and economic loss. These parameters could include biochemical oxygen demand (BOD), nutrients, pH and turbidity;

(d) Water pollution parameters that were often found to exceed the maximum allowable concentration (MAC);

(e) Experience gained from other parts of the world, particularly the United States of America and Canada.

In order to permit comparisons of water quality from one area or country to another, it is desirable to select water quality variables that are generally significant in most parts of the country or region.

In the present case-study, the selection of parameters was based on the extensive investigation conducted by Brown et al. (1970), in which a panel of 142 of the most recognized experts in the field of water quality management in the United States were asked to select the 35 most substantial parameters for possible inclusion in a WPI. These 35 parameters were narrowed down to 9 parameters following a series of modifications through additional questionnaires coupled with statistical analysis to determine the most significant ones. The most prominent parameters were found to be the following:

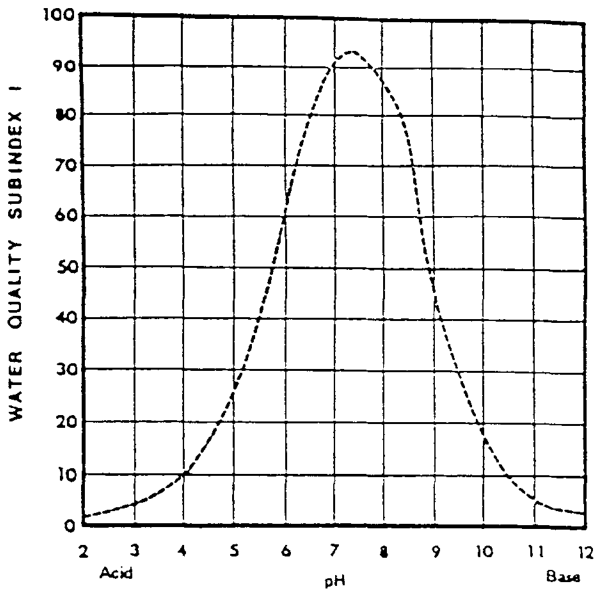
(a) Dissolved oxygen (DO)
(b) Fecal coliform density (MPN/100ml)
(c) pH
(d) Biochemical oxygen demand (BOD)
(e) Nitrate
(f) Total phosphate
(g) Temperature C°
(h) Turbidity
(i) Total solids (T.S.)

In the present case-study, provisions were made concerning pesticides and toxic elements. For pesticides it is proposed that if the total content of detected pesticides (of all types) exceeds 0.1 mg/l (100 ppb), the water should automatically be registered at the highest value on the WPI scale. The suggested procedure for including toxic elements and substances in the WPI is based on the setting of accepted values for critical allowable upper limits for the presence of each of these elements or substances. If any of the toxic elements exceeds its assigned upper limit, the WPI will automatically designate this water as highly polluted. The maximum permissible levels included in the Egyptian Clean Water Act (ECWA) 48/1992 were observed in calculating the WPI.

E. Development of functions for sub-indices

To develop a WPI, the mathematical function to be used to calculate the sub-indices must be defined. It is fundamental to find valid mathematical functions relating WQ variables to their effects on man and the environment (sub-index). Such a relationship is usually called "damage function" or "dose-effect function". The simplest form of sub-index function as it appears in literature (Ott 1978; Smith 1989; Khordagui and Al-Ajmi 1993; Khordagui and Al-Ajmi 1994); Barbiroli et al. 1992 and Smith, 1989) is the linear function. With this function, a direct proportion exists between the sub-index and the WQ variable. That is, a doubling of quality variable X_z results in a doubling of sub-index I_z. These functions were found to be perfectly suitable for defining air quality sub-indices. However, when examining water quality variables such as pH, temperature and DO, much more complicated implicit non-linear functions were exhibited, some of them with bell curves as illustrated for pH in figure 2.

Figure 2. Example of implicit non-linear sub-index function for pH from a water quality index proposed by Brown et al. (1970)



In an effort to solve this problem, Brown et al. (1970) sent another questionnaire asking the respondents to develop a rating curve for each of the nine individual variables selected. This was accomplished by providing blank graphs to each respondent. Levels of water quality (sub-indices I_z) ranging from 0 to 100 were indicated on the ordinate of each graph, while various levels (or strengths) of each particular variable were arranged along the abscissa. The respondents were asked to draw a curve on each graph which, in their judgement, represented the variation of water quality produced by the various quantities of each quality variable. Brown et al. (1970) subsequently averaged the curves from the respondents to produce a set of "average curves", one for each variable. These averaged curves were used to determine the sub-index values.

Khordagui and Sharkawi (1988) noted that the relationships drawn by Brown et al. (1970) were solely based on the personal judgements of American experts. The former analysed these relationships and realized that they suffered from the following disadvantages:

(a) They had a relatively wide range of variability.

(b) They reflected the personal beliefs, experiences and perceptions of American experts who were most likely influenced by the imposed American water quality standards;

(c) They were an untenable choice for a water quality index (WQI) to be used regularly on a regional or national level;

(d) They were not specified for any particular water use;

(e) They were based on personal opinion and not on scientific grounds.

In an effort to solve these problems, Khordagui and Sharkawi (1988) established relationships between WQ variables and sub-indices. These relationships are established by relating each WQ variable to its MAC. The primary problem they faced was how to integrate the independent multiple items of WQ variables into a common expression. It has been noticed that there is often little correlation between the significance and the dimension of each pollutant. For instance, 1000 (MPN/100 ml) in coliform count when related to some kind of standard value of 200 (MPN/100 ml) can relatively be expressed as 5 (1,000/200=5) which is a non-dimensional relative value.

When the multiple items of water qualities are expressed as X_z and the permissible levels of the respective items for a particular use are expressed as S_{zn}, the WPI for the use n may be expressed as a function of the relative value I_z or (X_z/S_{zn}). Here z is the number of z^{th} parameter of water pollution and n is the number of the n^{th} water use:

$$WPI = f(X_1/S_{1n}, X_2/S_{2n}, X_3/S_{3n}, X_4/S_{4n}, ..., X_z/S_{zn}) \quad .... \quad (3)$$

Each value of I_z or (X_z/S_{zn}) shows the relative quality contribution of a single item. A value of 1.0 is the critical value for each sub-index I_z or (X_z/S_{zn}). Values greater than 1.0 indicate that the water exceeds the maximum allowable concentration for that specific parameter z for the specific use n.

Similarly, when combining several parameters (X_z/S_{zn})s into a common index, values > 1.0 signify a critical condition. For instance, when the quality of a sample of water is expressed as BOD (X_1) = 10.0 mg/l, coliform bacteria (X_2) = 1,300/100 ml, and hardness (X_3) = 80 mg/l, and their permissible levels for a particular use n are given as BOD (S_{1n}) = 20 mg/l, coliform (S_{2n}) = 1,000/100 ml, and hardness (S_{3n}) = 100 mg/l, then $(I_1 = X_1/S_{1n} = 0.5)$, $(I_2 = X_2/S_{2n} = 1.3)$ and $(I_3 = X_3/S_{3n} = 0.8)$ and the water is judged as polluted.

The advantages associated with the use of the given functions for the determination of sub-indices are the following:

(a) They can be applicable to any water use by inserting the proper permissible level for this particular use;

(b) They can accommodate any number of WQ variables as long as their MACs are available;

(c) They are based on solid scientific foundations extending from the knowledge used to develop the MAC;

(d) They can be universally applicable following minimal modifications.

It is important to note that, unlike air quality, every item of WQ does not always increase as pollution increases. Most organic and inorganic ions increase in concentration as pollution increases. However, pH values vary with pollution, ranging from 0 to 14. Dissolved oxygen, for example, also usually decreases within a limited range as pollution mounts. In addition, it is common to specify the permissible level by a range of values, such as pH from 7.0 to 8.5. In these cases, the (X_z/S_{zn}) values cannot be calculated in the same ways as previously suggested. Some mathematical manipulations are needed. For WQ variables that decrease in value as pollution increases, transparency and DO are good examples of these WQ variables. In this case, the (X_z/S_{zn}) will have the following form:

$$I_z = (Z_x/S_{zn}) = (X_z max - X_z)/(X_z max - S_{zn}) \quad .... \quad (4)$$

Where $X_z max$ = practical maximum value as DO saturation concentration at certain temperature.

For instance, if DO max=8.0 mg/l, and the maximum permissible DO according to the applied standard is 5.0 mg/l and the measured DO in the water body is 4.0 mg/l then:

$I_z = (X_z/S_{zn}) = (8.0 - 4.0)/(8.0 - 5.0) = 4/3 = 1.33$

For the contaminants which have permissible ranges, temperature and pH are good examples of these WQ variables. In this case the mean value of S_{zn} should be calculated by averaging the S_{zn} min and S_{zn} max.

$$S_{zn} \text{ mean} = (S_{zn} \text{ min} + S_{zn} \text{ max}) /2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$I_z = (X_z/S_{zn}) = (X_z - S_{zn} \text{ mean}) / (S_{zn} \text{ min}^{**} \text{ or } S_{zn} \text{ max}^{**} - S_{zn} \text{ mean}) \quad \ldots\ldots\ldots \quad (6)$$

where ** means to use whichever value is closer to the existing X_z value. For example, if the maximum allowable pH = 8.5 and the range is 7.0 to 8.0 when the measured pH = 10 then

$I_z = (X_z/S_{zn}) = (10 - 7.75) / (8.5 -7.75) = 2.25/0.75 = 3.0$

F. Selection of an aggregation function

Once the sub-indices $I_z=(X_z/S_{zn})$ for a particular water use n are calculated, the aggregation process starts to reduce the information. This process is the most important and complicated step in developing a WPI. This is where most of the simplification takes place, and where most of the distortion is likely to be introduced. Aggregation of sub-indices reduces the number of sub-indices and adds analytical and interpretative value to the process. The normal sequence used to find the most proper aggregation function is briefly reviewed below:

(a) Additive form: this function can be represented mathematically as:

$$WPI = \sum_{z=1}^{9} I_z \quad \ldots\ldots(7)$$

This function suffered from exaggeration and ambiguity.

(b) Weighted linear sum form: this function can be represented mathematically as:

$$WPI = \sum_{z=1}^{9} I_z W_z \quad \ldots\ldots(8)$$

where

$$\sum_{z=1}^{9} W_z = 1 \qquad .....(9)$$

This function suffered from significant eclipsing.

(c) Root-sum-power form: this function can be represented mathematically as follows:

$$WPI = \left|\sum_{z=1}^{9} I_z\right|^{1/P} \qquad .....(10)$$

This function suffered from partial ambiguity in case p=2. However, the ambiguity was gradually reduced when the power p was raised to higher values.

(d) Root-mean-square form: this function is similar to the root-sum-square, except that the arithmetic mean of the square of the sub-indices is calculated before the square root is taken. The general mathematical form of this function is as follows:

$$WPI = [(1/2)(I_1^2 + I_2^2 + I_3^2 + \ldots + I_9^2)]^{1/2} \;........\; (11)$$

Similar to the weighted linear sum function, this function suffered from two eclipsing regions.

(e) Maximum operator form: the general form of this function is as follows:

$$WPI = \text{Max}\ \{I_1, I_2, I_3, \ldots, I_9\} \quad .... \; (12)$$

In this function, WPI takes on the value of the largest of any of the sub-indices. It should be noted that the maximum operator aggregation function is nothing but an extreme case of the root-sum-power function in which the power p is extended to infinity. For different values of two sub-indices, the plot of equation 12 will appear as two straight lines joined at right angles, giving the appearance of a square box.

G. Applicability of the Developed WPI to Egypt

The application of WQIs is gaining momentum around the world (Khordagui and Al-Ajmi 1995; Ott 1978; Bhargava 1983; House 1990; Malin 1984; St-Louis and Legendre 1982; Couillard and Lefebvre 1985; Egborge and Benka-Coker 1986; Al-Ani 1987; Kwiathowski 1988; House and Ellis 1987; Tyson and House, 1989; and House and Newsome 1989). As an application of the developed WPI, the quality of the River

Nile at Kaft-Al-Zayat some 50 km south of Rosetta was identified. The implementation of the WPI process was designed to be simple, versatile, flexible and suitable for short skills in developing nations. The applied scheme is summarized as follows:

(a) Determination of the water use (n): due to the lack of environmental health awareness in developing nations, the general public is usually unable to distinguish between various classes of water uses. Any fresh surface water, particularly in rural areas, is likely to be used for washing, irrigation, recreation, fishing and sometimes for drinking following minimum treatment. It is then safe to identify most of the freshwater resources as for human use. The other two classes of water use (indirect contact and remote contact) are nearly nonexistent in rural Egypt;

(b) Determination of MAC (S_{zn}): one of the basic advantages of the developed WPI is its versatility in accepting any set of standards according to the various water uses. In the example presented herein, the implemented standards are abstracted from ECWA (48/1982). Any missing value from ECWA was substituted by permissible levels from the United States Environmental Protection Agency's Quality Criteria for Water (1986);

(c) Determination of Water Quality (X_z): water samples are collected and examined for the nine parameters selected for inclusion in the WPI. Usually, the data are abstracted from national routine monitoring programmes;

(d) Determination of sub-indices $I_z=(X_z/S_{zn})$: these calculations are illustrated in table 1;

(e) Determination of the WPI: apply the maximum operator function and report the WPI as 1.62. It is also advisable to report the average of all sub-indices to provide the reader with a collective assessment of the overall water quality. Statements indicating the reasons for exceeding the WPI critical level of 1.0 is also recommended. Five descriptive categories can be used to match the designated water quality (as listed in table 2) with its relative sub-index value. A tentative description of the potential health effects on the exposed population is provided at each index value.

The pollutant responsible for the maximum sub-index (in this case coliform bacteria) is called the "critical pollutant". For the purpose of completeness, it is recommended that the critical pollutant be reported along with the index. However, the basic reporting statement for the given application should read as follows: "Today, WPI at Kafr-Al-Zayat is 1.62, the use of water for body contact is unhealthy and the pollutant responsible is coliform resulting from domestic sewage discharge. No pesticides or toxic elements were detected."

TABLE 1. CALCULATIONS FOR DETERMINATION OF SUB-INDICES FOR N USE

Z	WQ variable	S_z	X_z	$(X_z/S_z)_n$
1	Temperature	30	26	0.86
2	Turbidity	40	34	0.85
3	pH	7.0-8.5	8.1	0.47 [a/]
4	DO	5.0	6.2	0.62 [b/]
5	BOD	6.0	6.6	1.10
6	Coliform (MPN/100 ml)	2 000	3 241	1.62
7	Nitrate	20	0.64	0.03
8	Phosphate	5	0.68	0.14
9	Total Solids	500	260	0.52

a/ Value calculated using equation # 6.
b/ Value calculated using equation # 4.

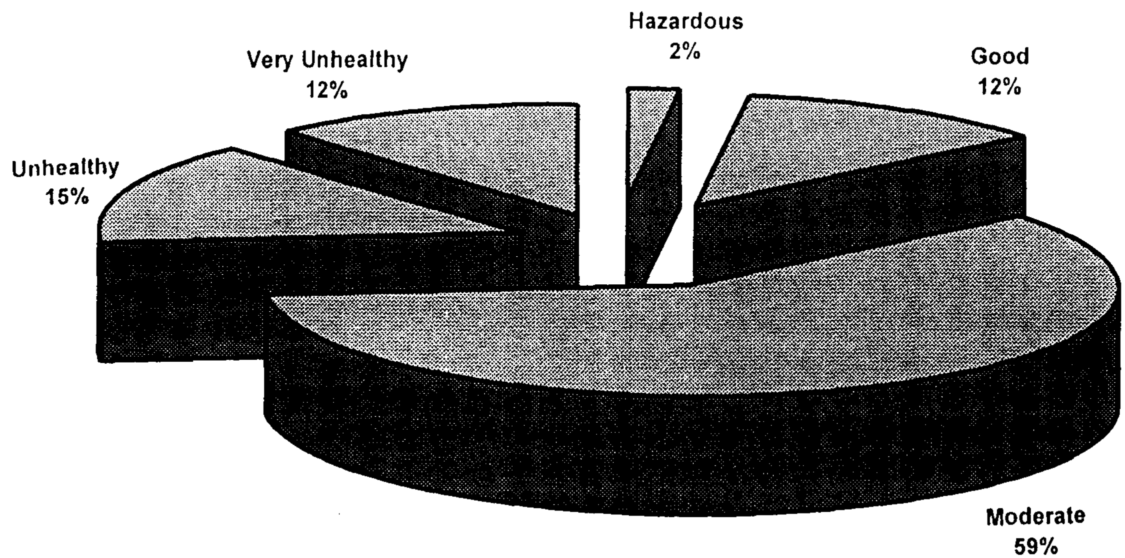
TABLE 2. WATER POLLUTION INDICES AND THEIR CORRESPONDING DESCRIPTIVE WORDS AND CODING COLORS

WPI value	Descriptor	Color code
0-0.5	Good	Blue
0.5-1.0	Moderate	Green
1.0-2.0	Unhealthy	Yellow
2.0-3.0	Very Unhealthy	Orange
3.0-4.0	Hazardous	Red

H. HOW TO REPORT A WPI

The best method of reporting WPI to non-technical sectors, such as the general public, students, politicians and decision makers, is through a visual scale or graph, accompanied by one of the descriptors. The colors appear well-suited to the perception of the general public and are designed to give a subjective impression of a gradual worsening or improvement of the water pollution problem with each descriptor. A report might include a table containing all the WPI sub-index values, along with sub-index values for several previous days. Reports to politicians, high-ranking officials and funding agencies might include discussions on WPI trends, seasonal variations and the point sources or industries frequently responsible for violations of wastewater discharge regulations. Graphic presentations, such as that illustrated in figure 3 can be employed as a good and accessible tool for conveying technical information.

Figure 3. Percentage distribution for water quality at Kafr-Al-Zayat during 1988



I. CONCLUSION

WPI, in association with other complementing environmental indicators, can play an important role in sustainable development. Steps involving the interlinking of economic, social, institutional and environmental indicators are considered as the most critical and difficult aspects of developing indicators. The sum of these linkages to describe the whole process of sustainable development is a multidisciplinary joint effort task that has to be developed at a later stage. The present work is an attempt to develop a simple WPI applicable to developing countries. The developed WPI can be used independently as an excellent tool for the management of water quality and later be integrated into an overall aggregated index for sustainable development.

The structure of the developed WPI includes nine WQ variables. It incorporates linear and non-linear functions for computing sub-indices and is based on a maximum operator aggregation function for figuring the overall index. It is flexible enough to accommodate amendments in regulations and can be applicable to different water uses. It includes five descriptive categories and their corresponding color codes.

The application of the WQI to Nile water suggests that it can reflect the day-to-day variations in water quality in a reasonable fashion and appears to be a useful tool for representing and interpreting the masses of routinely generated WQ data. It can also be used in trend studies to display annual WQ in more descriptive forms for politicians, decision makers and non-technical sectors in developing countries.

REFERENCES*

Al-Ani, M. (1988), "Water quality index for Tigris River classification" J. Biol. Sci. Res. vol. 19 (3), pp. 715-32.

Bakkes, J.A., G.J. Vandenborn, J.C. Helder, R.J. Swart, C.W. Hope, and J.D. Parker (1994), "An overview of environmental indicators: State-of-the-art and perspectives". UNEP/RIVM 1994.

Barbiroli, G., P. Mazzaracchio, A. Raggi, and S. Alliney (1992), "A proposal for a new method to develop synthetic quality indices for air and water", Journal of Environmental Management, vol. 36, pp. 237-52.

Bhargava, D.S. (1983), "Use of water quality index for river classification and zoning of Ganga River", Environmental Pollution (Series B), vol. 6, pp. 51-67.

Brown, R.M., N. McClelland, R. Deininger and R.G. Tozer (1970), "A water quality index - Do we dare?" Water Sewage Works, vol. 117, pp. 339-43.

Couillard, D., and Y. Lefebvre (1985), "Analysis of water quality indices", Journal of Environmental Management, vol. 21, pp. 161-179.

Egborge, A.B., and J. Benka-Corker (1986), "Water quality index: Application in the Warri River, Nigeria", Environmental Pollution (Series B) (12), pp. 27-40.

House, M.A., and D.H. Newsome (1989), "Water quality indices for the management of surface water quality", Wat. Sci. Tech. vol. 21, pp. 1137-1148.

House, M.A., and J.B. Ellis (1987), "The development of water quality indices for operational management", Wat. Sci. Tech., vol. 19, No. 9, pp. 145-154.

House, M.A. (1990), "Water quality indices as indicators of ecosystem change", Environmental Monitoring and Assessment, vol. 15, pp. 255-263.

Khordagui H.K., D. Al-Ajmi, and S. Bu-Nashi (1994), "An index for the management of air quality in Kuwait Shuaiba Industrial Area", in "Proceedings of the Second Conference on Chemistry in Industry", Manama, Bahrain, October 24-26.

Khordagui H.K., and F. Sharkawi (1988), "Indexing water pollution in developing nations", in The Bulletin of HIPH, vol. XVIII, No. 4, pp. 721-32.

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* Issued as submitted.

Khordagui H.K., and D. Al-Ajmi (1993), "An air pollution index for the Shuaiba Industrial Area", EES-171 Final Report, Kuwait Institute for Scientific Research, KISR publication # 4289.

Khordagui H.K., and D. Al-Ajmi (1995), "Application of indices for air quality management in Kuwait", accepted for publication in Environmental Management, in press.

Kwiathowski, R.E. (1988), "National water quality index network options to consider", Water poll. Res. J. Canada, vol. 23, No. 4, pp. 476-86.

Malin, V. (1984), "A general lake water quality index", Aqua Fennica, vol. 14:2, pp. 139-45.

Nemerow, N.L. (1985), "Stream, Lake, Estuary and Ocean Pollution", Van Nostrand Reinhold Company, Melbourne, Australia.

Ott, W. (1978), "Environmental Indices-Theory and practice", Ann Arbor, Michigan, Ann Arbor Science Publisher, MI.

Smith, D.V. (1989), "A new form of water quality index for rivers and streams", Wat. Sci. Tech. vol. 21, No. 2, pp. 123-27.

St-Louis, N., and P. Legendre (1982), "A water quality index for lake beaches", Water Res. vol. 16, pp. 945-948.

Tyson, J.M., and M.A. House (1989), "The application of a water quality index to river management", Wat. Sci. Tech. vol. 21, pp. 1149-1159.

United States Environmental Protection Agency (1987), "Quality criteria for water 1986", Office of Water Regulations and Standards, Washington, D.C., EPA 440/5-86-001.

VIII. WATER DESALINATION IN SELECTED ESCWA MEMBER COUNTRIES: OPPORTUNITIES AND CONSTRAINTS

Introduction

The availability of water in the Middle East has, throughout history, affected the life and livelihood of the inhabitants. In the past, a remarkable variety of adjustments to water supply fluctuations and deficits were made by the indigenous people. Recently, the introduction of modern water-lifting and -moving technology has contributed to increased water utilization. High population growth and increased economic development during the last two decades have rendered traditional water resource management practices obsolete and too inefficient to allocate and preserve adequately the limited water resources in the Arab world, particularly in some of the ESCWA member countries. In addition, the non-sustainable use of natural water resources to meet rising water demand has also contributed to water depletion and deterioration of quality in available sources. The growing gap between supply and demand for water in the ESCWA member countries can be attributed to limited availability of surface water, mining of fossil groundwater sources, water pollution of particularly the shallow aquifers, deficient institutional arrangement, poor management practices, and lack of trained personnel.

To meet domestic, industrial and agricultural water requirements, some of the ESCWA member countries rely on surface water from rivers, while others rely on groundwater. Egypt, Iraq, Lebanon and the Syrian Arab Republic may have adequate surface water from major rivers to meet water requirements for the immediate future. However, the headwaters of most of the major rivers are located outside the borders of the Arab countries, a fact that further compounds the water-related problems in these countries. Other countries, particularly those located in the Arabian Peninsula, depend on renewable shallow and deep fossil groundwater and on desalinated sea water.

An important aspect of the water problems in the ESCWA member countries is the fact that most are situated in arid and semi-arid zones. The major portion of the ESCWA region is considered to be desert, with the exception of Lebanon, the Syrian Arab Republic, parts of Iraq and Jordan, and a narrow strip of irrigated land adjacent to the Nile River in Egypt. Availability of natural water resources varies from country to country depending on hydrogeological setting. The northern ESCWA member countries have relatively dependable surface water sources owing to seasonal rainfall, regulated river flow, and renewable groundwater reserves sufficient to meet current water requirements. On the other hand, the countries located within the Arabian Peninsula are devoid of rivers, have harsh climates, are experiencing large urban expansion and rapid economic growth, and depend mainly on fossil groundwater and desalinated water to meet their requirements. Extreme rainfall variation in the region has reduced dependence on surface water generated from flooding. Renewable groundwater reserves of the shallow alluvial aquifers, especially those located in coastal zones, have limited storage capacity and reserves to meet increasing demand for water. In addition, most of these aquifers are subjected to pollution from irrigation return flow, wastewater disposal, and salt-water intrusion. The deep groundwater aquifers underlying the northern, central and eastern regions of the Peninsula contain extensive water reserves. However, water quality within these aquifers deteriorates towards the Gulf, where extensive urban population centres are located and where rapid economic development is taking place.

TABLE 1. POPULATION GROWTH OF THE ESCWA MEMBER COUNTRIES

(Thousands)

Country	1950	1970	1990	2000	2025
Jordan	1 237	2 299	4 009	5 624	10 807
Iraq	5 158	9 356	18 081	24 779	46 260
Lebanon	1 443	2 469	2 740	3 312	4 476
Syrian Arab Republic	3 495	6 258	12 355	17 546	35 250
Egypt	20 330	33 053	52 519	64 810	93 536
Saudi Arabia	3 201	7 740	14 870	20 667	40 426
Kuwait	0 152	0 760	2 143	1 718	2 789
Bahrain	0 116	0 270	0 503	0 653	1 014
Qatar	0 025	0 171	0 427	0 542	0 731
United Arab Emirates	0 070	0 505	1 589	1 970	2 792
Oman	0 433	0 750	1 524	2 168	4 705
Yemen	4 316	7 480	11 684	16 424	34 237
Total	39 956	71 111	122 445	160 213	277 023

Another factor that further compounds the regional water problem is the high population growth rate. The population of the ESCWA region was estimated at 122.2 million in 1990 and is expected to reach 160.2 million and 277 million in the years 2000 and 2025, respectively (United Nations 1994), as shown in table 1. Rapid population growth, along with the urbanization and improvement in the standard of living experienced during the last decade, have brought about substantial water demand increases and have resulted in overexploitation of natural water resources. This, in turn, has resulted in the construction of a large number of desalination plants with large water production capacities and excellent water quality for all the Gulf countries of the Arabian Peninsula. To meet water supply shortages in the domestic sector, water desalination presented a viable option for many countries in the region. The experiences of a number of countries in the Arabian Peninsula has demonstrated that water desalination has become a main and dependable water source. Even though the cost of desalination is relatively high, the countries of the Peninsula have limited prospects for additional water without depending on desalination. Reuse of renovated wastewater is a viable option to increase water supplies for industrial and agricultural purposes. To overcome supply limitations, all feasible options must be evaluated, including desalination.

To overcome future problems of water supply limitations and increasing water demand owing to high population growth and excessive consumption, all countries in the ESCWA region, particularly the Gulf States, need to implement and enhance water management practices and invest in water desalination and wastewater treatment technologies to provide additional sources. In addition, efficient management of the water resources of the ESCWA region requires undertaking of strategic planning in order to formulate and implement water policies that emphasize holistic and integrated management practices.

This paper investigates the role of water desalination in meeting water demand. Emphasis is placed on water desalination technology and trends, production cost and its role in meeting water demand in a number of ESCWA member countries of the Arabian Peninsula. Emphasis is also placed on addressing the water resources situation in those countries which have bridged the supply-demand gap through dependence on desalination for their domestic water requirements.

B. WATER RESOURCES

The Arabian Peninsula has a harsh environment and is devoid of natural surface water bodies such as rivers and lakes. The natural water resources consist of limited quantities of run-off resulting from floods, groundwater in the alluvial aquifers, and extensive groundwater reserves in the deep sedimentary aquifers. The supplementary non-conventional sources are those from desalinated sea and brackish water and renovated wastewater.

Surface water: Run-off occurs mainly in the form of intermittent flash floods, governed by rainfall patterns and topographical features over the Arabian Peninsula. Average rainfall values have little meaning since many areas receive no rainfall for months or even years owing to extremely random storm patterns. Intermittent surface run-off volume in the Peninsula is estimated at 6.8 billion cubic metres (bcm) (Abdulrazzak, 1995). Run-off variation and utilization in each country of the Peninsula is shown in table 2. The annual run-off volume generated in south-western Saudi Arabia and Yemen is estimated to be 1,450 million cubic metres (mcm) and 2,100 mcm, respectively. The national totals for Saudi Arabia (Authman 1983, BAAC 1980) and Yemen (Mohamed 1986, Al-Fusail et al. 1991) are estimated at 2,230 mcm and 3,500 mcm, respectively. Amounts of surface water available in Oman (El-Zawahry 1992) and the United Arab Emirates (Al-Asam 1992, Uqba 1992) were

TABLE 2. WATER RESOURCES IN THE COUNTRIES OF THE ARABIAN PENINSULA (1992)

Country	Area (km^2)	Population 10	Average annual rainfall (mm)	Annual evaporation (mm)	Run-off (mcm)	Shallow groundwater reserve (mm)	Run-off utilization	Groundwater recharge (mcm)	Groundwater use (mcm)	Desalination (mcm)	Wastewater reuse (mcm)
Bahrain	652	0.52	70	1650-2050	0.20	90	-	100	160	56	32
Kuwait	17,818	1.52	70	1900-3500	0.10	182	-	-	80	240	83
Oman	212,460	1.51	71	1900-3000	918	10,500	275	550	645	32	10.5
Qatar	11,610	0.50	67	2000-2700	1.35	2,500	0.25	42	144	83	22
Saudi Arabia	2,149,690	11.78	75	3500-4500	2,230	84,000	900	3,850	14,430	795	217
United Arab Emirates	83,600	1.81	105	3900-4245	150	20,000	75	125	900	330	65
Yemen	527,970	13.12	122	1900-3500	3,500	13,500	1450	1,550	1,200	9	6
Total	3,003,008	30.76	-	-	6,800	130,772	2700	6,220	17,559	1,557	433

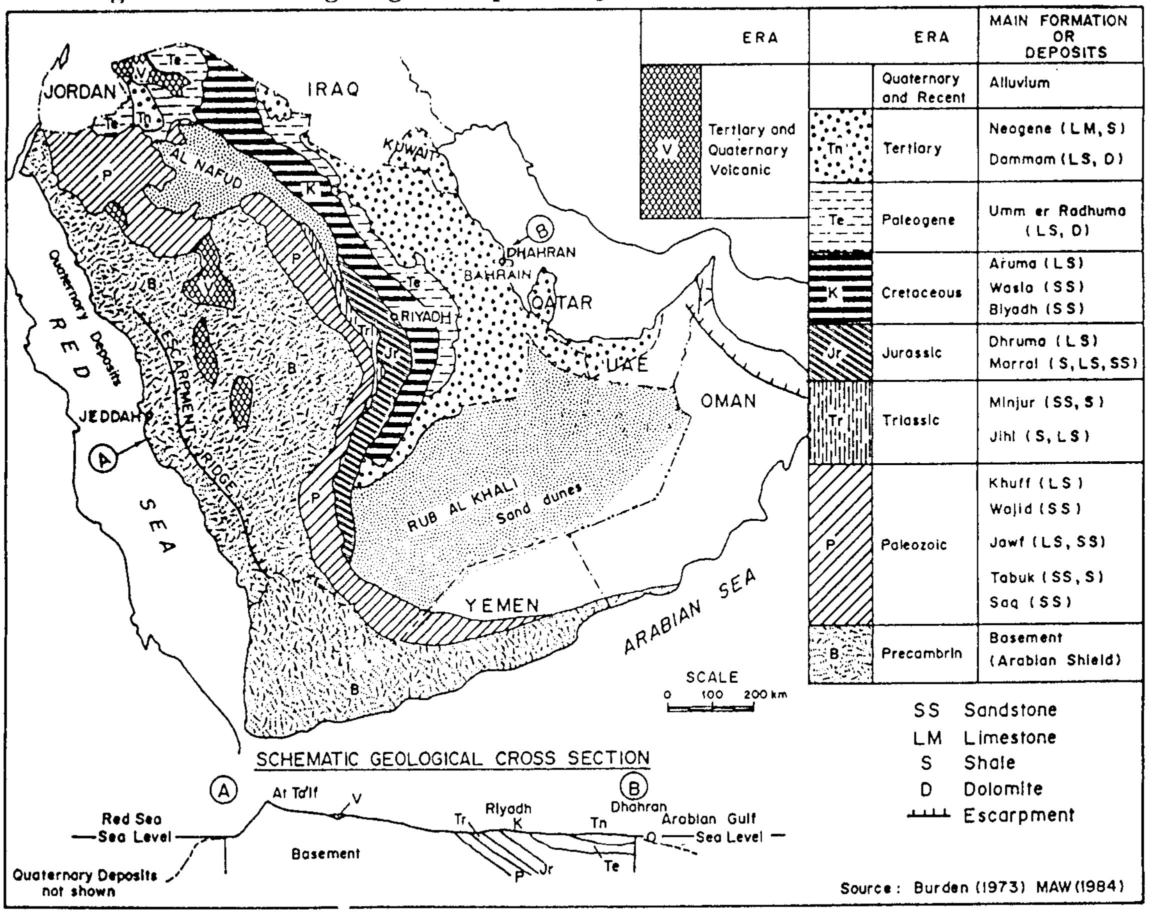
estimated at 918 mcm and 150 mcm respectively. The remaining countries have only negligible amounts of surface run-off.

In general, utilization of surface run-off is directed towards traditional flood irrigation, especially in the south-western region of Saudi Arabia and most of Yemen. In addition, the regulated and unregulated flood flow is the main source of groundwater recharge for the aquifers. Approximately 195 dams of various sizes have been constructed in Saudi Arabia for purposes of flood protection and groundwater recharge with a combined storage capacity of 475 mcm. Fifty-two dams have been or are being constructed in Yemen, the United Arab Emirates and Oman.

Shallow alluvial aquifers: Alluvial deposits along the main wadi channels and the flood plains of drainage basins make up the shallow groundwater system in the Peninsula. Groundwater in the shallow aquifers is the only renewable water source that these countries possess. The shallow aquifers in the eastern part of the Peninsula, particularly in the United Arab Emirates and Oman, are generally thicker and wider than in the western part, while alluvial thickness in the inland basins is greater than those of the coastal basins. Alluvial aquifer thicknesses generally range from 20 to 200 metres, with the exception of the coastal areas of Oman, where thicknesses may reach 400 metres. The width of these alluvial aquifers may range from a few hundred metres to several kilometres. The widths of the aquifers decrease in a southerly direction for basins on both the western and eastern coasts. The coastal alluvial aquifers are subject to salt-water intrusion, especially on the Gulf, owing to extensive groundwater withdrawal. Shallow aquifer water quality is generally good with total dissolved solids ranging from 300 ppm to 3,000 ppm. Combined reserves of the alluvial aquifers shown in table 2 are estimated at 131 bcm (Abdulrazzak 1992, Shahin 1989, Khoury et al. 1986), with the largest reserves for the large number of basins in Saudi Arabia estimated at 84 bcm (BAAC 1980, MAW 1984, Ukayli 1988). Groundwater from the shallow alluvials is used mainly for domestic and irrigation purposes.

Fossil groundwater aquifers: The other main source of water for the countries of the Arabian Peninsula is the non-renewable fossil groundwater stored in the sedimentary deep aquifers. The Arabian Shelf geological formations of sandstone and limestone, shown in figure 1, store significant amounts of groundwater that are thousands of years old (Burdon 1973, Edgell 1987). Those sedimentary aquifers have been classified as either primary or secondary based on their aerial extent, groundwater volume, water quality and development potential (MAW 1984). The primary aquifers are the Saq, Tabuk, Wajid, Minjur-Druma, Wasia-Biyadh, Dammam, Umm er Radhuma, and Neogene. The latter two are carbonate aquifers while the remainder are sandstone. Secondary aquifers are the Aruma, Jauf, Khuff, Jilh, Sakaka, the upper Jurassic, the lower Cretaceous, and Buwaib. These aquifers cover two thirds of Saudi Arabia, and some of them extend into Kuwait, Bahrain, Qatar, the United

Figure 1. General geological map and aquifers of the Arabian Peninsula



The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Arab Emirates, Oman and Yemen as well as into Jordan, Iraq and the Syrian Arab Republic.

Vast amounts of groundwater stored in the primary deep aquifers serve as a dependable source of water for the central and northern regions of Saudi Arabia and, to a lesser extent, the other countries of the Peninsula. Deep groundwater reserves for the aquifers in the Peninsula are estimated at 2,175 bcm with the major portion (1,919 bcm) located in Saudi Arabia. Recharge for all the deep aquifers is estimated at a very limited 2.7 bcm per year. This reserve represents groundwater that is exploitable by lowering the water level to 300 metres below the ground surface, the maximum depth currently possible with modern pumping technology.

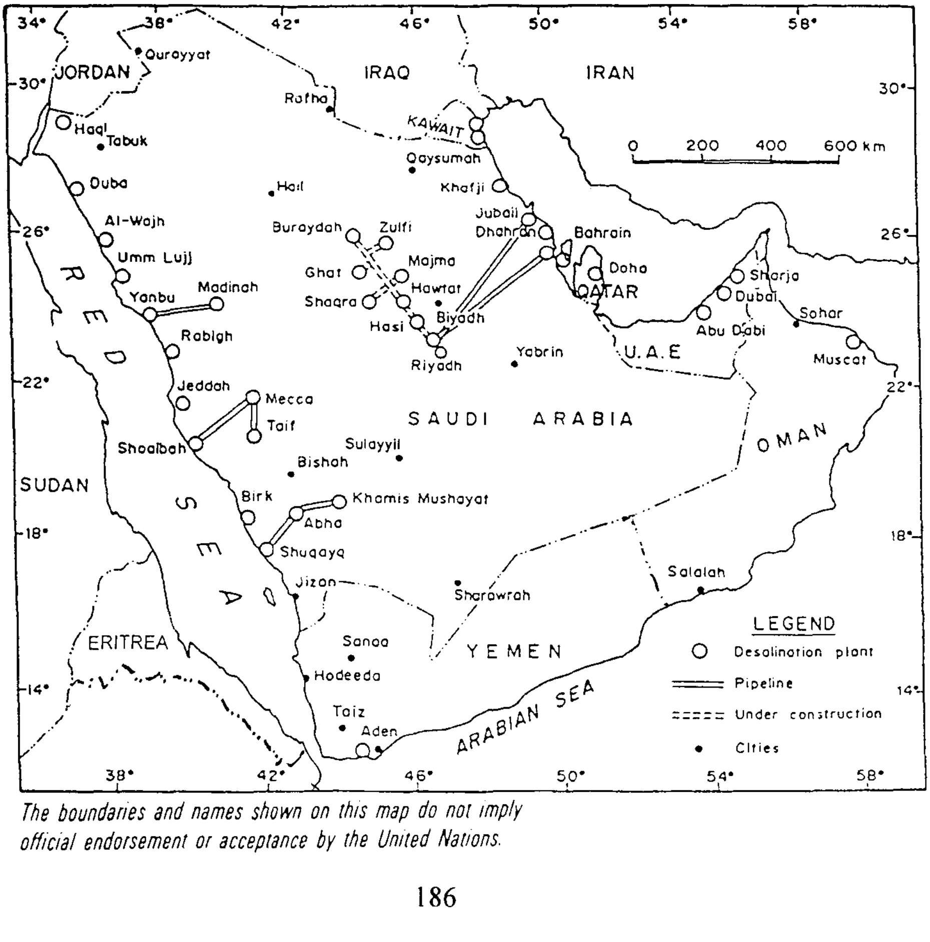
Although water in the deep aquifers is ample in quantity, the quality varies greatly and is suitable for domestic consumption in only a few areas, creating water supply problems. Total dissolved solids range from 400 to 20,000 ppm. Good quality water is stored in only a few aquifers: Saq, Tabuk, Wajid in Saudi Arabia, and Dammam in Bahrain and Kuwait. Brackish water from the Minjur, Wasia-Biyadh, Dammam and Umm er Radhuma aquifers usually requires treatment in most of the countries for hardness and high temperature. Water temperatures vary between 40°C and 65°C depending on the depth of extraction. Water from these deep aquifers tends to be saturated with calcium, magnesium and salt and to have high concentrations of sulphate and chloride ions, as well as relatively large quantities of hydrogen sulphide and carbon dioxide gases. The brackish water from some of these deep aquifers is usually used without treatment for agricultural purposes, and for limited domestic purposes in some locations in Saudi Arabia, Bahrain, Qatar and the United Arab Emirates. The groundwater of most of the deep aquifers requires treatment such as cooling, aeration to remove hydrogen sulphide and carbon dioxide gases, and lime soda processing.

Desalination: During the last 20 years, the countries of the Arabian Peninsula, with the exception of Yemen, have become increasingly dependent on desalination to meet their water supply requirements. They have become, by necessity, world leaders in desalinating sea water or brackish groundwater for domestic consumption. Urban expansion and improvement of the standard of living have led to increased domestic water requirements. Groundwater with high salinity in most of the Gulf countries has compelled them to rely on desalinated sea water. The present annual designed desalination capacity of the seven countries of the Peninsula, namely Saudi Arabia, Kuwait, Bahrain, Qatar, the United Arab Emirates, Oman and Yemen, has reached 2.02 bcm, compared with a worldwide capacity of 5.68 bcm (Wagnich 1992). These capacities cover all desalination plants and include numerous units in private sector ownership for industrial or other purposes. Saudi Arabia, Kuwait and the United Arab Emirates, in particular, rely on large-scale plants capable of producing up to 500 mcm per year.

Desalination production efficiency ranges between 70% and 85% of designed plant capacity. Total regional volume of actually produced desalinized water in 1992 was estimated at 1,550 mcm (Al-Mugran 1992, Al-Sufy 1992), as shown in table 2. Desalinated water provided 51% of urban and industrial water demand in 1992. The major producers of desalinated water are Saudi Arabia (51%), United Arab Emirates (22%), Kuwait (15%), Qatar (5%), Bahrain (4%), Oman (2%), and Yemen (1%) (Bushnak 1993).

The total number of desalination plants in operation as of 1992 reached 45: 23 in Saudi Arabia, 8 in the United Arab Emirates, 6 in Kuwait, 3 in Bahrain, and 2 each in Oman and Qatar, and 1 in Yemen (Al-Sufy 1992). In Saudi Arabia, 17 plants are located on the Red Sea coast and 6 on the Gulf. Three large-scale MSF plants are located at Al-Jubail, Jeddah and Al-Khobar with an annual production capacity of 394 mcm, 217 mcm and 83 mcm respectively. The locations of desalination plants in the Peninsula are shown in figure 2. There will be a review of desalination technologies and their role in alleviating current and future water shortages in a subsequent section.

Figure 2. Geographical location of desalination plants in the Arabian Peninsula



The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Renovated wastewater: Existing wastewater treatment facilities in the Arabian Peninsula face difficulties in handling the ever-increasing volumes of wastewater generated by increased water consumption and urbanization. Wastewater discharge from major urban centres is polluting shallow alluvial aquifers and the coastline and has caused urban water tables to rise. The main emphasis to date in these countries has been on simple disposal of wastewater, rather than on treating and reusing effluent owing to the extensive capital investment required. Planning for the full utilization of treated effluent remains in the early stages, and the regional treatment capacity is sufficient to handle only 40% of the domestic wastewater generated. The total volume of renovated wastewater used in the Arabian Peninsula is estimated at about 433 mcm, which is far less than the treated volumes. The reuse volumes are shown in table 2 and represent approximately 25% of the available treated wastewater.

Wastewater reuse ranges between 217 mcm in Saudi Arabia and 6 mcm in Yemen. The ratio of reuse to the domestic and industrial water requirements range from 27.7% to 30%. In the region as a whole, renovated wastewater meets about 2% of total water demand or 14% of domestic and industrial demand. In Saudi Arabia, reclaimed wastewater is used for irrigation of non-cash crops, landscape irrigation, and for industrial cooling. In Kuwait, Bahrain, the United Arab Emirates and Oman it is used for municipal irrigation of landscaped areas, while in Qatar it is used to irrigate animal food crops.

C. WATER REQUIREMENTS

Total demand: During the last decade, extensive development, rapid population growth and substantial improvement in the standard of living in the countries of the Peninsula have all intensified an imbalance between rising water demand and very limited existing water resources. Most of the countries have experienced a 20%-30% annual increase in domestic and industrial water demand over the last 10 years, mainly supplemented from desalinized water. Substantial increases in agricultural water use, as shown in table 3, were also experienced, particularly in Saudi Arabia.

Domestic and industrial water requirements are satisfied through desalination and by a limited portion of the groundwater pumping. Agricultural requirements are met through abstraction of water from shallow alluvial aquifers located in the coastal strips and inland basins and, more recently, are satisfied mainly from the deep aquifers covering most of the Arabian Peninsula. In Saudi Arabia, the rapid expansion of agricultural activities encouraged by the Government during the last 15 years has caused substantial increases in water demand, leading to extensive mining of the deep aquifers. Likewise, agricultural water demand has sharply increased in Bahrain, Oman, and the United Arab Emirates as a direct result of government policies encouraging self-sufficiency in food production. Government incentives and subsidies have made it possible for large areas to be cultivated, placing great strain on the existing ground-

TABLE 3. WATER DEMAND IN THE COUNTRIES OF THE ARABIAN PENINSULA FOR THE PERIOD 1980-1990

(Million cubic metres [mcm])

Country	1980		1990			Total demand (1980)	Total demand (1990)
	Domestic & industrial	Agriculture	Domestic	Industrial	Agriculture		
Bahrain	4,602	92	86	17	113	138	216
Kuwait	146	40	295	8	80	186	383
Oman	15	650	81	5	1,150	665	1,236
Qatar	50	60	76	9	109	128	194
Saudi Arabia	502	1,860	1,508	192	14,600	2,362	16,300
United Arab Emirates	229	560	513	27	950	789	1,490
Yemen	98	1,600	144	72	2,500	1,698	2,716
Total	1,086	4,862	2,703	330	19,502	5,948	22,535

water resources. High population growth, further improvement in the standard of living and continuation of the current agricultural policy will lead to increases in water requirements. Projected demand for the period 2000-2010 is shown in table 4, assuming a marginal decrease of agricultural water consumption. Availability of conventional and non-conventional water sources, as well as water requirements for various purposes, varies among countries of the Arabian Peninsula. The water supply and demand situations for each individual country of the southern ESCWA region are briefly reviewed below.

Saudi Arabia: In 1992, water demand for different sectors in Saudi Arabia was satisfied through desalinized water (795 mcm), surface water (900 mcm), shallow alluvial aquifers (950 mcm), reclaimed wastewater (217 mcm), and non-renewable deep aquifers (13.48 bcm). As of 1992, approximately 47% of the domestic demand was satisfied through desalination from 23 plants located in the coastal regions. The major cities which rely mainly on desalination are Jeddah, Mecca, Medina, Taif, Yanbu, Dammam, Jubail, Al-Khobar, Abha, Khamis, Mushat and Dahran as well as a large number of towns and villages located between these major centres. A large number of smaller coastal townships also rely on desalination for their water supply. Ambitious pipeline schemes were implemented to deliver desalinated sea water from the coast to the large inland cities of Riyadh, Mecca, Medina, Taif and Abha, as well as a number of towns and villages to meet growing demand. Desalination projects are being implemented to increase the annual supply from this source by 339 mcm.

Domestic demand experienced a threefold increase from 500 mcm in 1980 to 1.7 bcm in 1990, owing to urban expansion, improvement of the standard of living, lack of conservation measures, and excessive consumption. Future demand is expected to reach 2.9 bcm and 3.6 bcm in the years 2000 and 2010, respectively. Since the majority of domestic water demand has traditionally been satisfied through the use of desalinated sea water, the current production of 795 mcm will have to be increased threefold in order to meet the demand projected for the year 2010.

The major water consumer in Saudi Arabia during the last decade has been the agricultural sector (MOP 1990, Al-Tokhais 1992), where an eightfold increase has occurred, mainly through mining of the deep aquifers of Saq, Tabuk, Minjur-Dhruma, Wasia-Biyadh, Umm er Radhuma, Sakaka, Neogene, Damman, Jauf, and Aruma. Agricultural demand is forecasted to reach 21.7 bcm in the year 2010. However, owing to the present government decision to reduce wheat subsidies and limit crop production, agricultural demand will be maintained at the lower 1990 level. Groundwater abstraction for agricultural purposes is expected to reach 8.6 bcm and 11.9 bcm in the years 2000 and 2010, respectively.

Kuwait: Water demand is satisfied mainly through desalination, supplemented with a limited amount of groundwater and treated wastewater in amounts of 240 mcm,

TABLE 4. PROJECTED WATER DEMAND OF THE COUNTRIES OF THE ARABIAN PENINSULA FOR THE YEARS 2000 AND 2010

(Million cubic metres [mcm])

Country	Population (10^6)		Domestic and industrial		Agriculture		Total demand 2000	Total demand 2010
	2000	2010	2000	2010	2000	2010		
Bahrain	0.654	0.981	155	180	130	135	250	315
Kuwait	1.511	1.710	530	650	110	121	640	771
Oman	1.826	2.262	147	270	1,270	1,403	1,417	1,585
Qatar	0.425	0.525	140	184	185	204	334	388
Saudi Arabia	15.553	19.315	2900	3,700	9,500	11,500	12,400	15,100
United Arab Emirates	1.922	2.10	832	911	1,400	1,545	2,232	2,456
Yemen	17.75	23.45	360	640	3,250	4,000	3,610	4,572
Total	39.641	50.347	5,064	6,435	15,845	18,908	20,909	25,343

80 mcm, and 83 mcm respectively (Country Report, 1986, Bushnak 1990). Desalinated sea water is blended with small amounts of groundwater from the Neogene and Dammam aquifers to meet domestic and industrial requirements. Total water demand, including irrigation during the last 10 years, has increased from 186 mcm to 383 mcm. Demand is expected to reach 640 mcm and 771 mcm in the years 2000 and 2010, respectively. The major water consumer is the domestic sector, which relies mainly on desalinated sea water. Water requirements for the relatively modest amount of irrigated farming and urban landscaping are met mainly through the use of groundwater and treated effluent.

Bahrain: Water demand for the islands of Bahrain is satisfied mainly through deep groundwater sources supplemented with desalinated water and limited use of treated effluent. Water from the Neogene, Dammam, Rus, and Umm er Radhuma aquifers is used to satisfy most of the domestic, industrial and agricultural requirements (Al-Mansour 1986, Danish et al. 1992). The total annual water requirement increased from 138 mcm to 216 mcm from 1980-1990. It is expected to reach 250 mcm and 315 mcm in the years 2000 and 2010 respectively. Desalination now contributes approximately 56 mcm, while groundwater abstraction of 30 mcm meets domestic water requirements. The installed desalination capacity nowadays is inadequate to cope with the domestic demand. To bridge the gap, groundwater continues to be abstracted at an alarming level in order to meet domestic requirements and as well to satisfy the demand in the agricultural, industrial and commercial sectors. In 1991, the groundwater consumption from the water distribution network was on the order of 53.1 mcm. Similarly, the estimated groundwater consumption for agriculture and other purposes was in the order of 126.6 mcm, bringing the total to 179.7 mcm despite the preset maximum abstraction limit of 100 mcm required to maintain the balance between recharge and abstraction, as proposed by a consultancy firm engaged in 1981 to review the groundwater reserves.

Qatar: Water requirements are satisfied through groundwater from the shallow alluvial and the Rus and Umm er Radhuma deep aquifers, and from desalinated sea water. During the period 1980-1990, annual water demand increased from 128 mcm to 194 mcm (Al-Kenson 1986, Bushnak 1990). Domestic and industrial water requirements during the period 1980-1990 were satisfied mainly from a blending of 83 mcm of desalinated water with pumpage from the shallow aquifer. Agricultural water demand in 1990 was estimated at 180 mcm and will reach 200 mcm in the year 2000. Total demand is expected to reach 388 mcm in the year 2010.

United Arab Emirates: Total demand is satisfied through a combination of run-off diversion (75 mcm), groundwater exploitation, mainly from shallow aquifers (900 mcm), desalination (342 mcm) and reclaimed wastewater (62 mcm) (Country Report, 1986, Uqba 1992). Domestic water demand is being met through sea-water desalination and pumpage from shallow aquifers. Demand for water has increased substantially during the last 10 years, from 789 mcm to 1.49 bcm. This rise can be attributed to increased agricultural activities encouraged through government-sponsored financial incentives and to urban landscaping. Agricultural demand is met largely through groundwater abstracts from alluvial aquifers supplemented by pumping from the Dammam and Umm er Radhuma aquifers. Agricultural demand was estimated at 950 mcm in 1990 and is expected to reach 1.4 bcm and 1.55 bcm, respectively, in the years 2000 and 2010. Total demand is expected to reach 2.23 bcm and 2.45 bcm respectively in the years 2000 and 2010.

Oman: Oman's water requirement during the last 10 years has been satisfied through flood-water diversion (275 mcm), spring discharge (375 mcm), shallow alluvial (645 mcm), desalination (32 mcm) and reclaimed wastewater (10.5 mcm). Domestic water requirements are met mainly from shallow aquifers, supplemented by desalination. Agricultural water demand is satisfied mainly through exploitation of groundwater from shallow aquifers supplemented from the Neogene, Taqa, Aruma, Wasia and Saq aquifers. Traditional infiltration gallery systems known as qanats (aflaj), numbering more than 6,000, provide 50% and 70% of irrigation and water supply requirements respectively (Abdelrahman 1992). In 1980, water demand for various purposes in Oman was estimated at 665 mcm and increased twofold to 1,236 mcm in 1990. Agricultural water demand was estimated at 650 mcm in 1980 and 1.15 bcm in 1990. Demand for agricultural purposes by the years 2000 and 2010 is expected to increase to 1.27 bcm and 1.40 bcm, respectively. Total demand is expected to reach 1.42 bcm and 1.59 bcm in the years 2000 and 2010 respectively.

Yemen: Water demand for the now unified Republic of Yemen is met through the use of surface run-off (1.45 bcm), groundwater (1.7 bcm), and a limited amount of desalinated sea water (9 mcm) (Khoury et al. 1986, Mohamed et al. 1986). Domestic and industrial requirements are met largely through the use of groundwater from shallow alluvial and deep aquifers of Wajid, Wasia, Umm er Radhuma, Amran and Kohlan. Domestic and industrial demand, while relatively small in comparison with the rest of the countries in the Peninsula, has increased from 98 mcm to 216 mcm between 1980 and 1990 (Al-Fusail et al. 1991). It is expected that such demand will reach 360 mcm by the year 2000 and 640 mcm by 2010. Agricultural water demand is met largely through diversion of flood water and groundwater exploitation from shallow aquifers. Frequent rainfall produces a relatively dependable source of surface water. However, increased use of modern pumping technology has resulted in uncontrolled drilling, causing water consumption for agricultural purposes to rise from 1.6 bcm to 2.5 bcm in a 10-year period (1980-1990). At the current rate, agricultural requirements are expected to reach 3.2 bcm by 2000 and 4.0 bcm by 2010. Projected water demand for domestic, industrial and agricultural sectors in each country of the Peninsula, for the period 2000-2010, are shown in table 4.

Imbalance between demand and supply: Combined water demand in 1990 for all the countries of the Arabian Peninsula was estimated at 22.5 bcm. Consumption, by sector, was broken down as follows: agriculture (86%), municipal (12%) and industrial (2%). In 1990 the agricultural sectors consumed an estimated 19.5 bcm, with Saudi Arabia using the largest share, mainly from mining of deep aquifers. The estimated agricultural water demand is expected to decrease to 15.85 bcm by the year 2000 and 18.91 bcm by 2010, assuming an annual growth rate of only 1% from the 1995 level. This can be set against projected total water requirements for the Peninsula for the years 2000 and 2010 of 20.92 bcm and 25.34 bcm respectively, as shown in table 4. The major consumer, it is clear, will continue to be the agricultural sector. Based on current trends, future programmes and projections for individual countries, renewable water resources such as surface run-off, desalination, rechargeable alluvial aquifers, and reclaimed wastewater are already greatly insufficient to meet the expected demand. Supplies available from renewable sources for the years 2000 and 2010 are estimated at 6.71 bcm and 7.09 bcm respectively, as shown in table 5, which is far less than the projected water demand of 20.92 bcm and 25.34 bcm for the same years. It is expected that the deficit of 13.24 bcm for the year 2000 and 18.03 bcm for the year 2010 will be offset through the use of groundwater reserves, especially from the deep aquifers, as shown in table 5. Thus, by the year 2010, a total of 450 bcm will have been withdrawn, mainly for irrigation, reducing the total estimated groundwater reserves of 2,175 bcm by approximately 25%.

Expected domestic and industrial demand increases in the next 20 years will also necessitate the large-scale construction of additional desalination plants unless strict water conservation measures are implemented and good quality groundwater is used solely for domestic purposes. The countries on the eastern part of the Peninsula, namely Kuwait, Bahrain, Qatar and the United Arab Emirates and some parts of Saudi Arabia, are expected to face water shortages for the domestic supply by the year 2000, when existing desalination plants will reach the end of their operational lives. The groundwater in the deep aquifers under this area is usually highly saline and unfit for domestic consumption. If current domestic consumption patterns continue unaltered, countries in this region will be required to invest at least $30 billion towards the construction of new desalination plants and support facilities capable of handling future demand. A large number of waste treatment plants will also be required to handle the resulting wastes.

The major challenge facing countries of the Arabian Peninsula is to provide additional water supplies to meet the rising demand for the domestic water requirement. The imitation on the natural water supply imposed by quantity and quality constraints provides few feasible alternatives to alleviate the future demand-supply imbalance. The most logical alternatives are water desalination and reuse options, while implementing effective short- and long-term water management strategies. Desalination, currently a major water supply component, should be recognized as the most viable solution to future water shortages and must undergo further regional research and development to reduce the cost of production.

TABLE 5. PROJECTED WATER SUPPLY AVAILABILITY FOR THE YEARS 2000 AND 2010

(Million cubic metres [mcm])

Country	2000				2010			
	Surface[a/]	Reclaimed	Desalination	Groundwater[b/]	Surface[a/]	Reclaimed	Desalination	Groundwater[b]
Bahrain	-	42	141	67	-	53	141	121
Kuwait	-	80	428	132	-	106	428	237
Oman	227	50	68	1,072	227	61	68	1,229
Qatar	0.40	43	216	75	0.4	43	216	129
Saudi Arabia	900	710	1,290	8,600	900	1,000	1,300	11,900
United Arab Emirates	75	200	772	1,185	75	250	772	1,359
Yemen	1,450	36	10	2,105	1450	57	10	3,055
Total	2,652.4	1,161	2,925	13,236	2,652.4	1,570	2,935	18,030

a/ Diversion of surface run-off.

b/ Mainly deep aquifers.

The foregoing background material on the water supply and demand situation has demonstrated the vital role being fulfilled by the different sea- and brackish-water desalination processes. The next section highlights the important role that desalinated water will play in alleviating future water shortages.

D. WATER DESALINATION

Sea- and brackish-water desalination has been accepted worldwide as a viable solution to domestic water supply shortages. Technological advances, increases in water consumption and deterioration of water quantity and quality have necessitated increased reliance on desalinated water as a reliable resource in different parts of the world, especially in arid and extremely arid regions of the Middle East. Worldwide desalination capacity has increased substantially over the last three decades, from 0.2 mcm in 1965 to 18.8 mcm in 1993. The total number of desalination plants has increased from 1,500 in 1970 to 8,886 in 1993. Over the last decade, annual production increases in desalinated water ranged from 7% to 10%. Currently, two thirds of the world's total desalination capacity is installed in the Arab countries, mainly in the Arabian Peninsula, as shown in tables 6 and 7. Out of 18.8 mcm per day of desalination capacity, the countries of the Gulf account for over half of the production (53%). Saudi Arabia alone accounts for one fourth of world capacity in desalination. Three Arab countries, Saudi Arabia, Kuwait and the United Arab Emirates, rate first, third and fourth, respectively, in desalination capacity. The Gulf States of the Arabian Peninsula, namely Saudi Arabia, Kuwait, Bahrain, Qatar, the United Arab Emirates and Oman, are becoming increasingly dependent on desalination as their primary source of water, mainly for domestic purposes. Desalination of sea and brackish water has become an essential water supply component for many urban centres in these regions. This has compelled these countries to make substantial investments in desalination technology. The availability of financial resources from oil income, and free energy sources, has further encouraged reliance on water desalination as a primary source of water. These factors, in conjunction with natural supply limitations, make it likely that reliance on desalination will continue to increase in the future. Future projections indicate that more investments in desalination technology will be required to offset over-exploitation of water resources and increased public demand.

Desalination technology: Current desalination technology for sea and brackish groundwater can be classified according to the energy source used: either thermal- or electric-powered. Desalination processes that utilize thermal energy are multi-stage flash (MSF) and multi-effect distillation (MED). Desalination processes that use electric power are known as vapour compression (VC), reverse osmosis (RO) and freezing. There are other desalination processes which depend on solar energy and a combination of thermal and electric power, and these are currently being emphasized. Most of these desalination techniques have advantages and limitations depending on the quantity and quality of water required, and the site requirements.

TABLE 6. DESALINATION CAPACITY SOLD WORLDWIDE

Region	Percentage sold	GCC countries	Percentage sold
North America	13	Saudi Arabia	51
Europe	5	Kuwait	16
Gulf Cooperation Council countries	53	Qatar	6
Remaining Middle East	10	United Arab Emirates	22
Asia	8	Bahrain	3
Other countries	11	Oman	2

TABLE 7. DESALINATION CAPACITY SOLD IN ARAB COUNTRIES DURING THE PERIOD 1963-1993 (BUSHNAK 1995)

Country	Total capacity (cubic metre/day)
Bahrain	315 197
Egypt	87 044
Jordan	8 445
Iraq	333 093
Kuwait	1 523 210
Oman	162 096
Qatar	562 074
Saudi Arabia	5 020 324
Syrian Arab Republic	7 703
United Arab Emirates	2 081 091
Yemen	37 188
Algeria	204 312
Djibouti	404
Libyan Arab Jamahiriya	666 750
Morocco	15 325
Mauritania	4 654
Somalia	408
Sudan	1 776
Tunisia	50 914
Total	11 093 008

Thermal processes of desalination, especially the MSF, have been used extensively in the Arab world. In the MSF system, water to be desalinated first enters a brine heater. Hot brine is subjected to reduced pressure, which causes it to boil immediately. A portion of the brine is instantaneously transformed (flashes) into vapour. The hot brine continues to move through a series of chambers at increasingly lower temperatures and pressures, vapourizing in the process. The vapour is then recondensed into purified water. MSF plants have anywhere from 20 to 50 chambers through which the water must pass. The higher the number of chambers, the more efficient the desalination process is. More chambers also translates into higher initial construction costs; however, production will be more cost-effective. This method of distillation was developed in the late 1960s. The first plant to use this method of desalination was constructed in Kuwait in 1977. Following the development of this method, approximately 70% of desalination plants used it. However, new, more efficient methods were subsequently developed, and as at 1991, only about 50% of the plants still in operation use this method.

Multi-effect distillation (MED) was originally developed for large-scale operations and was in use before the MSF system was developed. In this method, water is fed through a series of horizontal evaporator tubes. This method results in a 40%-65% recovery rate; however, maintenance and operational difficulties resulted in a decline in use. It is currently used in only 6% of operational plants, mainly those constructed in the 1960s. The MED method is also based on evaporation. Ejector steam, coming from an ejector chamber, is transferred into a series of evaporation tubes under low pressure. Sea water is sprayed on the outside of the tubes, and the latent heat from the steam causes it to vaporize. This steam moves into pipes where it condenses and is turned into distilled water. The condensed steam also supplies heat for continued vaporization of sea water. The process is continual, with each evaporator serving as a condenser for the steam created in the previous evaporator. Steam from the last evaporator is condensed and released into the cooling system.

Electric-powered desalination processes are based on the concept of the heat pump. Vapour compression involves the use of compressed water vapour. Compressing the water vapour increases its enthalpy and temperature. Thus, it can be used as a source of heat resulting from condensation in an evaporator. The energy required to compress the vapour can be supplied by either a mechanical vapour compressor or jet ejectors.

Reverse osmosis (RO) uses pressure to separate the salts from the water. This method can reduce the salinity of sea water from 40,000 ppm to 400 ppm. In this method, the pressure of a sea-water solution is raised above osmotic pressure. The solution then is passed through a semi-permeable membrane, which allows the water to pass, but filters out the dissolved solids. There are several types of membranes, including tubular, plate and frame, hollow fine fibre and spiral wound. The most widely used types are the spiral wound and the hollow fibre types. Required osmotic pressure for brackish water ranges from 200 to 500 psi, and for sea water the range is 800 to 1,200 psi. RO plants usually operate at a recovery rate anywhere between 20% and 50%.

There are several alternative methods of desalination including electrodialysis (ED) and freeze desalination (FD). However, these have not been developed sufficiently to allow large-scale use. In the freezing method, a solution is partially frozen. During the process of freezing, impurities are naturally excluded. After being frozen, the ice crystals are washed to remove impurities and then melted to form purified water. Owing to the complexity of this method, only a few plants of this type have been constructed. A solar-powered freezing plant was constructed as an experimental project in Saudi Arabia. Since the process was shown to be inefficient, the plant was disassembled.

Electrodialysis purifies water by filtering out separate ions. Cation- and anion-permeable membranes are used, and the stream of water solution is subjected to a direct electric current. This causes ions which carry electricity to migrate across the stream and through the membranes. Cations travel through a membrane on one side, while anions travel through the membrane on the other side. The result is desalination. Electrodialysis has not been very successful in the desalination of sea water and is used mainly for brackish water.

Brackish-water desalination is being used more nowadays to reduce the salinity of groundwater. Desalination plants for groundwater are usually found inland near urban centres, especially in the Gulf countries of the Arabian Peninsula. Such plants generally have smaller capacities on the order of up to 20,000 m^3 per day in comparison with large sea-water desalination plant capacities which exceed 100,000 m^3. To desalinate a large volume of water would require drilling a large number of wells. Brackish water desalination usually uses the reverse osmosis process. Owing to low salinity, the cost of treatment is much lower than sea-water desalination, usually ranging from \$0.3 to \$0.65 per m^3. In addition, the cost of water production depends on plant size and also on the concentration of certain salts, such as silicon, heavy metals and organic material. The major cost components consist of investment in well-drilling and pumps, and brine water disposal. The disposal of brine presents a major environmental constraint of brackish water desalination. Careful consideration is usually needed to avoid contamination of the groundwater source.

More than 80% of desalinated water in the Gulf region is produced through MSF distillation. RO accounts for 16.1%. This translates into three quarters of the world capacity for MSF desalination, and about one quarter of RO production. The Gulf countries share in MED, ED and VC, as well as other processes, at the respective rates of 16.4%, 16.6% and 5.5%.

Experience with the desalination of sea water and brackish groundwater within many of the Gulf States began as early as 1938. This technological know-how contributed significantly to the initial depletion of natural water supplies, particularly in Saudi Arabia and Kuwait. Currently, the largest desalination centre in the world is located in Al-Jubail, in the eastern province of Saudi Arabia. One third of the desalinated water for Saudi Arabia is produced at this plant, equivalent to 7.5% of world capacity. The plant consists of 40 MSF units producing approximately 1 million cubic metres of desalinated water. The desalinated water is transferred through pipelines having a total length of over 3,000 km, and a total capacity of 1.8×10^8 m^3/d. One of these pipelines runs as far as Riyadh, which is 465 km from Al-Jubail, and the other delivers water to Qasim. A considerable number of urban centres are being supplied with desalinated water through this system.

The characteristics of different desalination processes relevant to their suitability and disadvantages is shown in table 8. The volumes of desalinated water produced by the Gulf States of the Arabian Peninsula, under different desalination processes are shown in table 9. The planning of desalination facilities requires extensive technical and financial evaluation of all major factors such as investment and energy costs, site requirement, choice of desalination process, quality of feed water, and quantity and quality of desalted water.

The cost of building a desalination plant depends on its production capacity, type of process, plant location, and available utilities and services on site. It also depends on the degree of plant reliability, the specifications of the material of construction, and the desired plant life.

Capital costs: Plant-capital and operating-unit cost decreases significantly as plant capacities increase up to about 3 MGD for brackish water and 5 MGD for sea water (Bushnak 1993). Beyond these limits, costs decrease only slightly as plant size increases. The rate of cost decrease with increasing size is more significant for thermal processes compared with RO or ED. RO and ED costs for desalting brackish water are about equal, with each having unique advantages depending on feed-water quality.

By the 1980s the costs of desalinating sea water using RO or distillation for plants larger than about 5 MGD had become roughly the same—about $1.5 per cubic metre. Dual-purpose plants for production of power and water can lead to distillation cost reductions of 20% to 30% compared with the overall cost of separate power and desalination plants.

TABLE 8. CHARACTERISTICS OF DESALINATION PROCESSES (DABBAGH ET AL. 1993)

Method of desalination	Advantages	Disadvantages
Multi-effect distillation (MED)	* High production capacity * Low capital costs * High purity (<30 ppm) * Energy input independent of ppm * Minimal skilled operator	* Dependence of output on local power availability * Long construction period * Difficult to control water quality * Low conversion of feed water (30%-40%) * Labour-intensive * Large space and material requirements
Reverse osmosis (RO)	* Suitable for both sea and brackish water * Flexibility in water quantity and quality * Low power requirement compared with MED and VC * Flexibility in site location * Flexibility in operation start-up and shut-off * Simple operation	* Low quality (250-500 ppm) * Requires high-quality feed water * Relatively high capital and operating costs * High pressure requirements * Long construction time for large plants
Vapour compression (VC)	* High water quality (20 ppm) * High operational load * Short construction period * Small space requirement * Operation and production flexibility	* High operational costs * High energy consumption * Lack of water quality control
Electrodialysis (ED)	* Low operating and capital costs * Flexible energy source * High conversion ratio (80%) * Low energy consumption * Low space and material requirements	* Low to medium brackish water capability (3,000 ppm) * Requires careful pretreatment of feed water * Low production capacity * Purity affected by quality of feed water

TABLE 8. *(continued)*

Method of desalination	Advantages	Disadvantages
Multi-stage flash (MSF)	* Flexibility in salinity of feed water * High purity production (< 30 ppm) * High production capacity * Low skill requirement * Production of both water and electricity * Low energy input	* Labour-intensive * Low conversion ratio (30%-40%) * Requires pretreatment of feed water * High operating costs * High construction requirements * Limited potential for improvement

TABLE 9. DAILY DESALINATION CAPACITIES OF THE GULF STATES (1991)

(Millions of cubic metres)

Desalination process	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates	Total
Multi-stage flash	160 820	1 350 514	134 645	368 025	2 678 135	1 503 745	6 213 884
Reverse osmosis	119 343	51 783	19 336	4 715	954 009	93 692	1 242 878
Multi-effect distillation	1 175	4 904	4 200	3 642	16 456	8 266	38 643
Electrodialysis	13 914	4 493	719	896	94 638	5 102	119 762
Vapour compression	2 589	150	1 504	1 994	49 578	41 552	97 367
Other	-	1 766	177	917	7 213	2 800	12 873
Total	297 841	1 413 610	160 581	398 189	3 800 029	1 655 157	7 725 407

Operation and maintenance costs: This includes the costs of energy, labour, chemicals, consumables, spare parts and major replacements or refurbishments required over the life of the plant. Increasing the energy efficiency of desalination plants usually requires more equipment and capital. The energy requirement to produce 1 cubic metre of potable water from sea water is about 5 kW or less for a well-designed RO plant utilizing energy recovery devices. Other processes require higher equivalent energy per unit of water produced, but usually of different quality (i.e. steam).

Energy costs account for about 20% to 30% of desalination unit water cost using international energy prices. In general, for low salinity water (less than 3,000 ppm), ED is the most energy-efficient process to produce 1 cubic metre of potable water. As the salinity of feed water increases above 3,000 ppm, RO becomes the most energy-efficient process. The energy input is a function of water salinity and plant design. To desalt 1 cubic metre of sea water, RO uses 9 to 12 kilowatts of electric energy. This energy consumption rate can be reduced by 20% to 30% using energy recovery devices connected to the brine stream (Bushnak 1993, Sadeqi et al. 1993, Al-Sofi 1993, Buros 1990). Reductions of 50% have been reported in some tests, but field experience of all energy recovery devices is still limited to date. Distillation is energy-efficient only when there is a source of low-cost steam, such as in power plants. A recent study (Al-Arrayedh, 1993) analysed the impact of oil prices on unit water cost, and the results indicated the cost of water produced by MSF doubled as the oil price rose from zero to $30 per barrel, while the cost of sea water desalted by RO increased by only 20%.

Labour cost varies from 15% to 30% of operation and maintenance (O and M) costs, depending on plant type, size and location, as well as the skill of the operators. The experience and skill of operators is the major determinant of other O and M costs, plant reliability and plant life. Plant automation is desirable in general to increase plant reliability but may only be economical in large plants. For small plants, automation may decrease the number of operators required but not necessarily their cost, inasmuch as more qualified staff will be required.

Chemical consumption costs represent less than 10% of O and M costs for MSF plants but may exceed 20% for RO plants. Experience indicates that chemical cost is a function of the operator's skill and commitment to cost reduction (Al-Sofi 1993). Major cost reductions can be achieved through process optimization for a given site and plant design. There are cases where chemical cost can be as low as 1% to 3% of total water production cost (Al-Sofi 1993, Largier et al. 1993).

Water source and production costs: The source and quality of feed water is a major cost factor. Desalting sea water, using either distillation or RO, can be from three to as much as seven times more expensive than desalting brackish water using

RO or ED. Distillation costs are high, regardless of feed water quality, owing to the larger amount of energy required to vaporize water (Bushnak 1993, Wagnick 1994). RO and ED costs are very sensitive to feed water salinity and quality. ED tends to be more economical than RO at salinities of less than 3,000 ppm and less economical than RO at salinities greater than 5,000 ppm. All costs depend to a large extent on pre- and post-treatment requirements, particularly for RO. Beach wells are a preferred source of sea water for RO plants, compared with an open sea-water intake. If plant location and ground conditions allow the use of beach wells, the cost of developing a proper feed water source could be a large percentage of the total cost of a plant.

Any one of the distillation processes can produce comparatively pure water. Manufacturers typically submit bids containing warranties that total dissolved solids (TDS) will be less than 25 ppm and, in some bids, less than 10 ppm (Bushnak 1993). However, such pure water is very aggressive, causing excessive corrosion of the distribution pipeline network. In addition, potable water needs a minimum salt content to give it a desirable taste. Potable water from distillation plants is achieved by adding lime or mixing with brackish water to obtain TDS of about 200-500 containing calcium ions. This post-treatment causes a marginal rise in the cost of the final product water.

The product water of RO processes, on the other hand, is a function of the level of salinity of sea water, the number of stages of RO membranes, and other design parameters. Most RO membranes allow less than 1% salt passage in a single stage, resulting in TDS levels of 300-400 ppm of product water. This salinity level can be further reduced by using a second stage membrane at additional cost. Potabilization would be as essential since TDS are over 90% NaCl.

Cost of financing: Desalination plants require major initial capital outlays that need to be depreciated over plant service life, which could be 30 years or more. Hence, the cost of capital has a significant impact on unit water cost since capital contribution is about 50% to 60% of unit water cost. A recent analysis (Al-Sofi 1994, Sudeqi 1994) of actual bid data for a large MSF desalination plant in the Gulf indicates a large variance of the capital contribution to unit water cost over plant life, which was specified as 25 years.

Cost allocations between water and power in dual-purpose plants has a major impact on unit water cost. This factor has been demonstrated by Al-Sofi (1994) using the actual cost data of an existing major plant in the Gulf. The result of the study demonstrated that the unit water cost ranged from \$0.125 per m^3 to \$1.125 per m^3 with various assumptions on allocation of the cost of components, cost of energy, and capital cost. Gulf countries use different cost allocation assumptions, since some consider water a secondary product of dual-purpose plants, while others consider it a primary product.

Cost comparisons using different desalination processes ranged from \$1 to \$3.5 per m^3 for sea water, and \$0.4 to \$1.5 per m^3 for brackish water. A survey of water production costs indicates wide variation depending on plant size and energy prices. Usually, costs decrease with increased plant capacity. Costs reported by the Gulf countries are usually less than for countries in the rest of the world because of minimal energy charges. For example, the cost of water production in Saudi Arabia ranges from \$0.48 to \$2.2; in the United Arab Emirates water costs from \$1 to \$1.45; and in Qatar, the range is \$1.14 to \$1.64. A sample of water production costs in different parts of the world, including the Arabian Peninsula, is shown in table 10. In general, water production costs in many of the ESCWA member countries where desalination is used extensively, cost distributions are as follows: 38% for capital investment, 20.5% for energy, 21.3% for labour, 16.2% for maintenance and 4% for chemicals.

1. *Desalination opportunities*

Water desalination in some of the ESCWA member countries, particularly the Gulf States, has offered flexible opportunities for alleviating water supply shortages over the past two decades. Water quality has been substantially improved, which in turn contributes to the well-being of society in relation to sanitation, health and quality of life. Desalination also provided a reliable water source and resulted in increased urban, commercial and industrial activities.

One of the major problems previously associated with the production of desalinated water was the high cost associated with initial capital investment for construction and operation. This posed a major problem to those countries with limited financial resources. Currently, however, desalination technology has been developed to the point where it can provide a reliable source of water at competitive costs. In fact, for many of the ESCWA member countries, especially those of the Gulf, desalination by large-scale plants has proven to be a more economical alternative than constructing new dams or pipelines to supply water from other regions, taking into consideration required water quality standards, and political vulnerability.

Several of the Gulf countries, however, have no option but to rely on the desalination of sea water or brackish groundwater. This is because freshwater supplies in the region are very small, and the quality is often in excess of 1,000 ppm owing to limited recharge magnitude. The deep aquifers usually contain highly saline water requiring desalination. The same conditions exist for some coastal areas of Saudi Arabia and areas in the north and southern regions of the Arabian Peninsula. Costs associated with the development of deep fossil groundwater sources in these areas would be comparable to sea-water desalination, taking into consideration pumping, transportation and treatment cost. Most of the aquifers with good water quality are located at great depths and in remote areas far from urban centres.

TABLE 10. COST SURVEY OF DESALINATING SEA-WATER

Country	Process	Capacity (m^3/day)	Year	US$ per cubic metre
Bahrain	MSF	23 000	1975	0.56
Canary Islands	RO	36 000	1989	1.62
Malta	RO	15 000	1986	1.18
Saudi Arabia (Al-Jubail)	MSF	1100 000	1980	2.36[b/] 2.61[c/]
Saudi Arabia (Jeddah)	RO	57 000	1989	0.48
U.S.A. (Florida)	MSF	10 000	1967	0.22[a/] 2.69
U.S.A. (Virginia)	MED	26 000	1991	2.06

a/ Initial period of operation: 1967.
b/ Fuel substitutes as 0.22/MBTU.
c/ Interaction mark of $2.25/MBTU.

Based on the conditions in the ESCWA member countries, past experience indicates that desalination is a viable solution for the provision of potable water. A number of solutions have been suggested to alleviate regional water shortages, including: mining of groundwater, desalination, wastewater reuse, icebergs, and short- and long-distance conveyance systems either through pipelines or tanker trucks. Costs of wastewater treatment, as reported by some of the Middle Eastern countries, range from $0.12 to $0.41 per m^3 for secondary treatment level (World Bank, 1993). However, cost substantially increases as the level of treatment to meet normal environmental standards increases. Good quality renovated wastewater can help alleviate water shortages, particularly in the industrial and agricultural sectors. However, this option is not suitable for domestic requirements owing to the fact that it is unacceptable to the public, and costs would be prohibitive for tertiary level treatment in the majority of the Gulf countries. In addition, social non-acceptance and uncertainty concerning water-borne viruses discourage large-scale use of recycled wastewater. The cost of tertiary treatment of wastewater ranges between $0.54 to $2.2 per m^3. However, the high cost of desalination technology is expected to be offset, in the near future, by the promise of innovative hybrid processes such as chemical separation processes (adsorption or ion exchange) in combination with physical processes such as membrane filtering, which will render this method comparable in cost to tertiary treatment of wastewater. Additionally, such technology will result in nearly 100% water recovery, which will improve plant efficiency and reduce or eliminate waste. The use of electrically charged membranes to filter out impurities also appears to be promising.

Alternative options for regional water importation schemes such as iceberg towing, pipeline systems, tanker trucks, and large capacity rubber (Medusa) bags, require substantial initial investments for the construction of canals, pipeline systems, and pumping stations to convey water over long distances, through a variety of natural terrains, and possibly through several countries. The towing of icebergs to the shores of Saudi Arabia was considered as an alternative to desalination. However, such major technical difficulties as the mode of transport, entry into the Red Sea or the Gulf, availability of receiving facilities, and environmental impact made this alternative unacceptable. Some of these technical problems could have been solved by a prototype design, but the cost of the water would have been extremely high, and continued availability was in question. Given the political instability of the Middle East, water consumers could possibly be subjected to supply interruptions where water must be transported internationally. Another example of a water importation scheme was the proposed Turkish "Peace Pipeline". This supply system was to service a number of countries in the Middle East and would supply 15 million people with 350 l/p/d (Dabbagh et al. 1993). At a cost of \$20 billion and with a construction period of 8 to 10 years, the initial capital costs would range between \$1.735 and \$1.758 per m^3 of water delivered. A dual-pipeline system would transfer water to the Gulf States from rivers in Turkey that flow towards the Mediterranean. The pipeline was designed to move 2.2 billion m^3 of water per year, with approximately half of the volume going to Jordan and the Syrian Arab Republic, and the remainder delivered to the Arabian Peninsula. The large western pipeline would pass through Jordan and the Syrian Arab Republic and terminate in Mecca in western Saudi Arabia. The smaller eastern pipeline would cross Iraq and the Syrian Arab Republic and pass down the western side of the Gulf, supplying water to Kuwait, the eastern province of Saudi Arabia, Bahrain, Qatar, the United Arab Emirates and Oman. Saudi Arabia and Kuwait would be supplied with 840 million m^3 and 220 million m^3, respectively. Although this importation of water would ease water shortages in the region, countries in the Arabian Peninsula were concerned about the political implications of becoming dependent on upstream States for the security of their water supply. In addition, the pipeline system would be vulnerable to sabotage and could potentially be used for political coercion; therefore, this alternative was not acceptable. In addition, there would have been a number of incidental costs, such as charges for water provided by the supplying country, toll charges for countries through which the pipeline would pass, and operational and maintenance costs including pumping, energy costs and costs for replacement parts, as well as treatment costs. In general, desalination would be at least as economical as such a pipeline system.

Two other importation proposals involved pipelines under the Gulf: one from the Garon river of the Islamic Republic of Iran to Qatar, and the other from Pakistan to the United Arab Emirates. The Islamic Republic of Iran-Qatar scheme involved a 1.5 metre diameter gravity pipeline extending 770 km, 560 km of which were within Iranian territory. The system was to provide Qatar with an estimated annual volume of 135 million m^3. The cost was estimated at $1.5 billion and completion time was estimated at three years. Considering the political instability of the region, major concerns regarding the guaranteed life of the project would arise. The current strained relations between Turkey and the neighbouring Arab countries of the Syrian Arab Republic and Iraq clearly demonstrate the vulnerability of such a system to interruption or cessation of supply owing to unforeseen political situations. In addition, the cost of water delivered through such a system is high, as illustrated by a pipe transport system constructed to deliver water from the coastal zone of Saudi Arabia to the interior cities: water costs were in excess of $1.5 per m^3.

Tanker trucks have been suggested as an alternative means of water importation to provide freshwater to the countries of the Arabian Peninsula. The mode of transport is either through back-haul or shuttle tankers (Al-Laylaa 1991). Back-haul consists of using a crude oil tanker to carry freshwater back to water-deprived areas, and the shuttle method involves the use of dedicated water tankers that carry only water to be delivered, and then return empty to the country of origin. Major concerns are the cost of water, required treatment and the dependability of the supply. Costs associated with the back-haul means of providing water include the cost of the water at the source, transportation costs, loading and unloading costs, and costs associated with pipeline infrastructure to convey the water to urban areas. In addition, availability could possibly be limited in direct relation to the oil market. The cost of water delivered by these methods was estimated in 1991 at $1.61 per m^3 (Al-Layla 1991), with transportation accounting for $1.2 of that amount, $0.2 to $0.75 for water purchase, and $0.04 to 0.07 for tanker cleaning.

In order to make dedicated tanker transport cost-effective, large-capacity trucks would have to be used over short distances, with rapid loading and unloading times. The estimated cost of this method ranges between $1.30 and $1.75 per m^3, including the purchase price (Al-Layla 1991). The major limitations were capital investment to purchase the tanker fleet, associated operation and maintenance costs, and storage, loading and unloading facilities.

Costs for the rubber bag method of transport, wherein large bags of freshwater are towed through the Mediterranean and Red seas, were estimated at $22 per m^3. This did not include the cost for loading/unloading, storage or distribution. As is evident, the water would be extremely expensive.

All of these methods involve an element of uncertainty, particularly in terms of long-range planning. The current estimates of the cost of water importation and delivery often exceed those for desalination, especially in the Gulf countries, where energy is both abundant and inexpensive. Funding for desalination is more flexible: the capital expenditure for desalination can be carried gradually in stages (Dabbagh et al. 1993), whereas a pipeline must already be in place before water delivery can be made.

Groundwater resources in the ESCWA member countries are already being mined at a rate that far exceeds natural replenishment. This leads to a drop in the water level, making water increasingly more expensive to process because deeper wells are required, as well as pumping and casting costs. Some deep aquifers are located at a depth of 1 km or more. Production costs are reflected in the depth to the groundwater table, the efficiency of the equipment, and height of the water tower required. Groundwater from shallow alluvial aquifers is much cheaper to recover than that contained in deep aquifers; however, capacity is limited. Fossil groundwater is more abundant owing to extensive aerial coverage of some of the deep aquifers throughout the Arabian Peninsula. For example, the cost of water production from shallow aquifers in Saudi Arabia ranges from \$0.2 to \$0.6 per m^3, energy costs being subsidized. In comparison, production costs for water from deep aquifers ranges between \$0.4 and \$1.1 per m^3, including treatment costs. The cost of groundwater in Jordan is estimated to be \$0.41 for shallow aquifers, while for deep aquifers the cost is comparable to desalinated water produced in the countries of the Peninsula.

The above review of the various water production and importation schemes indicates that desalination can be a cost-effective answer to water shortages. The output of a desalination plant can be adjusted according to capacity limits. They can be constructed in close proximity to urban centres where the water is to be used, making the system less vulnerable to outside intervention, especially for inland facilities. In addition, technological developments may lead to further reduction in water production costs, making desalination a more attractive and cost-effective means of providing water. The costs of producing desalinated water in different parts of the world are shown in table 10. Low production costs for the Gulf States of the Arabian Peninsula is attributed to energy subsidies. The cost of electric power generated by the desalination plants and sold to the public is included in the estimation of water production costs, depending on plant capacity. Production costs range from US\$ 1.3 to US\$ 2.02 per m^3, as shown in figure 6. Current cost estimates show that desalination is economically competitive and can be less expensive than either pipeline systems or truck transport.

2. *Desalination constraints*

The major constraint to worldwide utilization of desalination technology is the high cost of production. High capital investment in desalination infrastructure, together with energy costs, poses a major limitation to many countries. The availability of financial resources and subsidized energy costs has resulted in increased utilization of desalination without regard for efficient energy use. This has resulted in high production costs. Increased oil prices, however, have resulted in concentrated efforts to streamline and economize the desalination process in order to make it cost-effective. Currently, trends in desalination include dual-purpose plants that provide water as well as energy. This is expected to reduce not only energy consumption but water production costs as well.

Another important consideration for countries that depend largely on desalination is the possibility of sabotage or a sudden breakdown of the plant. Sabotage, unfortunately, cannot be entirely eliminated. However, desalination technology is currently geared towards the improvement of infrastructure and longevity within the plant, so that the likelihood of plant shut-down is minimized. Improvements in technology, however, have reached a point where desalination has become competitive with traditional water sources, and advances are expected to continue until the method is perfected as far as possible.

The construction of a large number of desalination plants may have detrimental effects on the surrounding ecosystems. Early desalination plant construction emphasized water and power production with little consideration for environmental impact. Desalination plants can cause air and water pollution as a result of the combustion process they employ. The release of carbon oxides and other gases into the air affects air quality of the surrounding area. Water pollution may result when concentrated brine is discharged back into the feedwater source. Discharge effects may be categorized as physical, chemical or biological, owing to increased salt concentration and to residual treatment chemicals and trace elements picked up within the plant. Physical effects refer to the consequences of releasing hot brine. Chemical effects occur as a result of increased brine concentration, treatment chemicals remaining in the brine, as well as trace elements resulting from corrosion. Biological effects are the change in biological oxygen demand in the water from its intake value to its final value at the point of discharge. The degree of brine salinity depends on the original salinity of the feed water and the amount of desalinated water which has been extracted. Recovery from sea water produced intensifications ranging from 20% to 68% depending on the type of desalination process used. This translates into a concentration ratio of 1.25 to 3. Reverse osmosis and electrodialysis range from 50% to 90%, with corresponding salinity concentrations 2 to 10 times greater than the original feed water. Treatment chemicals and internal plant corrosion cause heavy metals such as copper, iron, nickel, and molybdenum to be released in the brine. The amount of ions is directly related to the water's pH and the concentration of materials released from the plant. Evaluation of the effects of discharge depends, to a large extent, on the physical characteristics of the marine environments where the brine is released. Environments that are semi-closed or inhabited by sensitive or high-value organisms are most vulnerable. Effects in an open environment with active currents will only be noticeable within 300 metres of the discharge point.

Inland disposal is resorted to when desalination plants are located far from large water bodies. This is usually the case with RO and ED desalination of brackish water. Options for brine disposal in this case are: pumping into evaporation ponds, injection into deep underground formations, spreading on unusable arid land, discharge through pipelines into sewers, rivers or other water bodies, or concentration of solid salts. Cost plays an important role in choosing the method of disposal. Costs may range from 5% to 33% of the total cost of desalination, depending on waste concentration characteristics, level of treatment before disposal, the means of disposal and the nature of the environment where disposal takes place. While deep well injection may cost between $0.1 and $1.15 per 1,000 gallons of desalinated water, properly constructed lined evaporation ponds may be more costly. Concentration of salts using solar evaporation may cost between $1.15 and $1.85 per 1,000 gallons. Regardless of the type of land disposal used, there is always a risk of groundwater contamination, but the salt concentration method is the least invasive.

Intake effects may result when raw water needed for desalination purposes is either screened to remove aquatic organisms, or when the filtered organisms are exposed to high temperature and pressure conditions within the plant. Both of these effects increase the mortality rates for aquatic plants and animals of all types.

Future desalination: The current installed capacity of Government-owned desalination plants in the Arabian Peninsula is 2.02 bcm. Dependence on desalinated water has substantially increased during the last 15 years in most countries. Kuwait and Qatar seem to have sufficient desalination capacity to meet all of their current domestic and industrial water demand, while in Saudi Arabia, the United Arab Emirates, Bahrain and Oman, desalination accounts for between 47% and 75% of the domestic and industrial public supply. Only Yemen, with more rainfall, places little reliance (5%) on desalination.

Additional desalination tends to be regarded as the easiest means of meeting the ever-increasing demand for water in the region. Most of the countries are constructing and planning significant expansion of their desalination capacity to meet future water requirements, as shown in table 7. Saudi Arabia, the largest producer of desalinated water in the region, is constructing additional plants with a capacity of 126 mcm for the major cities of Medina, Yanbu, Jeddah and Al-Jubail. Future plans call for an additional capacity of 213 mcm for the cities of Jeddah and Al-Khobar. The United Arab Emirates is also expected to increase its desalination capacity by 270 mcm in the near future for its urban centres at Abu Dhabi and Dubai. Kuwait is planning to increase its desalination capacity by 110 mcm by 1997. In Qatar, the current desalination capacity of 112 mcm at Ras Abu Fontas will be raised by 16 mcm in the near future, and an additional capacity of 88 mcm will be added to the system by the end of this century. In Bahrain, desalination capacity reached 75 mcm in 1993, and 25 mcm of further capacity is proposed for Maharraq City, while a further 40 mcm of capacity is being studied as part of a privatization scheme for power and water. In

Oman, the current desalination capacity is 55 mcm and will be increased by 13 mcm with the construction of several smaller units by 1995. Current and future capacities for countries of the Peninsula are shown in table 11. They will reach 2.92 bcm by the year 2000.

Desalinated water now constitutes 51% of the region's domestic and industrial water and is expected to constitute 58% by the year 2000. However, many existing desalination plants are heading towards the end of their economic life. In addition to the costs of new capacity (at least $30 billion as mentioned above), a huge investment estimated at approximately $20 billion will be needed after the year 2000 to replace the large number of ageing plants constructed during the period 1975-1985. The capital cost of new units is increasing, and operation and maintenance costs for desalination plants are very high as well. The average cost of desalinated water reaching the end user in the region ranges from $0.5 to $2.5 per m^3 (Bushnak 1993). Higher costs are expected for locations dependent upon small-scale desalination plants. Budget allocations for desalination have been adversely affected by falling oil revenues and by increased expenditure on regional defence. Many proposed new desalination projects are being delayed by budget restrictions, and new approaches, such as privatization plans, are being given serious consideration by several of the countries of the Arabian Peninsula.

Technological evolution and development: Overexploitation of available water resources and increased water demand worldwide has focused attention on existing desalination technology to bridge the gap between supply and demand. Major development efforts over the last 10 years have focused on the improvement of energy efficiency and membrane performance and replacement. Current technological trends are oriented towards the use of hybrid processes with emphasis on innovative combinations of chemical-physical and electrochemical methods. The integration of desalination and energy production facilities provides an incentive for reduced desalination energy costs. Energy costs represent a major portion of the total cost of the desalination process. The Gulf countries report lower production costs in comparison with the rest of the world, owing to energy subsidies. Efforts are currently being geared towards the use of a single energy source to perform several functions within the plant, a process known as cogeneration. Hybrid desalination processes have been developed in which sea-water plants using various processes are built at the same site, making use of the electrical and thermal energy produced in the process. Such plants use evaporation processes in combination with reverse osmosis. Electrical energy is supplied by local power facilities or by gas-turbine generation, and heat from the power plant is used to preheat feed water for the desalination plant. A portion of the electricity generated and exhaust heat from the turbine would power the desalination plant. This combination improves the efficiency of energy utilization. A cogeneration scheme involving an RO plant would include using part of the electricity generated to power the desalination plant, with the remainder being sold to the public. Exhaust heat from the gas turbine could be used to provide steam to operate thermal

TABLE 11. DESALINATION SCHEMES IN EACH COUNTRY OF THE ARABIAN PENINSULA

Country	1990				2000			
	Installed desalination capacity (mcm)	Desalination production (mcm)	Domestic/ industrial demand (mcm)	Desalination to demand ratio (mcm)	Planned desalination capacity (mcm)	Total desalination capacity (mcm)	Domestic/ industrial demand (mcm)	Desalination ratio (%)
Bahrain	75	56	103	54	66	141	155	91
Kuwait	318	240	303	80	110	428	530	81
Oman	55	32	86	37	13	68	147	46
Qatar	112	83	85	98	104	216	140	>100
Saudi Arabia	950	795	1 700	47	339	1 289	2 900	44
United Arab Emirates	502	342	540	63	270	772	832	93
Yemen	10	9	216	4	0	10	360	3
Total	2 027	1 557	3 033	-	902	2 924	5 029	-

MED units. This scheme allows optimum energy use while providing flexibility to meet variable water demand. The cogeneration arrangement also allows the RO units to operate at maximum capacity in conjunction with the operation of the thermal plant.

The principles of building energy production and desalination plants jointly and integrating the different desalination processes into one plant is the focus of future development in desalination throughout the world. Efforts are also being invested in further improvements in the process, equipment and knowledge of the desalination process. There is a consensus in the desalination industry that MSF distillation has reached maturity, and no further substantial progress is expected. Other thermal methods, however, will continue to be refined and improved. Work is being done to create reliable, large, low-temperature alternatives using MED or TVC units. Lower-cost material is also expected to be used in the construction of MED and VC distillation plants. Technical advancements are expected in membrane processing, and concentrated efforts are under way in many countries where membrane separation is used. The combined experience of owners and manufacturers of RO plants will lead to improved product design and operational procedures. Improvements are still needed in pre-treatment of feed water, especially for surface sea-water intakes. The development of low-cost UF membranes is expected to result in an economical alternative to feed water pre-treatment.

Other aspects of the desalination process which are being studied and further refined include the use of chemicals to reduce scale deposits, improved structure and materials for heat transfer surfaces where the evaporation process is used, the use of corrosion resistant materials, increased resistance of RO membranes, improved membrane selectivity, improved water production per unit area of membrane, and improvements in the efficiency of auxiliary equipment involved in the RO process. Improvement in desalination processes may lead to a reduction in operation and maintenance costs. Substantial progress has already been made in the improvement of the MSF process. Nevertheless, further perfection in processes such as enhanced heat transfer will make continuous operation possible. Improved scale and corrosion control, flow range, workmanship and automated monitoring and control will also improve the efficiency and longevity of desalination by this method. The MED process is also well developed; however, specific aspects, such as the use of thin titanium tubing, need to be improved to maximize efficient heat transfer. Further improvement is also needed in the area of raw sea water entering from outside the plant. Vapour compression in combination with MED units need further development in compressor design to enhance their efficiency and reliability and provide higher capacities.

The membrane processes of RO and electrodialysis are potentially applicable to large-scale sea-water desalination. Improved membrane efficiency and technology are expected to lower production costs and make these processes more reliable. New membrane manufacturing processes such as plasma polymerization or radiation-induced grafting may result in membranes with higher specific fluxes, higher temperature tolerance and high chemical stability, as well as anti-fouling mechanisms. Improved backing materials will allow production of compaction-resistant membranes and will enable operation at higher pressures. It is expected that these improvements will result in conversion rates as high as 50%, thereby decreasing production costs.

Integrated water resource management: The ESCWA member countries are faced with the major challenge of managing their limited water resources. The need to improve water sanitation has added a further constraint to the provision of freshwater. Water management programmes have largely been oriented towards providing adequate supplies of good quality water to urban and rural communities, while trying to preserve environmental equilibrium, which counterbalances increasing economic development. Some of the ESCWA member countries, particularly the Gulf States of the Arabian Peninsula, are financially capable of using innovative desalination technology to offset water shortages. The use of desalination has been employed, in varying degrees, in a number of the countries. However, water scarcity, economic and social barriers, and lack of efficient water management practices have all imposed limitations on the use of desalination within most of the countries. The major constraint has been disaggregation of authority and lack of coordination in water resources development and management.

The solution calls for integrated water resource planning and management within each country. Such integration must include both conventional surface and groundwater sources, as well as non-conventional water resources such as desalination and wastewater renovation, while taking into consideration quantity and quality requirements. The multisectoral nature of water use dictates that water must be optimally allocated, with emphasis on cost recovery. In addition, water utilization, especially from non-renewable sources and costly desalination, must be supported with concurrent water conservation measures.

Integrated water resource development and management, as envisaged in Agenda 21, emphasizes the use of water sources to satisfy basic needs, while safeguarding environmental ecosystems. Agenda 21 objectives further stipulate that beyond basic water requirements, appropriate fees should be assessed to reflect water production costs.

Most of the countries of the Arabian Peninsula have directed their efforts towards satisfying domestic demand. Water of ample quantity and quality has been provided to both urban and rural communities. Even Yemen, in spite of limited financial resources, has made significant progress in improving the urban water supply. Substantial investments have been made by most of the countries in the desalination process to meet public demand. However, water has been provided to the residents at a cost substantially lower than actual production costs. The current policy of subsidized water pricing, together with the absence of conservation campaigns, has encouraged wastefulness. The financial burden of such inefficiency will ultimately rest on the Governments of these countries in the form of additional desalination plants which will be required to handle increased demand. Environmental strains with respect to the volume of water generated, both treated and untreated, as well as urban groundwater rise, will also become burdens for each country where conservation methods are not enforced. Each country must develop an integrated water resources development programme that encompasses renewable and non-renewable groundwater sources, desalination, and renovated wastewater, in order to attain sustainable resource utilization. Sustainable development of all water sources must be achieved at both the national and international levels to manage local and shared water resources better.

An integrated water resources development and management scheme for the countries of the Arabian Peninsula is essential to optimize water allocation. Optimization can be achieved through appropriate pricing policies and regulations. Schemes should take into consideration socio-economic factors. Dependence on desalination dictates that water pricing mechanisms reflect, as far as possible, the true cost of water production and delivery, as well as the ability of the public to pay. Field tests of public acceptance and finances would be in order prior to implementing pricing policies. Appropriate pricing mechanisms should be implemented in conjunction with management practices which promote conservation. Emphasis should be placed on education of the public concerning the importance of water and proper management. These measures will not only improve water utilization efficiency, but could defer construction of additional desalination plants, thereby contributing to the shift of financial resources from water to other sectors such as social and/or economic development.

Integrated water resources development and management incorporates the application of modern technology to manage existing supplies and produce new sources. Such concepts as capacity-building and public participation in the decision-making process are integral parts of integrated water management systems.

To cope with future water demand in many of the ESCWA member countries, emphasis must be placed on efficient management of water resources, as outlined in the conservation programme of Agenda 20, and in Agenda 21. It is essential that each country of the region establish an up-to-date water plant that not only emphasizes the sustainability of water resources, but promotes a number of important policies such as optimum allocation of water in accordance with market values, availability of additional water sources at reasonable cost, conservation, pollution control and improvement of the coordination of efforts between water institutions. Technical research and development, as well as manpower development and training, are also essential aspects of any water programme. Key policies for short- (1990-2010) and long-term (2010-2050) goals should be designed for urban, industrial and agricultural development, capacity-building, water pricing, development and improvement of appropriate technology, institutional arrangements and water importation. An institutional infrastructure capable of coordinating and managing complex water policies within each country, and between countries, must be recognized as a fundamental element in resource management. Finally, utilization of water resources, especially groundwater sources which most of the ESCWA member countries share, requires comprehensive regional coordination and cooperation in order to assure optimum development and management, and to avoid future conflicts.

E. Conclusions

The countries of the ESCWA region face continuing water shortages and probably always will. To overcome supply problems, many of these countries have come to rely on the desalination of sea and brackish water. Desalinated water, by necessity, has become a major supply component. Experience in the Gulf States demonstrates that desalination technology has developed to a level where it can be used to supply reliable sources of water at prices comparable to conventional sources. Desalination remains the most feasible alternative to meet future water requirements in the region. Costs are expected to decrease, making desalination increasingly attractive in comparison with water importation schemes. However, in conjunction with the use of desalination to augment existing supplies, the ESCWA member countries must implement an efficient programme which emphasizes an integrated and holistic approach to the management of water resources. It is essential that each country in the region establish a comprehensive water plan that not only stresses the sustainability of water resources, but promotes such important aspects as optimum allocation of water in accordance with market value, conservation, pollution control, and increased cooperation and coordination among water institutions. Research and development, as well as manpower development and training, are also essential aspects of any water programme. Key policies should address short- and long-term goals for agricultural development, capacity-building, water pricing, reduction of subsidies, development and application of appropriate technology, and an enhanced institutional infrastructure which is capable of coordinating and managing complex water policies. Coordination and cooperation within each country, as well as between countries, must be recognized as a fundamental element in a viable comprehensive, holistic and integrated water management system.

REFERENCES*

Abdulrazzak, M.J. (1995), "Water supplies versus demand in countries of Arabian Peninsula", *J. Water Resource. Plan.& Man.* May/June 1995.

Abdelrahman, H. (1992), "Irrigation systems in Oman." *Proc. of First Gulf Water Conference*, Oct. 10-14, Dubai.

Abdulrazzak, M.J. (1992), "Water resources assessment and management for the Gulf Cooperation Council Countries", *Proc. of First Gulf Water Conference*, Oct. 10-14, Dubai.

Abu Rizaiza, S.O., and N.M. Allam (1989), "Water requirements versus water availability in Saudi Arabia," *J. Water Resource. Plng. and Mgmt.*, ASCE, 115(1), 64-74.

Akkad, A. (1990), "Conservation in the Arabian Gulf countries". *J. Mgmt Operat.* AWWA, 82, 40-50.

Al-Arrayedh, M., K. Burashid, and K. Almansour (1993), "Ras Abu Jarjur RO plant operational cost optimization:," *Proc. of the IDA and WRPC World Congress on Desalination and Water Treatment,* vol. II, 1993.

Al-Asam, S.M. (1992), "Modern irrigation systems and their role in water conservation in the United Arab Emirates," *Proc. of First Gulf Water Conference*, Oct. 10-14, Dubai.

Al-Fusail, A.M., B.M. Al-Selwi, G.A. Said, and A. Badr (1991), "Water resources and population distribution in the Republic of Yemen," *Proc. of First National Population Policy Conference*, Oct. 20-29, Sana'a, Yemen.

Al-Gazi, A. (1990), (in Arabic) "Migration movement between rural and urban centres in the Arab world," *Journal of Secure.* pp. 87-120.

Al-Ibrahim, A.A. (1990), "Water use in Saudi Arabia. Problems and policy implementation," *J. Water Resour. Plng. and Mgmt.*, ASCE, 116(3), 375-388.

Al-Kenson, D.J. and Aykliston (1986), "Water resources and water utilization in Qatar" (in Arabic). *Proc. of the Symposium on Water Resources and Utilization in the Arab World*, Kuwait, pp. 299-330.

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* Issued as submitted.

Al-Mahmoud, M.A. (1992), "Water resources development in Qatar," *Proc. of First Water Conference*, Oct. 10-14, Dubai.

Al-Mansour, K., and M. Al-Arady (1986), (in Arabic), "Water resources and its utilization in Bahrain", *Proc. of the Symposium in Water Resources and Utilization in the Arab World*, Kuwait, 1986, pp. 159-189.

Al-Mugran, A. (1992), "Strategy of water resources development in the GCC countries," *Proc. First Gulf Water Conference*, Oct. 10-14, Dubai.

Al-Sofi, M.A., "Water scarcity - The challenge of the future", *Proc. of the IDA and WRPC World Congress on Desalination and Water Treatment*, vol. II, 1993.

Al-Sufy, A.M. (1992), "Development of water resources suitable for consumption," *Proc. of First Water Gulf Conference*, Oct. 10-14, Dubai.

Al-Tokhais, A.S. (1992), *Groundwater management strategies for Saudi Arabia*. Ph.D. dissertation, Colorado State University, Ft. Collins, CO, 220 pp.

Authman, M.N. (1983), *Water and development processes in Saudi Arabia*. Tihama Press, Jeddah, Saudi Arabia, p. 302.

British Arabian Advisory Company (BAAC) (1980), *Water resources of Saudi Arabia*, vol. 1. Prepared for the Ministry of Agriculture and Water, Riyadh, 280 pp.

Burdon, D.J. (1973), "Hydrogeological conditions in the Middle East". *J. Eng. Geol.* (15) 71-82.

Buros, O.K. (1990), "The desalting ABC's", *International Desalination Association.*

Bushnak, A.A. (1990), "Water supply challenge in the Gulf Region," *J. Desalination*, (78) 133-145.

Country Report (1986), Water resources and utilization in the United Arab Emirates. (in Arabic), *Proc. of the Symposium of Water Resources and Utilization in the Arab World*, Kuwait, 141-157.

Country Report (1986), Water Resources and Utilization in Kuwait. *Proc. of the Symposium on Water Resources and Utilization in the Arab World*, Kuwait, 331-360.

Dabbagh, T., P. Sadler, A. Al-Sagabi, and M. Sadeqi (1993), "Desalination: the neglected option", Kuwait Fund for Arab Economic Development.

Danish, S., A. Khater, and M. Al-Ansari (1992), "Options in water reuse in Bahrain". *Proc. of First Gulf Water Conference*, Oct. 10-14, Dubai.

De Jong, R. (1989), "Water resources of the GCC countries - International Aspects," ASCE *J. Water Resour. Plng and Mgmt*, 115(4) 503-510.

Del Bene, J.V., G. Jirka, and J. Largier, "Ocean brine disposal", *Proc. of the IDA and WRPC World Congress on Desalination and Water Treatment,* vol. II, 1993.

Edgell, H.J. (1987), "Geological framework of Saudi Arabia - groundwater resources," *KAU J. Earth Sci.* 3, 267-285.

El-Zawahry, A.E., and A.A. Ibrahim (1992), "Management of irrigation water in Oman," *Proc. of First Gulf Water Conference*, Oct. 10-14, Dubai.

FAO (1979), "Shared water resources in the Gulf States," *United Nations,* Rome. 1, 310 pp.

Khoury, J., W.R. Aga, and A. Al-Derouby (1986), "Water resources in the Arab world and their future projection," *Proc. of the Symposium on Water Resources and Utilization in the Arab World*, Kuwait, 186, 577-634.

Lloyd, J.W., and R.H. Rim (1990), "The hydrogeology of groundwater resources development of the Cambio-Ordovician sandstone aquifers in Saudi Arabia and Jordan," *J. Hydrology*, 121, 1-20.

Ministry of Agriculture and Water (MAW) (1984), *Water Atlas of Saudi Arabia*, Riyadh, Ministry of Planning (MOP) (1990), *Fifth development plan 1990-1995 for Saudi Arabia.* Riyadh, 520 pp.

Ministry of Planning (MOP) Fourth Development Plan, 1985-1990, Riyadh, Saudi Arabia, 400 pp.

Mohamed, A.K. (1986), "Water resources and development in the Republic of Yemen," *Proc. of Symposium on Water Resources and Utilization in the Arab World*, Kuwait, 411, pp. 923.

Shahin, M. (1989), "Review and assessment of water resources in the Arab region". *J. Water International*, 14, 206-219.

Spielger, K.S., and A.D.K. Larid (1980), "Principles of desalination", Academic Press, N.Y.

Ukayli, M.A., and T. Husain (1988), "Evaluation of surface water availability, wastewater reuse and desalination in Saudi Arabia". *J. Water International.* 13, 218-225.

Uqba, A.K. (1992), "The need for national and regional integrated water resources management in the Gulf Cooperation Council region," *Proc. of First Gulf Water Conference*, Oct. 10-14, Dubai.

United States Congress, Office of Technology Assessment (1988), "Using desalination technology for water treatment", OTA-0-46 (Washington, D.C., U.S. Government Printing Office).

Wagnick, K. (1992), Worldwide Desalting Plants Inventory, Report 12, Wagnick Consulting, Gnarrenburg. IDA.

IX. APPLICATION OF ISOTOPE HYDROLOGY TECHNIQUES IN THE ESCWA REGION

by

*Mebus A. Geyh**

A. IMPLICATIONS OF AGENDA 21 FOR ISOTOPE HYDROLOGY

The implications of Agenda 21 for integrated water management in the ESCWA region provide a challenge to emphasize the application of modern technologies such as isotope hydrology in order to influence in a positive way the future direction of water management policies. The scarcity of water resources and the rapid increase of water demand in the ESCWA member countries require the rationalization of water utilization to sustain the water quality. For this task, various parameters must be known such as the size and quality of assessable water resources. Classical hydrogeological methods are only partly usable for the provision of this information. The application of modern tolls, such as numerical modeling for groundwater budgeting, remote sensing and satellite imaging, is essential.

In arid and semi-arid climatic regions difficulties exist in the geohydraulic modeling inasmuch as the groundwater may be partly or wholly fossil. Such modeling usually assumes hydraulic steady state conditions by which the proportion of renewable groundwater is overestimated. This is due to the fact that the actual gradient of the piezometric surface is only partly or not at all controlled by the recent groundwater recharge. The difference in gradient is due to the relict water head from one or several former pluvial periods.

In order to enable model adaptations and to estimate precise rates of recent groundwater recharge in arid regions, the application of isotope hydrologic techniques is indispensable (Verhagen et al. 1991).

B. COMMON APPLICATION OF ISOTOPE TECHNIQUES IN APPLIED HYDROLOGY

Isotope techniques are widely used in ESCWA member countries, such as the successfully operating Isotope Laboratory of the Water Authority in Jordan. There are various fields in which they are applied to solve local and regional hydrological problems.

Tritium, a radioactive tracer of hydrogen with a half-life of 12.43 years, is used to detect recent groundwater recharge. Nuclear weapons tests contaminated the hydrosphere mainly at 1963/1964 and have marked the precipitation with a locally and

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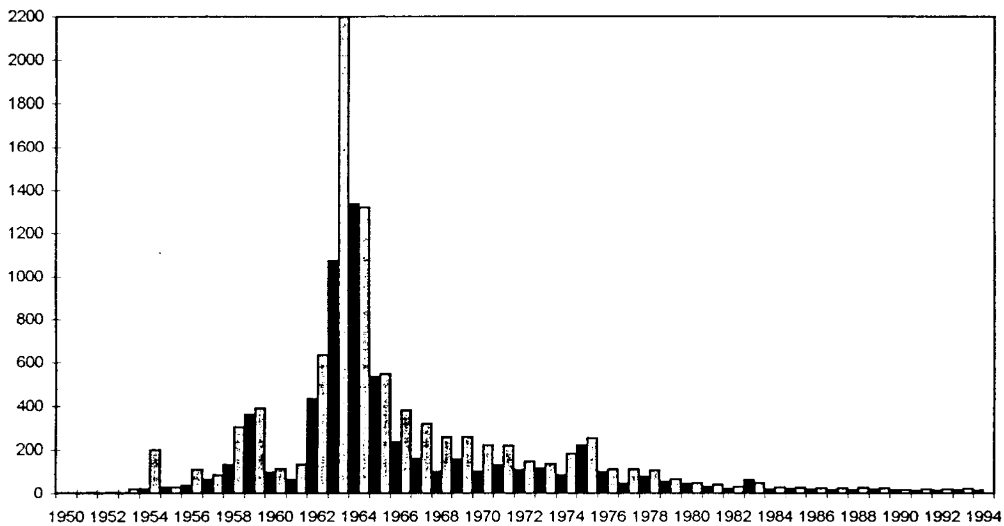
temporally varying isotope signature since then (figure 1). The latter is monitored worldwide by the International Atomic Energy Agency, Vienna (IAEA, 1960-1990). The presence of tritium in a water sample is definite proof of recent groundwater recharge. Under suitable hydraulic conditions, e.g. for continuously running springs, the turnover time of the groundwater can be calculated by various models (e.g. Richter & Szymczak 1992).

Figure 1. Tritium values of precipitation in Central Europe since 1950. The input curve for the ESCWA member countries has a similar shape but different amplitudes



The stable isotope compositions of oxygen, hydrogen and carbon help to determine the:

(a) Origin of the water (meteoric, vadose);

(b) To localize catchment areas and storm trajectories;

(c) To quantify the mixing of groundwater from different resources;

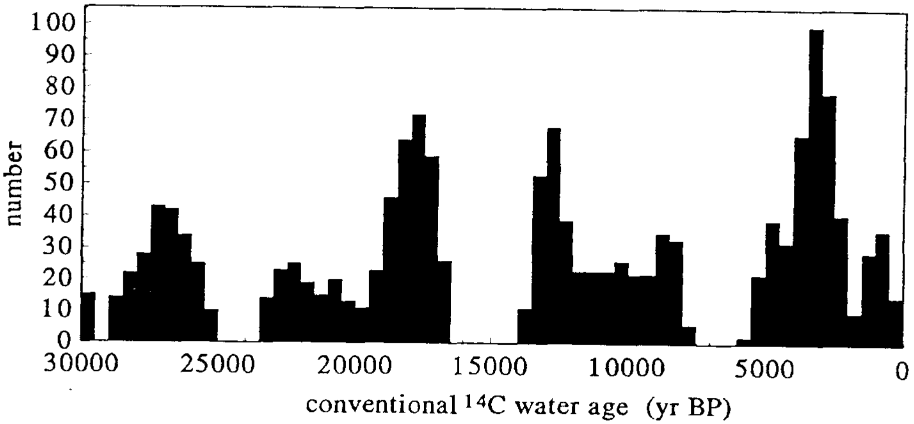
(d) To estimate turnover times up to 4-5 years;

(e) To distinguish groundwater recharged in different pluvials;

(f) To define processes in the aquifer which modified the isotope signature since the groundwater recharge occurred, e.g. evaporation.

For the evaluation of the corresponding isotope date, the usually given $\delta^{18}O$ and $\delta^{2}H$ values are plotted on a $\delta^{18}O/\delta^{2}H$ diagram (figure 2).

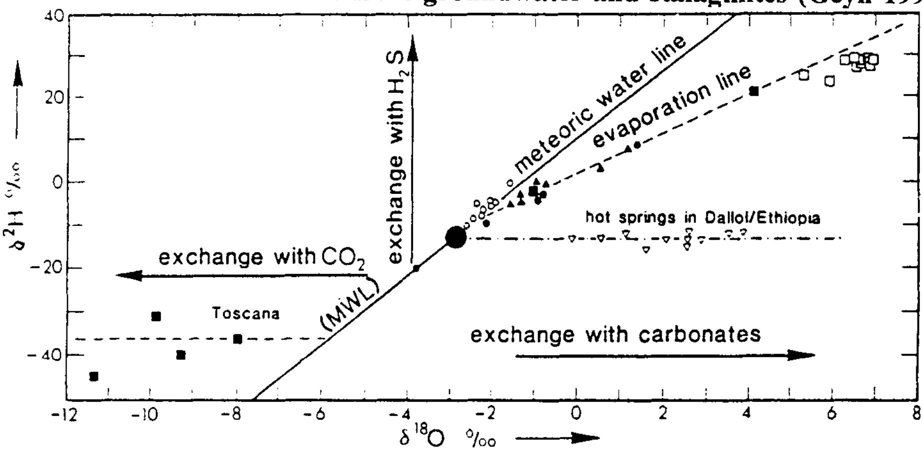
Figure 2. The isotope data of groundwater of meteoric origin fit the so-called meteoric water line (MWL)



The ^{14}C method is used to date groundwater by means of the dissolved inorganic carbon compounds (TDIC) in the range of 1,000 to about 40,000 yr BP. In arid and semi-arid regions dating is very important to distinguish fossil groundwater resources from different pluvial periods (figure 3).

The corresponding results of partly evaporated groundwater, e.g. from seepage of a braided river, are grouped right from that (evaporation line). The more negative the data, the lower the temperature at groundwater recharge. Therefore, water from higher altitudes or cooler climatic periods is isotopically more depleted than that from low altitudes and warm periods.

Figure 3. Paleohydrological situation in the eastern Mediterranean based on ^{14}C dates from groundwater and stalagmites (Geyh 1994)



C. Isotope hydrology techniques in ESCWA member countries

There are three main fields for the application of isotope hydrological techniques in ESCWA member countries:

(a) The determination of precise groundwater recharge rates for the vast areas of deserts;

(b) The calibration of geohydraulic and numerical models and the correction of their results by means of isotope hydrological data for non-steady state conditions (discharge is not balanced by recharge);

(c) The support of groundwater mining studies.

1. *Groundwater recharge*

Precise groundwater recharge rates have to be determined for the vast areas of the deserts in the ESCWA member countries. Each square kilometre yields 1,000 m^3/yr from 1 mm annual recharge. This means, e.g. $2x10^9$ m^3/yr for Saudi Arabia alone. An overestimation of the actual contribution of rainfall to the groundwater recharge may result in wrong decisions in the water management policy.

The Azraq springs in Jordan are an example. They discharged about 16 x 10^6 m^3/yr before starting pumping in the 1980s. From ^{14}C water ages of more than 15,000 yr BP it was concluded that about two thirds of the discharge is fossil (Verhagen et al. 1991). That means that only 5 x 10^6 m^3/yr are recently recharged or even less. This is not detectable by tritium measurements as the travel time is too long from the catchment area to the springs.

In 1982, the ASWA well field came into operation with an initial abstraction rate of $16x10^6$ m^3/yr. As a result, the hydrochemical and isotopic compositions changed (section 3), reflecting overexploitation. Based on an estimate of the actual sustainable groundwater recharge rate of 2.8 mm/yr or $36x10^6$ m^3/yr by means of the chloride method, the abstraction rate has been increased to 40 x 10^6 m^3/yr (Almomani 1994). The discharge of several springs ceased, salination increased considerably and a reversal of the flow direction in the Azraq Basin mobilizing brine is considered as possible (Almomani 1994).

The estimate of the recharge rate by the chloride method is questionable. This method is based on the concept that the chloride content in precipitation becomes enriched by evaporation during the process of groundwater recharge. Hence, the ratio of chloride concentrations of rain c_p (assumed to be 1.5 mg Cl/l in the Azraq Basin) and in the groundwater c_w ($\approx$ 1.3 meq Cl/l=46 mg Cl/l) is a function of the recharge rate r[mm/yr] and the annual precipitation p ($\approx$ 87 mm/yr):

$$r = \frac{C_p}{C_w} p = 2.8 \ mm/yr$$

In arid and semi-arid regions there is usually a wide variation in the annual precipitation, which is why the only reliable means is long-term monitoring of the rainfall. For the Azraq region a scatter of 20% is probable (Kattan 1994), but more important is the spread of the chloride data of the precipitation. The results for the Syrian Arab Republic (Kattan 1994) yield 16 $\pm$ 14 mg Cl/l. Adopting this estimate for the Azraq Basin, the chloride method cannot distinguish any recharge rate between 0 and 6 mm/yr.

There are three other fundamental problems involved in the application of this method:

(a) The chloride concentration may change temporarily during the course of a rain shower by up to one order of magnitude without knowing which part actually contributes to the groundwater recharge;

(b) The chloride concentration of fossil groundwater is compared with that of present-day precipitation, overlooking the possibility that during the pluvial periods the recharge rate or evaporation loss might have been different, as well as the chloride concentration of the rain;

(c) Finally, any geogen contribution of chloride from the aquifer is discarded.

Owing to the increased demand for freshwater in the ESCWA region, a wrong water management policy may arise if groundwater recharge rates are overestimated. Hence, a reliable method to determine this important parameter for groundwater budgeting in the arid ESCWA region is highly recommended.

2. *Calibration of numerical modeling*

In arid and semi-arid regions, non-steady state conditions dominate the groundwater systems and usually groundwater discharge exceeds recharge. Large proportions of such resources must be considered as fossil. The gradient of the piezometric surface allows the calculation of the Darcy velocity if the hydraulic conductivity is known. The tracer velocity determined by the ^{14}C method is related, however, to that of the pluvial period when the groundwater was recharged. At that time the piezometric surface might have been different from today. On the other hand, the actual Darcy velocity only reflects the recent discharge but does not allow any conclusion on the contribution to the actual recharge.

Numerical modeling for groundwater budgeting is still based on the assumption of steady-state conditions. Interrupted periods of groundwater recharge (figure 3) are not taken into account, resulting in an overestimation of the actual groundwater recharge (Verhagen et al. 1991).

There is a case-study from the Ad-Dawwa Basin in the Syrian Arab Republic where the geohydraulic model by ACSAD, Damascus, and BGR, Hannover, was successfully calibrated by ^{14}C dates. The study area stretches from the flanks of the Anti-Lebanon Mountains in the west to the Sabkha Al-Mouh in the east. The annual precipitation decreases from 150-300 mm/yr to a maximum of 100 mm/yr in the same direction. Catchment areas are the Anti-Lebanon Mountains as well as the Northern and Southern Palmyrides. The latter form a water divide along a fault stretching from SW to NE (figure 4). The studied Turon/Cenoman/Coniac aquifer in the Ad-Dawwa Basin is confined.

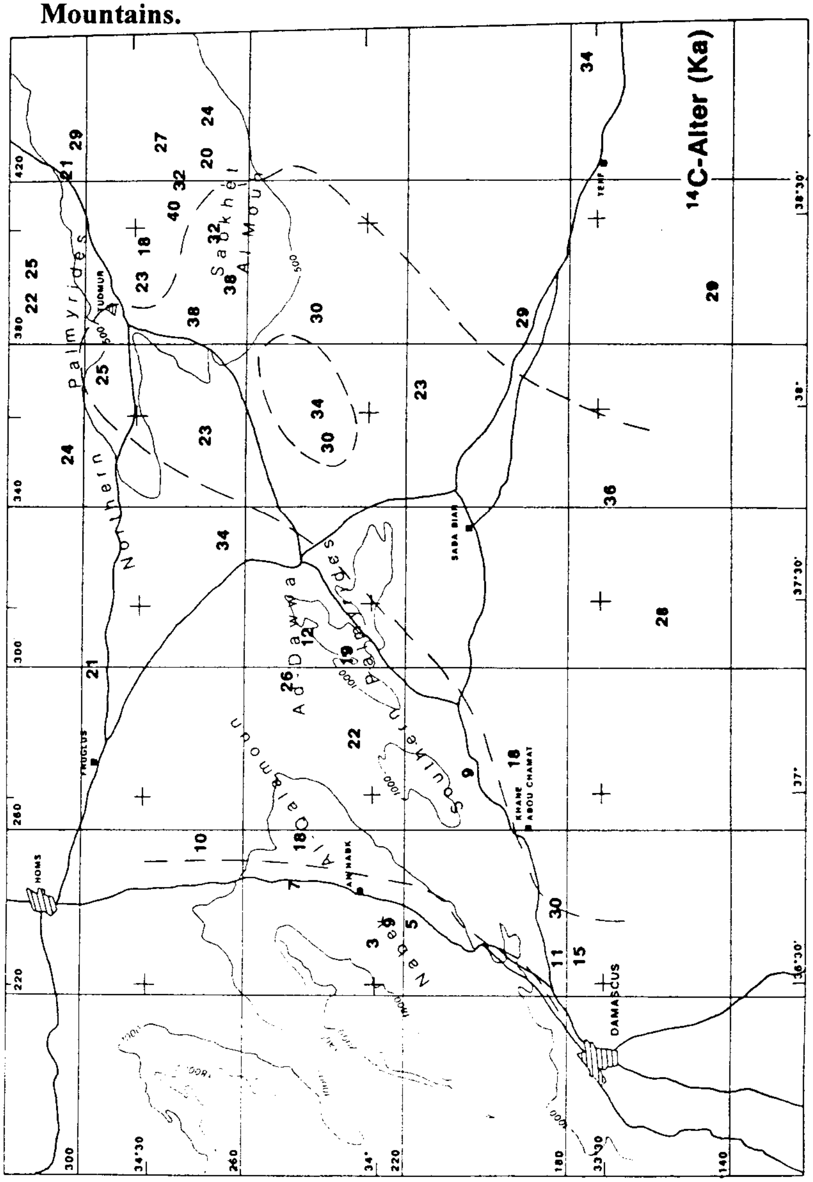
A hydrochemical survey of the groundwater within the Ad-Dawwa Basin showed that the central part contains predominantly freshwater while highly saline groundwater is found along the foothills of the Northern and Southern Palmyrides. Surprisingly, the ^{14}C dates of groundwater prove that very recent groundwater containing tritium is highly mineralized while the huge freshwater resources in the centre of the basin have ^{14}C water ages exceeding 20,000 yr BP. Obviously, present-day groundwater recharge is so weak that it can only dissolve salt formed by weathering of the rock during the year and transport it into the aquifer. As a result, Holocene groundwater is only found within the aquifer below the Palmyrides; that means to a maximum of 10% of the total groundwater resources in the studied area.

In the southern part of this aquifer system the ^{14}C water ages increase from 15,000 in the west to up to 35,000 yr BP in the east in agreement with the hydraulic flow direction reflected from the piezometric surface. At the beginning of the Holocene (Geyh et al. 1985) the aquifer was mostly filled with groundwater, and only in the east near the catchment areas was there some space for new groundwater.

The geohydraulical model covers an aerial extension of 160 x 100 km^2 and assumes a thickness of the aquifer of 250 m and a porosity between 2.5% and 10%. Adopting these values the total volume of the groundwater resource is 100×10^9 to 400×10^9 m^3.

A Russian consultant (Selkhozpromexport 1987) postulated a groundwater recharge rate of 3% of the main annual precipitation corresponding to 58.2×10^6 m^3/yr, which should be balanced by the evaporation loss in the Sabkha Al-Mouh. Adopting these figures for the geohydraulic modeling and assuming a longitudinal extension of the aquifer by 200 km, a maximum height of the groundwater head above the depression (Sabkha Al-Mouh) of 400 m and a K value of 5×10^{-5} m/s, the tracer velocity should be 126 m/yr for a porosity of 2.5% and 32 m/yr for 10%. This corresponds to a transit time of the groundwater of about 1,000 or 4,000 yr only, respectively. As 35,000 yr were found, the hydraulic parameters used in the Russian study must be inaccurate as the aquifer would be already empty.

Figure 4. There is a trend towards increasing conventional ^{14}C ages (kyr BP) of groundwater in the aquifer of the Ad-Dawwa Basin south of the Southern Palmyrides. The hatched line marks the water divide of a tectonic fault stretching from SW to NE. The oxygen isotope composition of the groundwater is uniform and corresponds to that of groundwater occurring at the flanks of the Anti-Lebanon Mountains.



The ^{14}C water ages agree with the geohydraulic modeling if the K value is reduced by one order of magnitude to about 1 x 10^{-5} m/s or even less. Pumping tests in the centre of the Ad-Dawwa Basin (ACSAD, 1990) yielded transmissities exceeding 1,000 m^2/d with a mean of 23 m^2/d = 1.1 x 10^{-6} m/s. Forced by the isotope results, Brunke (1994) adopted a hydraulic conductivity of 3.5 x 10^{-6} m/s for the model and reduced the turnover time of the groundwater in the aquifer by a factor of 10.

There is another case to be described: the groundwater resource is fossil without or with but the recharge rate is unknown. An example is a fresh groundwater saturated aquifer in the Thar Desert of Pakistan. It has a total volume of 10 km^3 and is completely embedded by brackish to saline groundwater. It was explored by both a resistivity and a heliborne electromagnetic survey. Indirect recharge occurring during flash-floods and some groundwater through-flow was assumed to replenish the resource from high mountains in the east.

This fresh groundwater resource is located along the former course of the no-longer-existing Old Hakra River. Between 4,000 and 3,500 yr BP its discharge gradually decreased as its headwaters shifted southwards. It stopped running perennially around 2,500 yr BP.

An estimate of the maximum possible groundwater recharge of this groundwater resource was derived from ^3H values. All water samples from dug wells were below the detection limit of 1.5 TU resulting in actual recharge rates of <0.8 mm/yr or <0.4% of the mean actual rainfall. In contrast, the ^{14}C age/depth gradient of the groundwater of one test hole yielded a recharge rate of 4 mm/yr. This is at least five times higher than the actual groundwater recharge rate and can only be explained by river seepage in a former pluvial. The latter concept is supported by the $\delta^{18}O/\delta^2H$ plot (Geyh et al. 1992). The $\delta^{18}O$ and δ^2H values form a cluster along an evaporation line. A final support of this interpretation comes from the conventional ^{14}C ages of 16 freshwater to saline water samples from the study area ranging from 7,700 to 15,900 yr BP. Applying a reservoir correction of -3,000 yr, the termination of the groundwater recharge of this resource coincided with the deterioration of the paleohydrological conditions within the desert belt, extending from North Africa to the Thar Desert after 4,000 yr BP and the disappearance of the Old Hakra River. Present-day recharge of the Thar freshwater resource is absent. The groundwater is fossil as a whole.

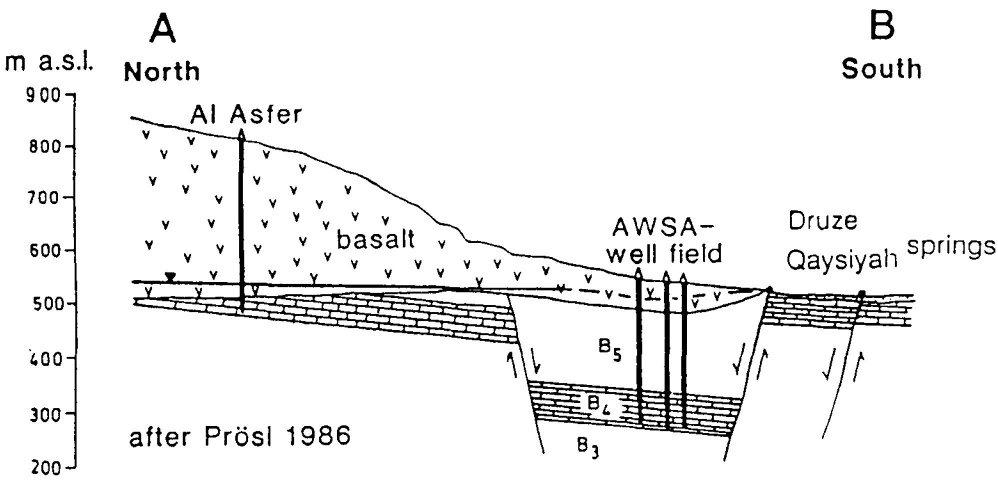
3. *Groundwater mining*

The water management policy of fossil groundwater resources, of which natural discharge is not balanced by recharge, can only be modeled properly if the hydraulic system is well simulated. In order to check whether the model assumptions are correct, long-term and regional monitoring of environmental isotopes and the hydrochemical properties over a period of up to one decade may be helpful and sometimes even indispensable. One example is, again, the Azraq Basin in Jordan.

According to the former hydraulic and hydrogeological concept, present-day groundwater recharge counterbalanced the rate of groundwater abstraction. In contrast, the interpretation of the environmental isotope results using mass transport modeling showed that about two thirds of the pumped groundwater is derived from fossil relict groundwater recharged during former pluvial periods (Verhagen et al. 1991).

The Azraq Basin is part of the NE/NW trending Azraq/Sirhan graben system. More than 1,000 m of Cretaceous, Tertiary and Quaternary sediments are present in its central part. The geological structure is characterized by a sequence of horsts and grabens (figure 5) of which the main graben is 8 to 10 km wide. Basalt overlies the sediments in the northern part of the basin in the direction of the Syrian Arab Republic. The main recharge area is around the Jebel Druze in the north, with a mean rainfall of 400 mm/yr. The whole region receives 800 mm/yr on average. From the catchment area, the water flows radially, partly SW to the Dhuleil region and partly SE to Azraq. In the centre of the Azraq Basin, several springs discharge into pools situated along the northern and western margins of sabkhas. There, the water partly evaporates or percolates into the phreatic aquifer, which contains highly mineralized groundwater. All groundwater to the SE is abstracted with increasing rates in the new ASWA well field since 1982. As a result, the discharge of the springs has decreased considerably (Almomani 1994).

Figure 5. Very schematic N-S geological section through the area north of the Azraq Basin (Verhagen et al. 1991)

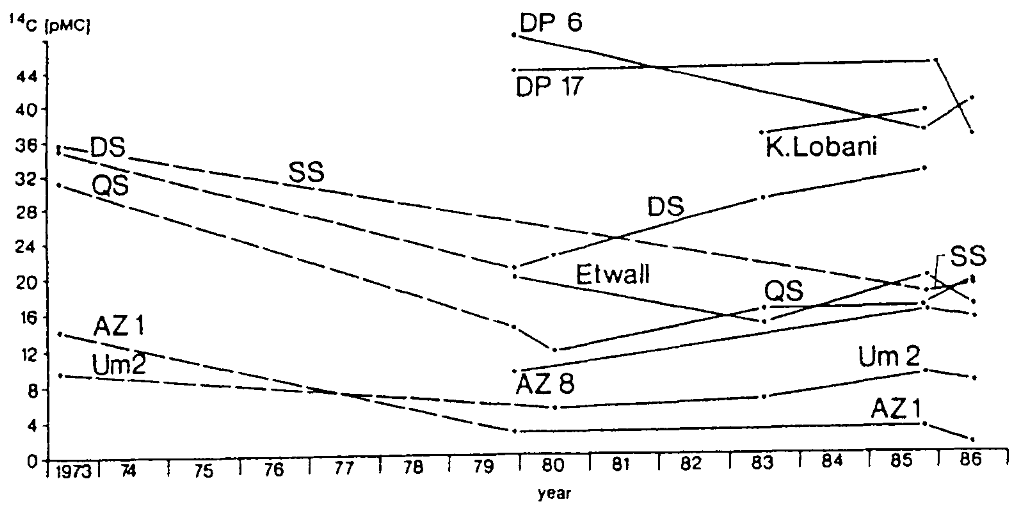


In the Dhuleil region west of the Azraq Basin, the exposed basalt aquifer is hydraulically connected to the B7/B2 aquifer. Both form a phreatic aquifer. In the Azraq region, the basalt aquifer is linked to the Rijam aquifer B4 (figure 5). The pumped groundwater is predominantly low mineralized groundwater from the basalt aquifer mixed with water from the underlying B4 aquifer. The mineral content of the pumped water, which depends upon the pumping rate, is increased slowly by a rising admixture of highly mineralized groundwater due to the drop of the groundwater table.

In order to make a forecast, the contribution of both aquifers—basalt and B7/B2—must be estimated. For this, a time series of ^{14}C data has been determined since 1973 (figure 6). There is a clear trend that the ^{14}C values decreased before 1979/1980 and increased afterwards. Due to the consistency of the ^{14}C values and the hydrochemical results of the samples collected after 1979, the interpretation of the isotope data is restricted to this period.

The ASWA wells penetrate the basalt into the B4 aquifer (figure 4). The change in the ^{14}C values for groundwater from the springs and wells (figure 5) as a function of time is governed by the rate of abstraction, which controls the degree of mixing of groundwater from the basalt and B4 aquifers. The chemical data of various well- and spring-water samples from the Azraq region were given by Rimawi (1985).

Figure 6. Changes in the ^{14}C dates between 1973 and 1979/1980 for various wells and springs in the Azraq Basin



In order to estimate the proportions of the two components, regionally representative bicarbonate and ^{14}C values must be known for both the basalt and the B4 aquifer. The results are given in table 1.

TABLE 1. REGIONALLY VALID HYDROCHEMICAL AND ISOTOPE HYDROLOGICAL REFERENCE VALUES

Aquifer	HCO_3 (mg/l)	^{14}C activity (p MC)
Basalt water	105	32.0
B4 water	130	7.0

The proportion of basalt groundwater q is calculated with the mass balance equation:

$$m = m_1 \times q + m_2 \times (1-q)$$

where m, m_1, and m_2 are the products of the bicarbonate contents and the ^{14}C data for the mixed water, the basalt groundwater and the B4 groundwater, respectively.

Because the ^{14}C data for the two groundwater types differ, the inflow rates to the Azraq spring area can be estimated precisely. Before pumping began, the water discharged from the Druze spring contained 65% basalt water, when discharge from the pool ceased, it was about 100%. In the Qaysiyah spring, the basalt water discharge increased from 44% to 71% totally between 1979 and 1986. Even the water pumped from the B4 aquifer finally contained 35% basalt water (table 2).

TABLE 2. PROPORTIONS Q OF BASALT WATER IN THE AZRAQ SPRINGS

Well (geology)	HCO_3 (mg/l)	^{14}C value (pMC)		q (percentage)	
		1979	1986	1979	1986
Druze spring (basalt/B4)	120	20.9	31.8	65	100
Qaysiyah spring (Quaternary/B4)	140	14.2	19.0	44	71
AZ 8 well (Quaternary/B4)	125	9.3	14.2	10	35

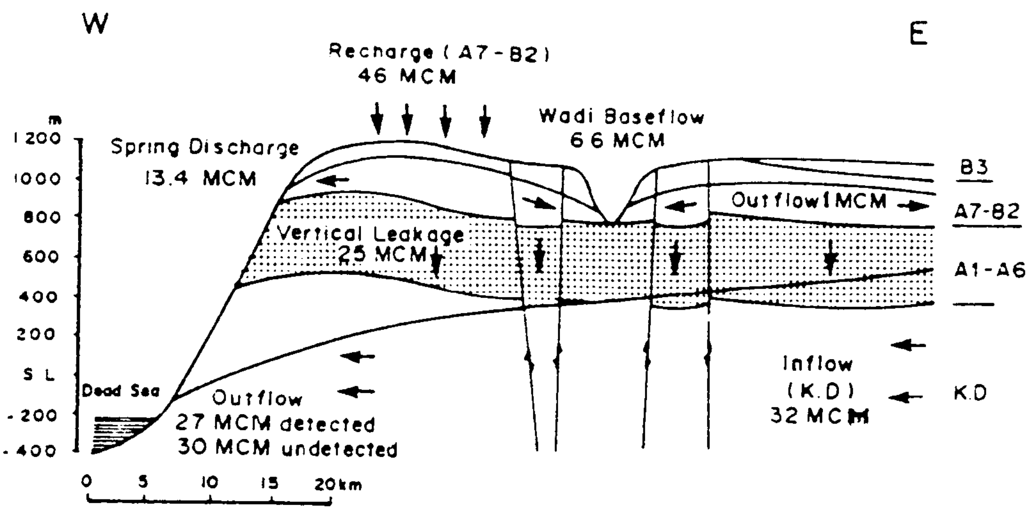
The change in the inflow rates is explained by the hydraulic situation: owing to groundwater abstraction in the AWSA well field, the hydrostatic pressure in the B4 aquifer decreased, and the ascent of B4 groundwater to the springs declined. The groundwater table in the basalt aquifer was not yet influenced because the B5 aquitard separated it from the B4 aquifer. The proportion of young basalt groundwater will start to decrease too, and spring discharge will cease. Highly mineralized water from the shallow aquifer may then become increasingly admixed with freshwater from the deeper aquifer.

Another example for useful future application of the isotope techniques is the area around El Lajjun, in Central Jordan (Bender et al. 1989). A water balance was numerically modeled for this rather complex aquifer system (figure 7). Many aquifer parameters had to be assumed.

Based on the published data the spring discharge of the A7/B2 aquifer should be around 600 years old. Therefore, tritium may not be detected in the water samples, but the initial ^{14}C value needed for the transformation of ^{14}C values into absolute water ages can be estimated. The vertical seepage into the K.D. aquifer with an assumed total water volume of about 50,000 MCM might have a transit time of about 2,000 years. Even if the horizontally inflowing groundwater has an infinite age, ^{14}C analysis of the spring water from both the A4/B2 and the K.D. aquifers will enable a check to determine whether or not the used parameters of the numerical modeling has to be corrected.

Both of these examples have demonstrated that a qualified water management policy in the arid to semi-arid ESCWA region should be based on groundwater modeling calibrated with isotope hydrology results.

Figure 7. Groundwater balance and aquifer system for the Mujib Basin (Bender et al. 1989)



D. SUMMARY

The isotope hydrology techniques can be widely used in applied hydrological studies in the ESCWA member countries. There are, however, several fields where these techniques have a unique potential. Such special fields are the determination of the regional groundwater recharge rates for the vast areas of the Arabian deserts and the calibration of numerical models with their adaptation to non-steady-state conditions. Finally, groundwater mining studies should include isotope and hydrochemical analyses in order to improve numerical model assumptions on the aquifer system and to optimize the water management policy.

REFERENCES

Almomani, M. (1994a). Environmental isotope and hydrochemical study of the shallow and deep ground water in the Azraq Basin, Jordan-Final IAEA Coordination Meeting "Isotope Hydrology in the Middle East", Ankara, 21-25 November 1994.

ACSAD (1990). Mathematical Model for El Sawaneh Basin, 122 pp. Report H.S/R69, Water Resources Division, Damascus.

Bender, H., M. Hobler, H. Klinge, and K. Schelkes (1989). Investigations of groundwater resources in central Jordan. Desalination, 2: 161-170.

Brunke, H.P. (1994). First results of the model activities within the Palmyra Project. Intermediate Report. Technical Cooperation Project No. 88.2205.8.

Geyh, M.A. (1994). The paleohydrology of the Eastern Mediterranean. In: Bar-Yosef, O., and R. Kra (eds), Late Quaternary Chronology and Paleoclimates of the Eastern Mediterranean, 131-145. Radiocarbon, Tuscon.

Geyh, M.A., J. Khouri, R. Rajab, and W. Wagner (1985). Environmental isotope study in the Hamad Region. Geol. Jb., C38: 3-15.

Geyh, M.A., D. Plöthner, W. Wagner, H. Bender, and W. Müller (1992). Angewandte isotopenhydrologische Studien in ariden und semi-ariden Gebieten. Z.dt.geol. Ges., 143: 236-244.

IAEA (1969, 1970, 1971, 1973, 1975, 1979, 1983, 1986 and 1990). Environmental Isotope Data Nos. 1, 2, 3, 4, 5, 6, 7, 8 and 9. World Survey of Isotope Concentrations in Precipitation (1953-1963, 1964-1965, 1966-1967, 1968-1969, 1970-1971, 1972-1975, 1976-1979, 1980-1983 and 1984-1987). IAEA Technical Reports Ser., Nos. 69, 117, 129, 149, 165, 192, 206, 226, 264, 311; Vienna.

Kattan, Z. (1994). Chemical and environmental isotope study of precipitation in Syria. Final IAEA Coordination Meeting "Isotope Hydrology in the Middle East" in Ankara, 21-25 November 1994.

Richter, J., and P. Szymszak (1992). MULTIS Release 2.1. A computer program for the interpretation of isotopehydrogeologic data based on combined lumped parameter models. Mining Academy of Freiberg, Subdepartment of Hydrology.

Rimawi, O. (1985). Hydrochemistry and Isotope Hydrology of the Ground and Surface Water in North Jordan. Dissertation, Technical University, Munich.

Selkhozpromexport USSR (1987). Water Resources Use in the Syrian Desert, Syrian Arab Republic, for Pasture Water Supply, Scheme, I(2), 356 pp. Moscow.

Verhagen, B. Th., M.A. Geyh, K. Fröhlich, and K. Wirth (1991). Isotope Hydrological Methods for the Quantitative Evaluation of Ground Water Resources in Arid and Semi-arid Areas. Development of a Methodology. 164 pp.; Ministry of Economic Cooperation. Weltforum, Cologne.

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X. تقنية قليلة الكلفة لتنقية المياه العادمة واعادة استعمالها

ألف- مقدمــة

على الرغم من أن كمية المياه على الأرض يفترض أنها بقيت ثابتة خلال تاريخ الانسان، الا أن توزيعها الجغرافي والزماني وعدم توافقه مع احتياجات الانسان المختلفة والمتزايدة، وزيادة هدر المياه وسوء استغلالها في بعض المناطق، وما نتج عن ذلك من استنزاف للمياه وتدهور لنوعيتها، كل هذه العوامل أحدثت خللا بين الموارد المائية المتاحة والطلب عليها.

وتشكل ندرة المياه في منطقتنا العربية وتعاقب فترات الجفاف، والزيادة المطردة في النمو السكاني واحتياجات التنمية الاقتصادية والاجتماعية، تحديا كبيراً وضغطاً اضافيا على الموارد المائية المحدودة والمتاحة بالنسبة لكميتها ونوعيتها.

وكان التجاوب لمشاكل المياه حتى الآن يتركز على تطوير مصادر مياه جديدة لسد الاحتياجات على المدى القصير والمتوسط، خاصة في مجال الانتاج الزراعي وذلك لمحاولة سد الفجوة الغذائية الناتجة عن زيادة الطلب على الانتاج المحلي.

وفي ضوء ذلك وعدم توفر مصادر مائية بديلة بكلفة اقتصادية معقولة أدرك المسؤولون عن قطاعات التنمية والمياه، أنه لا نستطيع اتباع سياسة أو فلسفة استعمال المياه لمرة واحدة ثم صرفها والتخلص منها دون فائدة. وكان من نتائج ذلك ضرورة تبني مفهوم الادارة الفعالة والمتكاملة لموارد المياه بشكل عام، والاهتمام باعادة استعمال المياه العادمة بعد تنقيتها كمصدر مائي جديد ومتنامي بشكل خاص. وكذلك زيادة الاعتماد على مصادر المياه الغير تقليدية والتي على رأسها تحلية مياه البحر في سد احتياجات الشرب وإعادة استعمال المياه العادمة في مجالات مناسبة.

كما أدت ندرة المياه السطحية في الكثير من الدول العربية وزيادة الطلب على المياه الجوفية، والمحددات الهيدرولوجية والهيدروجيولوجية لهذه المصادر الى استنزاف كبير في الكثير من هذه المصادر وتدهور نوعيتها، مما يهدد بخروج بعض الخزانات الجوفية عن نطاق الاستعمال المفيد والدائم، مالم تتخذ التدابير الاحتياطية الوقائية والتصحيحية لمعالجة المشاكل الناجمة، وتحقيق مفهوم الادارة المتكاملة لكافة الموارد المائية التقليدية وغير التقليدية واستعمالاتها.

ومن ملامح أزمة المياه في المستقبل في منطقة الإسكوا أن مصادر مياهها التقليدية يتوقع أن تصبح مستغلة بالكامل مع حلول عام ٢٠٠٠. لذلك فانه لابد من توسيع استخدام تقنيات حديثة لدعم الموارد المائية والتي من أهمها تقنيات اعادة استعمال المياه العادمة وتقنيات التغذية الاصطناعية لمخزون المياه الجوفية، وذلك ضمن ادارة متكاملة لمصادر المياه المختلفة واستعمالاتها.

ان إعادة استعمال المياه العادمة للري أصبح ممارسة عادية في الكثير من بلدان العالم والوطن العربي التي تعاني من شح الموارد المائية الطبيعية. الا أنه لا يزال هناك بعض المحاذير المتعلقة بالنواحي الصحية اضافة الى الحاجز النفسي عند الانسان اتجاه هذا الاستعمال في انتاج المحاصيل الغذائية، والكلفة العالية نسبيا لوسائل التنقية التقليدية. لذلك لابد من اعادة النظر في وسائل ومستوى التنقية المتبعة.

وتشكل طريقة التنقية الطبيعية للمياه العادمة من خلال عملية الرشح في قطاعات مناسبة من الصخور والتربة وتحت ظروف هيدرولوجية مناسبة أحد أكثر الوسائل الهامة والواعدة في تحقيق الاستعمال الأمثل لهذه المياه، وخاصة في المناطق الجافة، وذلك في سبيل زيادة الموارد المائية القابلة للاستثمار.

وقد أظهرت الدراسات في هذا المجال أن هذه الطريقة للتنقية واعادة الاستعمال هي وسيلة آمنة وفعالة واقتصادية ليس فقط في تحقيق تنقية متقدمة لهذه المياه بكلفة أقل من كلفة الطرق التقليدية للمعالجة، بل لما لها من تأثير نفسي على اعادة استعمال هذه المياه للري نتيجة للمستوى العالي للتنقية وكذلك للانطباع النفسي عند الانسان والهوية الجديدة التي تكتسبها هذه المياه بعد اعادة استخراجها عن طريق آبار أو ينابيع.

ومن هنا نلاحظ الفرق بين هذه الطريقة وغيرها من طرق التنقية من أجل اعادة استخدام المياه العادمة والتي يجب أن ينظر اليها كوسيلة فعالة للمحافظة على المياه وكمصدر مائي متنامي وجديد وليس فقط كطريقة للتنقية أو لصرف المياه العادمة.

وفي المناطق الجافة، حيث تكون تغذية المياه الجوفية من مياه الأمطار محدودة، فان هذه التنقية يمكن أن تشكل عنصرا هاما في زيادة تغذية المياه الجوفية وزيادة مخزونها.

باء- تنقية المياه العادمة عن طريق الرشح خلال قطاعات الصخور والتربة

١- مقدمة

أثبتت التجارب العلمية والعملية، أنه وتحت ظروف جيولوجية وهيدروجيولوجية مناسبة فان عملية رشح المياه العادمة من خلال قطاع مناسب من الصخور والتربة يمكن أن تحقق تحسنا كبيرا على نوعية المياه العادمة لتجعلها صالحة لاستعمالات الزراعة الغير مقيدة والصناعة وبكلفة اقتصادية بسيطة بالنسبة لوسائل التنقية التقليدية. ويشمل هذا التحسين في نوعية المياه الخصائص الكيماوية والعضوية والبيولوجية والفيزيائية. وتتم التنقية من خلال عدة عمليات هي: الترشيح والتبادل الأيوني والادمصاص والنشاط الميكروبيولوجي. فطبقة التربة السطحية الغير مشبعة بالمياه، والتي تعلو طبقة المياه الجوفية تعمل كمصفاة، وتمكن من التخلص من المواد العالقة، والبكتيريا والفايروسات وغيرها من الكائنات الحية الدقيقة الضارة بصحة الانسان. أما من الناحية الكيماوية فيمكن التخلص من معظم مركبات الفوسفور والنيتروجين والكثير من العناصر الثقيلة.

وتحت الظروف الهيدرولوجية المناسبة فان المياه الراشحة يمكن ان تصل الى المياه الجوفية لتغذيتها وزيادة مخزونها وبالتالي اعادة ضخها واستعمالها عن طريق الآبار. ولذلك فان هذه الطريقة للتنقية يمكن النظر اليها كاحدى وسائل التغذية الاصطناعية للمياه الجوفية باستعمال مصدر مائي جديد غير المياه السطحية.

وبهذه الطريقة، فان حركة هذه المياه في الطبقة الصخرية الحاملة للمياه الجوفية تحقق تنقية اضافية للمياه الراشحة مثل التخلص من الكائنات العضوية الدقيقة، وترسيب مركبات الفوسفات، وأدمصاص بعض المواد العضوية الموجودة في المياه العادمة.

٢- الظروف والمتطلبات

ولكي تكون هذه العملية للتنقية والتغذية الاصطناعية للمياه العادمة ومن ثم اعادة استعمال المياه ناجحة يجب أن تتحقق عدة شروط أهمها مايلي:

(أ) خصائص المياه العادمة

تحتاج المياه العادمة معالجة أولية مناسبة للمياه العادمة تختلف درجتها حسب عدة عوامل أهمها:

(١) نوع الاستعمال المطلوب للمياه بعد التغذية؛
(٢) مدى توفر الاستعدادات للقيام بأعمال الصيانة لأحواض الرشح؛
(٣) نوعية التربة في موقع التغذية المقترح والعمق الى المياه الجوفية؛
(٤) فترة الانتظار بين زمن التغذية وزمن استرجاع المياه من أجل استعمالها.

وفي حالة توفر ظروف تربة وظروف هيدروجيولوجية مناسبة وادارة جيدة لأحواض الرشح فانه يمكن استعمال مياه عادمة معالجة للدرجة الأولى (Primary Treatment) تشتمل التخلص من المواد الخشنة العالقة في المياه بواسطة أحواض ترويق وترسيب لفصل المواد الصلبة العالقة.

أما التنقية للدرجة الثانية (Secondary Treatment) فتشمل التخلص من حوالي ٩٠٪ من المواد العضوية بواسطة عمليات التهوية والأكسدة العضوية، اضافة الى التعقيم بالكلور في أغلب الأحيان. وتقلل المياه العادمة المنقاة لهذه الدرجة من تكاليف وتكرار عملية صيانة الأحواض. وتلزم هذه الدرجة من التنقية للمياه العادمة في حالة قرب مستوى المياه الجوفية من سطح الأرض.

أما التنقية الثلاثية المتقدمة (Tertiary Treatment) والتي تحقق التخلص من كل ما يشكل خطرا على الصحة العامة من رائحة ولون وعكورة وملوثات عضوية وكيماوية وعناصر ثقيلة والأحياء الباثوجينية الدقيقة مثل البكتيريا والفيروسات والطفيليات، فهي مطلوبة فقط في حالة الاضطرار الى تخزين هذه المياه في باطن الأرض عن طريق الحقن بالآبار.

(ب) <u>ظروف التربة التي تعلو منسوب المياه الجوفية</u>

لكي تتحقق التنقية المطلوبة للمياه العادمة وبشكل اقتصادي معقول فانه يجب أن يكون لعمود التربة الموجود فوق منسوب المياه الجوفية خصائص مناسبة أهمها:

(١) معدل رشح عالي كما هو للرمال والحصى؛

(٢) قدرة عالية للترشيح وللادمصاص والتبادل الأيوني مع المياه المتسربة؛

(٣) سماكة مناسبة لاتقل عن متر في حالة التربة الطينية الرملية وأكثر من ذلك في حالات التربة الحصوية والرملية الخشنة.

وتـَوفر طبقات الحصى معدلا عاليا للرشح، الا أن التربة الطينية تمتاز بخصائص أفضل لعمليات الترشيح والادمصاص والتبادل الأيوني. وأما الرمل الناعم الغير متماسك فيشكل حلا وسطا لجميع هذه المتطلبات. وفي المناطق التي لايتوفر فيها سمك كاف من هذه المواد والتي تعلو طبقات صخرية متشققة كتلك الموجودة في الصخور الجيرية الكارستية، فلا تصلح عملية التنقية هذه.

(ج) <u>الظروف الهيدروجيولوجية</u>

يجب أن تكون الظروف الهيدروجيولوجية في موقع التنقية ومنطقة استرجاع المياه مناسبة. وأهم هذه الظروف والشروط المطلوبة مايلي:

(١) وجود المياه الجوفية في الوضع الغير محصور (الغير ارتوازي)؛

(٢) أن يكون للصخور أو المواد الموجودة بين طبقة التربة السطحية ومنسوب المياه الجوفية قدرة جيدة لتسرب المياه وأن لايتوسط هذه المسافة طبقة أو طبقات كتيمة لتحاشي انسداد مثل هذه الطبقات بمخلفات رشح المياه حيث يصعب معالجة هذه الطبقات التحت سطحية لاستعادة نفاذيتها؛

(٣) أن يكون العمق الى منسوب المياه الجوفية (المنطقة المشبعة بالمياه) مناسبا لسببين: توفير حيز لتخزين المياه والمحافظة على منطقة غير مشبعة بالمياه لاتقل عن متر تحت أحواض التغذية، وذلك للحاجة لهذه الطبقة الغير مشبعة لتحقيق معظم عمليات التنقية قبل وصول المياه الراشحة للمياه الجوفية؛

(٤) أن تكون الخواص الهيدروليكية للطبقة الحاملة للمياه مناسبة للعمليات التالية:

أ- تخزين المياه الراشحة بأن يكون محامل التخزين لها عاليا نسبيا؛

ب- القدرة على نقل المياه أفقيا في وقت مناسب من أسفل أحواض التغذية الى مناطق استرجاعها؛

ج- القدرة على اعطاء المياه واسترجاعها عن طريق آبار أو مصارف أو ينابيع؛

(د) أن يكون هناك وقت مناسب لجريان الماء من موقع التغذية الى موقع استرجاع المياه.

(٥) أن يؤخذ في الاعتبار عند اختيار موقع التنقية عدم وجود حقول آبار مياه الشرب في المنطقة وكذلك اتجاه حركة المياه الجوفية المتوقع تحاشيا لاحتمال تلوث هذه الآبار.

(د) عوامل أخرى

وهناك عوامل اقتصادية تؤثر على جدوى عملية تنقية المياه العادمة أهمها:

(١) توفر الأرض وكلفتها؛
(٢) بعد الموقع المقترح للتنقية عن نقطة اعادة استعمال المياه؛
(٣) متطلبات نوعية المياه بالنسبة لنوع اعادة الاستعمال.

(هـ) الظروف الطوبوغرافية

يفضل عند استعمال أحواض الرشح في تنقية المياه العادمة وتغذية المياه الجوفية أن تكون الأراضي منبسطة قليلة الميول للتقليص من أعمال التسوية من أجل المحافظة على غطاء التربة الطبيعي وتحاشي الآثار السلبية لأعمال التسوية على الخصائص الفيزيائية للتربة.

وتشكل المساطب الحصوية على جانبي الأودية والأنهار وغيرها من الرواسب الرملية والحصوية الحديثة، ظروفا ملائمة لأحواض التنقية والتغذية واسترجاع المياه بطريقة الصرف الطبيعي أو الاصطناعي كما سيتضح في الجزء التالي من هذه الورقة.

٣- الظروف السلبية

ومن الناحية الأخرى فان أهم العوامل والظروف الغير ملائمة لعملية تنقية وتغذية المياه العادمة للخزان الجوفي بالطريقة المقترحة تشمل ما يلي:

(أ) وجود طبقة المياه الجوفية محصورة وتحت ضغط ارتوازي عالٍ نسبيا وذلك عندما تعلوها مباشرة طبقة صخرية غير منفذة لاتسمح للمياه الراشحة الى أسفل تحت تأثير الجاذبية الأرضية من دخول الطبقة المائية (المشبعة)؛

(ب) في حالة المياه الجوفية الغير محصورة ولكن عندما تفصلها عن سطح الأرض طبقة غير منفذة مشابهة لما ورد أعلاه تمنع وصول المياه الراشحة الى الخزان الجوفي؛

(ج) عندما تكون خصائص التربة الموجودة فوق منسوب المياه الجوفية غير مناسبة من حيث معدل الرشح وقدرتها على عملية الادمصاص والتبادل الأيوني مع المياه الراشحة؛

(د) في المناطق التي لايوجد فيها غطاء تربة أو أن يكون رقيقا ويعلو مباشرة طبقات مائية مكونة من الصخور المتشققة وخاصة الصخور الجيرية الكارستية.

٤- تصميم أحواض التنقية ووسائل استرجاع المياه

هناك عدة نماذج طبقت في مشاريع تنقية المياه العادمة وتغذية للمياه الجوفية واعادة استعمال المياه العادمة، وتختلف كفاءة هذه النماذج وتصاميمها باختلاف الظروف الخاصة بكل موقع والتي نلخصها فيما يلي :

(أ) درجة التنقية للمياه العادمة المستعملة؛

(ب) كفاءة أعمال صيانة أحواض الرشح والتنقية؛

(ج) العمق الى المياه الجوفية؛

(د) نوعية وخصائص قطاع التربة؛

(هـ) سرعة واتجاه حركة المياه الجوفية وبعد نقاط استرجاع المياه عن أحواض التنقية؛

(و) فترة التخزين المطلوبة للمياه في باطن الأرض لحين الحاجة لاعادة استعمالها؛

(ز) الغرض من اعادة استعمال المياه: زراعة، صناعة، مرافق ترفيهية، أخرى ويؤثر هذا على مستوى التنقية ومدة التخزين اللازمتين قبل اعادة الاستعمال؛

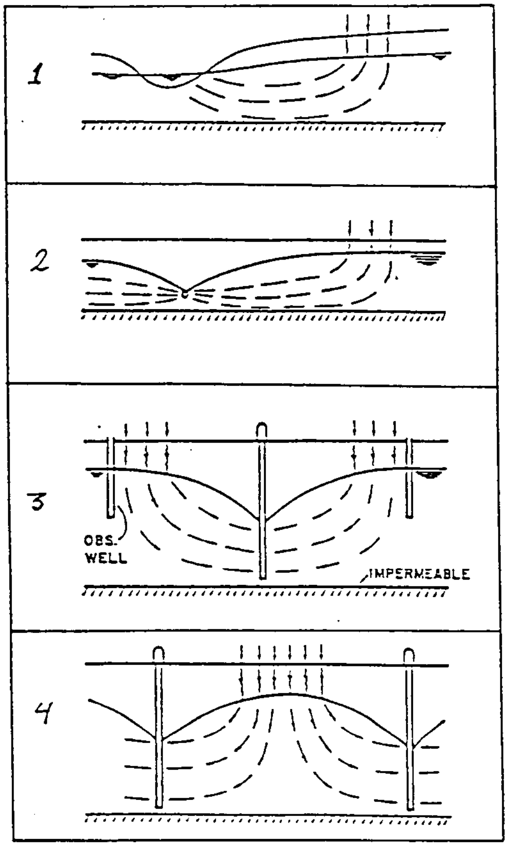
(ح) بعد موقع اعادة استرجاع المياه؛

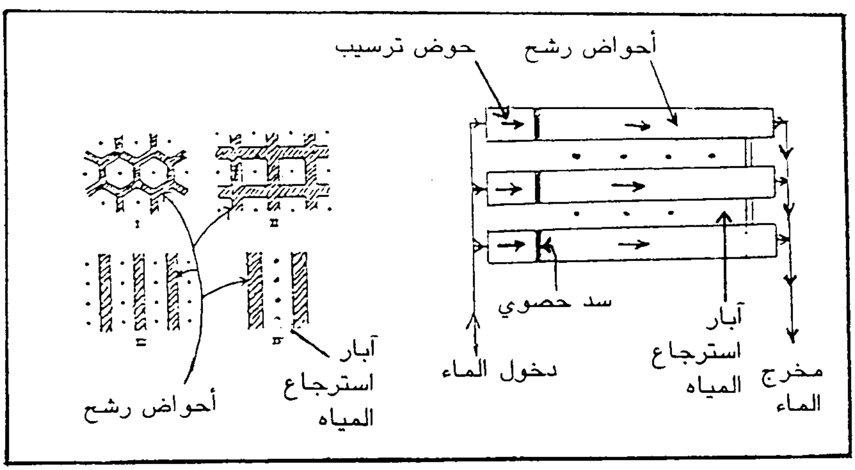
(ط) كمية المياه العادمة المتوفرة والمساحات المتوفرة واللازمة لأحواض التنقية.

ويمكن اعطاء الأمثلة التالية لتصميم أحوض الرشح ووسائل استرجاع المياه وكما هي مبينة في الرسومات من ١-٤ من الشكل ١:

ويبين النموذج الأول في الرسم رقم (١) أبسط هذه النماذج حيث تكون أحواض الرشح في مكان مرتفع نسبيا كالمساطب الحصوية على جانبي الوديان والأنهار، حيث ترشح المياه في اتجاه منطقة منخفضة مجاورة والتي يمكن أن تكون طبيعية مثل مجرى وادي أو نهر، أو اصطناعية مثل مصرف سطحي للمياه وتغذي هذا المجرى المائي.

الشكل ١- نماذج عن تصميم أحواض التغنية وآبار ضخ المياه في مشاريع التغنية الاصطناعية للمياه الجوفية





والنظام المبين في الرسم رقم (٢) مشابه للنظام الأول الا أن وسيلة استرجاع المياه عبارة عن مصارف جوفية كتلك المستعملة في بعض المشاريع الزراعية.

ويستعمل النظامين الثالث والرابع عندما تكون المياه الجوفية عميقة نسبيا ويصعب استرجاع المياه الراشحة بوسائل الصرف المعروفة. ونحتاج هنا الى آبار لضخ هذه المياه. ويستعمل النظام الثالث، رسم (٣)، اذا أردنا ضخ المياه العادمة لوحدها ودون خلط بالمياه الجوفية الطبيعية. وأما النظام الرابع فيستعمل اذا أردنا ضخ المياه العادمة مختلطة بالمياه الجوفية. ويستعمل النظام الثالث لحماية حقول مياه الشرب القريبة من التلوث بالمياه العادمة الراشحة.

٥- <u>ادارة وتشغيل أحواض التنقية والرشح</u>

يتم تشغيل أحواض في مشاريع تنقية المياه العادمة وتغذية المياه الجوفية على فترات متعاقبة من الغمر بالماء والتجفيف على التتابع. وهذا يتطلب مجموعتين من أحواض التغذية تغمر بالماء بالتناوب. وتتراوح فترات الغمر والتجفيف ما بين (١٦) ساعة غمر و (٨) ساعات تجفيف الى أسبوعين غمر واسبوعين تجفيف.

كما تتراوح معدلات الرشح السنوية من ١٥ متر الى ١٥٠ متر في السنة، اعتمادا على خصائص التربة، والمياه ودرجة التنقية للمياه المستعملة والمناخ وعلى تتابع فترات الغمر والتجفيف للأحواض.

يمكن أن تكون سطوح التربة في أحواض التغذية خالية من أي غطاء نباتي ويمكن أن يزرع فيه أنواع خاصة من الأعشاب. ويتميز سطح التربة الخالي من الأعشاب بسرعة الجفاف وسهولة تنظيف الأحواض من الرواسب المتخلفة من المياه بعد عملية الرشح. بينما تتميز الأحواض المزروعة بالأعشاب بالمحافظة على معدل رشح عال لفترة أطول وذلك بفضل خلخلة جزئيات التربة بواسطة الجذور. كما تساعد جذور الأعشاب على استهلاك وتثبيت بعض العناصر الثقيلة الموجودة في المياه العادمة.

وكما ورد سابقا فان نصف الأحواض يغمر بينما يترك النصف الآخر ليجف حتى يستعيد قدرته على الرشح باستعادة نفاذية التربة السطحية في الأحواض. وخلال فترة غمر الأحواض تترسب المواد العالقة في المياه سواء كانت عضوية او غير عضوية وتتشكل طبقة فوق التربة السطحية للأحواض، الأمر الذي يقلص من نفاذيتها وبالتالي معدل رشح المياه خلالها. وأثناء فترة تجفيف الأحواض تجف هذه الطبقة وتتشقق. كما تتحلل المواد العضوية فيها، وتستعيد التربة معظم قدرتها على الرشح. الا أنه على المدى البعيد تتراكم مواد صلبة غير متحللة في قعر الأحواض الأمر الذي يتطلب تنظيفها وازالة هذه الطبقة بالطرق الآلية.

وتختلف فترات الجفاف والغمر حسب نوعية المياه ودرجة تنقيتها قبل ملء الاحواض بها. فاذا كانت منقاة للدرجة الثانوية فان تركيز المواد العالقة ممكن أن يتراوح ما بين ١٠ ٢٠ ملجم/اللتر. وهذا يتطلب فترات غمر وتجفيف لمدة اسبوعين لكل منها كما يتطلب تنظيف الأحواض مرة واحدة كل سنة أو سنتين. أما اذا كانت المعالجة للدرجة الأولية فقط، فان تركيز المواد الصلبة العالقة يكون أكثر بكثير من ذلك، وعليه فقد يتطلب تنظيف الأحواض في نهاية

كل فترة تجفيف، كما يتطلب فترات جفاف لمدة (٨) أيام مقابل فترة غمر لمدة يومين، وعلى أية حال فان أفضل برنامج للتشغيل يجب التوصل اليه من خلال تجارب عملية في الموقع ومن خلال مراقبة التناقص في معدل الرشح. ويمكن ملء الأحواض بالمياه بعمق من (٢٠ سم) الى متر أو أكثر. الا أن كفاءة التشغيل وكمية الرشح السنوية تكون أكثر في حالة المياه الضحلة للأسباب التالية:

(أ) تسمح المياه العميقة، والتي تملأ الأحواض لفترة أطول، بنمو الطحالب التي تمتص ثاني أكسيد الكربون من المياه فتخفف درجة حموضة الماء الى ٨-١٠ وحدات. مما يؤدي الى ترسيب كربونات الكالسيوم في التربة السطحية. الأمر الذي يؤدي الى تقليل نفاذيتها ومعدل الرشح فيها؛

(ب) يؤدي نمو الطحالب في المياه العميقة الى ازدياد ترسب المواد العضوية على التربة السطحية في الأحواض مما يقلص من معدل رشح المياه؛

(ج) تسمح المياه الضحلة بمرور ضوء الشمس من خلالها كما يمكن أن تحقق تهوية أفضل للمياه مما يتيح كمية أكبر من الاكسجين الذائب في الماء. الأمر الذي يساعد على تحلل المواد العضوية العالقة في الماء أو المترسبة في الأحواض.

الا أن المياه الضحلة في الأحواض تكون أكثر عرضة للتسخين بأشعة الشمس مما يؤدي الى زيادة التبخر منها.

٦- المعالجة المسبقة للمياه العادمة

ان المطلب الرئيسي للتنقية المسبقة للمياه العادمة قبل نشرها في الأحواض هو التخلص من المواد الصلبة العالقة. كما يفضل تخفيض الاحتياجات الحيوية للاكسجين (BOD) والبكتريا على الرغم من أن ذلك أقل ضرورة.

وتعمل التنقية الثانوية بالطرق المختلفة على التخلص من المواد العضوية القابلة للتحلل والمعبر عنها بواسطة (BOD). وبما أن بكتيريا التربة يمكن أن تقوم بهذا العمل بشكل كامل، فان المعالجة الأولية للمياه يمكن أن تكون كافية لهذا الغرض. ومع أن هذه المرحلة الأولية من التنقية تقلل من معدل رشح المياه وتزيد من متطلبات صيانة الأحواض، الا أن الوفر المالي في الغاء التنقية الثانوية يكون كبيرا ومجديا.

٧- استرجاع المياه

يتم استرجاع المياه اما بالضخ من الآبار أو شبكة صرف خاصة معدة لهذا الغرض (سطحية أو جوفية)، أو من مصرف طبيعي مجاور لأحواض التغذية.

ويكون تعيين مواقع الآبار كما ورد في بند سابق من هذه الورقة. ويجب مراعاة حالة الميل الهيدروليكي وسرعة واتجاه حركة المياه الراشحة بعد أن تصل الى منسوب المياه الجوفية والتحكم في معدل الضخ بحيث يتم استرجاع معظم المياه الراشحة دون تسربها الى حقول آبار

مجاورة لا يراد لها أن تتلوث بالمياه الراشحة من مشروع التنقية. كما يمكن تعيين مواقع استرجاع المياه لتكون قريبة من مواقع اعادة استخدامها للري أو غيره. وكذلك بما يتناسب مع فترة التخزين اللازمة لسد الاحتياجات المائية في الزمن المطلوب.

وأفضل أسلوب لمشاريع اعادة استعمال المياه العادمة هو اختيار موقع اعادة الاستعمال وموقع منشآت التنقية معا منذ البداية.

جيم- تأثير عملية التنقية المقترحة على نوعية المياه العادمة

تتم تنقية المياه العادمة من خلال عملية الرشح من أحواض التغذية بواسطة عمليات الترشيح والادمصاص والتبادل الأيوني والتحلل العضوي. وتتم معظم التنقية في المنطقة الهوائية الغير مشبعة بالماء الموجودة بين منسوب المياه الجوفية وسطح الأرض. وتشمل التنقية والتحسن على نوعية المياه بهذه العمليات المواد التالية: الكائنات الحية الدقيقة، المواد العالقة، النيتروجين، الفوسفور والمواد العضوية الذائبة والعناصر الثقيلة. وفيما يلي ملخص للتحسن الممكن أن يطرأ على نوعية المياه:

١- المواد الصلبة العالقة: يتم ترسيب معظم هذه المواد في طبقة تعلو التربة السطحية في أحواض التنقية. ويتم احتجاز الجزء الأنعم نسبيا في البضع سنتمترات من التربة تحت سطح الأرض. وقد يصل هذا العمق الى متر واحد في التربة الرملية المتوسطة والخشنة. ويمكن لعملية الترشيح هذه التقليص من تركيز المواد العالقة الى ١ ملجم/اللتر، مقابل ١٠-٢٠ ملجم/اللتر بواسطة طرق التنقية التقليدية للدرجة الثانية.

٢- ملوحة المياه: تزداد ملوحة المياه العادمة نتيجة لعمليتين: الأولى زيادة التركيز بسبب التبخر الذي قد يصل الى نسبة ٢٪ يتبعها زيادة في الملوحة بنفس النسبة. والثانية بسبب اذابة الأملاح من الطبقات الرملية والصخرية أثناء عملية الرشح فوق منسوب الماء الجوفي. وتعتمد هذه الأخيرة على العمق للمياه الجوفية ومعدل الرشح ونوعية الصخور.

٣- النيتروجين: تحتوي المياه العادمة على النيتروجين بتركيز يتراوح مابين ٢٠-١٢٠ ملجم/اللتر. ويمكن التخلص من النيتروجين من خلال أحواض الرشح بنسبة قد تصل الى ٧٥٪. ويعتمد ذلك على معدل الرشح وطول وتعاقب فترات الغمر بالمياه والتجفيف وتوفر الهواء أو عدمه فوق منسوب الماء الجوفي. وتحقق فترات غمر لمدة يومين وفترات تجفيف لمدة خمسة أيام متعاقبة التخلص من كامل النيتروجين الذي مصدره الأمونيا. وبتعاقب الغمر والتجفيف لمدة اسبوعين لكل منها يمكن التخلص من ٧٥٪ من النيتروجين المتبقي على شكل نيترات من خلال تبادل العمليات الهوائية واللاهوائية للتخلص من النيتروجين في الطبقة العليا من التربة خلال فترات التجفيف والغمر على التتابع. ويلزم للعملية الأخيرة وجود الكربون العضوي كمصدر طاقة للبكتيريا الغير هوائية والذي يجب أن يضاف اذا لم يكن متوفر في المياه العادمة بتركيز كاف.

٤- الفوسفور: يتحول الفوسفور العضوي من خلال عمليات التقنية المسبقة ومن خلال الرشح خلال التربة الى فوسفات. ويوجد الفوسفور في المياه العادمة بتركيز يتراوح ما بين ٥-

٥٠ ملجم/اللتر. وتترسب الفوسفات على شكل فوسفات الكالسيوم في التربة والصخور الجيرية (قلوية عالية). أما في الوسط الحامضي فيتفاعل مع الحديد وأكسيد الألمنيوم ليشكل مواد غير ذائبة تترسب في التربة.

وتزداد نسبة التخلص من الفوسفات مع زيادة المسافة التي تعبرها المياه العادمة في التربة. وقد قل تركيز الفوسفات في مشروع في ولاية اريزونا الأمريكية بنسبة ٤٪، ٨٠٪ بعد رشح المياه في التربة لمسافات ٣م، ٦م على التتابع (Bouwer, 1985). كما أورد نفس المصدر أن تركيز الفوسفات انخفض بنسبة ٩٥٪ بعد أن انتقلت نفس المياه افقيا في الطبقة المائية المشبعة ولمسافة (٦٠) مترا.

٥- <u>البكتيريا والفيروسات</u>: أثبتت العديد من التجارب أن رشح المياه العادمة في تربة مناسبة لمسافة ١-٣ م قد خلص المياه من البكتيريا ومعظم الفيروسات. كما أن اضافة الكلور للمياه بعد استرجاعها بكمية قليلة يمكن أن يخلص المياه بالكامل من البكتيريا والفيروسات. كما أن جريان المياه الراشحة في الطبقة المائية بعد وصولها اليها لعشرات أو بضع مئات من الأمتار، حسب نوعية الصخور فيها، قد خلص المياه من كافة البكتيريا والفيروسات.

٦- <u>المواد العضوية</u>: تتراوح كمية الأكسجين الحيوي المطلوب في المياه العادمة من ١٠٠٠ ملجم/اللتر قبل عملية التنقية الى ١٠-٢٠ ملجم/اللتر بعد مرحلة التنقية الثانوية. ويمكن للمعالجة بواسطة أحواض الرشح التخلص من كافة المواد العضوية المذابة في المياه بعد جريانها في التربة لمسافة ٣-٦ متر. ولكن هذه الازالة لا تشمل المواد العضوية المهلجنة.

٧- <u>العناصر الثقيلة</u>: تساعد عملية الرشح خلال التربة على التخلص من نسب متفاوتة من العناصر الثقيلة وصلت الى ٨٠٪ بالنسبة للزنك، ٨٧٪ بالنسبة للنحاس، ٧٪ بالنسبة للكاديوم، ٢٠٪ بالنسبة للرصاص. أما البورون فيحتاج التخلص منه الى وجود المادة الطينية في المنطقة الغير مشبعة التي تعلو المياه الجوفية.

دال- النواحي الاقتصادية

لإعادة استعمال المياه العادمة بشكل عام نواحي اقتصادية واجتماعية. اما العوامل الاقتصادية فأهمها:

- حجم المشروع؛
- خصائص مياه الصرف الصحي؛
- موقع المشروع؛
- كلفة البدائل لتوفير المياه؛

ومع أن وسائل التنقية معروفة الا أن النواحي الاقتصادية لاعادة استعمال المياه العادمة المعالجة لا تزال بحاجة الى تقييم أوفى. إن زيادة الاحتياجات المائية وزيادة شح المياه

وارتفاع كلفة موارد المياه البديلة، اضافة الى تلوث البيئة المحتمل من طرق الصرف الحالية، تزيد من أهمية تنقية واعادة استعمال المياه العادمة.

أن التحليل الاقتصادي لمشاريع المياه عامة ومشاريع اعادة استعمالها خاصة يجب أن لا تكون المقياس الوحيد لتقييم مثل هذه المشاريع. ويتطلب مفهوم الاستدامة للمشاريع المائية والزراعية ادخال مفهوم التكامل في استخدامات مصادر المياه، ومنها ادخال مبدأ اعادة استعمال المياه العادمة لأغراض مناسبة وضرورية، منها زراعة المحاصيل الغذائية ومحاصيل الأعلاف وري الحدائق الترفيهية للمدن، مما يخفف الضغط على المصادر المائية الأخرى ذات النوعية الأفضل لاستعمالها لأغراض تتطلب ذلك.

واذا ما استثنينا كلفة منشآت محطة التنقية التقليدية، وخطوط تجميع المياه العادمة في المدن فان كلفة المعالجة لوحدها لاتزيد عن ربع الكلفة الكلية. واذا ما اكتفينا بالمعالجة الأولية في مشاريع التغذية الاصطناعية فان كلفة التنقية يمكن أن تقل الى ١٥٪ من الكلفة الكلية. ويوضح الجدول رقم (١) كلفة تنقية المياه أو معالجتها لمختلف مستويات التنقية، كذلك كلفة مياه التحلية من أجل المقارنة. ويبين الجدول كذلك هذه الكلفة في حالة استخدام التقنية المقترحة للتنقية والتغذية الاصطناعية كوسيلة للمعالجة واعادة الاستعمال. وواضح أن هذه الطريقة الأخيرة منافسة لطرق التنقية التقليدية وتحلية مياه البحر بشكل لا بأس به. وخاصة اذا ما اعتبرنا مبدأ ضرورة المحافظة على مياهنا الثمينة والشحيحة، ومبدأ حماية البيئة ومنع تلوث مصادر المياه الجوفية والسطحية. وتكون هذه الطريقة أكثر اقتصادية اذا ما استخدمنا مياه معالجة للدرجة الأولى وبحيث يتم انشاء أحواض الترويق والترسيب في نفس منطقة أحواض التغذية.

هاء- النواحي البيئية والصحية

يجب وضع هدف حماية البيئة وصحة الانسان هدفا أساسيا عند تخطيط وانشاء وتشغيل مشاريع تنقية واعادة استعمال المياه العادمة في أغراض زراعية أو صناعية. كما يجب أن لا يعاد استعمال هذه المياه للأغراض المنزلية في منطقتنا العربية بسبب نقص الخبرة العملية في مجال التنقية المتقدمة. كما يجب أخذ الحيطة واجراء مراقبة حثيثة على اعادة الاستعمال للأغراض الأخرى، وذلك لوجود مواد كيماوية ذائبة وكائنات حية باثوجينية قد تسبب الأمراض للانسان على المدى القصير أو البعيد. ومع أن وسائل التنقية المعروفة يمكنها التخلص من هذه المواد الى درجة كبيرة، الا أن بعض المواد الكيماوية يصعب التخلص منها بشكل كلي. وأهم العناصر الممكن أن تكون سامه للانسان وموجودة في المياه العادمة هي: الكاديوم والزنك والنحاس والرصاص والى حد أقل النيتروجين والصوديوم. وقد بينا سابقا في هذه الورقة قدرة التخلص من ٨٠٪ من الزنك، ٨٧٪ من النحاس بطريقة التغذية الاصطناعية وهذا شيء جيد. الا أن التخلص من الكاديوم يحتاج الى ترشيح خلال طبقات تحتوي على مواد طينية وبدون ذلك فان معدل التخلص منه بالرشح خلال التربة الرملية لا يتجاوز ١٠٪ وكذلك بالنسبة للرصاص.

ان تراكم هذه المواد الكيماوية الخطرة في التربة الزراعية لا يشكل خطرا مباشرا على صحة الانسان. وبالتالي فان تراكمها في التربة في أحواض الرشح يكون تأثيره أقل، مالم تصل هذه المواد الى المياه الجوفية. وحتى في هذه الحالة فانه يحصل لها تخفيف في التركيز

نتيجة لاختلاطها بمخزون المياه الجوفية. كما أنه يتم التخلص من جزء اضافي من هذه المواد بعد أن تصل الى المياه الجوفية أثناء جريانها في الطبقات الصخرية الحاملة للمياه.

الجدول -١ كلفة تنقية المياه العادمة
(دولار لكل (م٣) من المياه)

(أ)	*	معدل كلفة تنقية المياه للمرحلة الثانوية:		
	-	في دول الخليج العربي	٠,٢٦	
	-	في دول العالم	٠,١٣ - ٠,٣٢	
	*	كلفة التنقية المتقدمة مع التناضح العكسي	٠,٨	
	*	معدل كلفة تحلية مياه البحر (حسب السعر العالمي للطاقة)	١,٥	
(ب)		<u>مستوى التنقية التقليدية</u>	<u>كلفة التنقية التقليدية(*)</u>	<u>كلفة التنقية المتقدمة بالطريقة المقترحة</u>
	*	أولية	٠,١٥	٠,٢٥
	*	ثانوية:		
	-	بالتنشيط الحيوي	٠,٢٤	٠,٣٤
	-	باضافة الترشيح	٠,٢٨	٠,٣٨
	-	باضافة الترشيح بالكربون المنشط	٠,٣٧	٠,٤٧
	-	باضافة التناضح العكسي	١,١٠	١,٢٠

(*) اعتماداً على أسعار عام ١٩٨٠ مع معدل نمو ٥٪ سنويا من عام ١٩٩٣.

وبالنسبة لمخاطر وجود الكائنات الحية الناقلة لبعض الأمراض في المياه، فانه اذا ما صممت أحواض الرشح وشغلت بأساليب علمية ومراقبة جيدة، فانه سيتم التخلص من هذه الكائنات الحية الضارة وكذلك من البكتيريا والفيروسات قبل وصولها الى المياه الجوفية أو السطحية أو الى المزروعات التي تروى منها. كما أنه زيادة للحيطة فانه يمكن اضافة كمية كلور بسيطة لهذه المياه قبل استعمالها.

أما بالنسبة لبعض الحشرات المائية مثل البعوض والتي يمكنها نقل بعض الأمراض الى الانسان فلا بد من برامج خاصة لمكافحة هذه الحشرات خوفا من انتشار مثل هذه الأمراض.

وعلى الرغم من أن إعادة استعمال المياه مستمر في منطقة الإسكوا منذ عدة عقود، الا أنه لم يؤدي الى انتشار أو ظهور أمراض مصاحبة خاصة بهذا الاستعمال، وذلك نظرا للمعايير العالية التي تطبق في معظم دول المنطقة حيث تصل درجة التنقية في بعض الدول كالمملكة العربية السعودية وبعض دول الخليج الى مستوى مياه الشرب.

واو- اعادة استعمال مياه الصرف الصحي المعالجة في منطقة الإسكوا

مع زيادة الطلب على المياه واستثمار معظم الموارد المائية الطبيعية يزداد شح المياه شيئا فشيئا في المناطق الجافة وشبه الجافة. وهذا ينطبق بشكل كبير على الدول العربية في منطقة الإسكوا. الأمر الذي اضطر المخططين والمختصين الى اعتماد أي مصدر مائي، تقليدي أو غير تقليدي، لتدعيم المصادر المائية المستثمرة، طالما يمكن استعماله بكفاءة وبشكل اقتصادي من أجل تدعيم مشاريع التنمية.

وعندما تنعدم أو تشح المياه ذات النوعية الجيدة، وهذا ينطبق على كثير من بلدان الإسكوا، يصبح اعتبار الموارد المائية الأقل جودة والهامشية أمرا ضروريا وخاصة في الزراعة والصناعة حيثما أمكن، على الرغم من عدم وجود معيار عالمي لتعريف المياه الهامشية. وعلى سبيل المثال، فالمياه الجوفية العالية الملوحة في مياه هامشية للزراعة، والمياه العادمة والصرف الزراعي هي أيضا هامشية. بسبب بعض المخاطر التي قد تترتب على استعمالها بشكل غير مدروس ومراقب.

كما أن التوسع الحضري المتسارع في بلدان الإسكوا وما يتبعه من زيادة كبيرة في كمية المياه العادمة المنتجة (٦٠ - ٧٠٪ من التزويد المائي للمنازل)، واذا ما توفرت وسائل صرف وتنقية جيدة تضمن المحافظة على البيئة، فان هذه المياه يمكن أن تسد جزءا من احتياجات الري في هذه المنطقة الجافة كاحدى الوسائل المحافظة على الموارد المائية العالية الجودة وذلك لاستعمالها لأغراض أخرى غير الري والتي تتطلب نوعية جيدة من المياه. اضافة الى أنه اذا ما أحسن تخطيط استعمال هذه المياه العادمة فان ذلك من شأنه تخفيف تلوث المياه السطحية والجوفية علاوة على المحافظة عليها. كما أنه سيتيح الاستفادة من المواد النيتروجينية والفوسفاتية الموجودة فيها والمطلوبة للمحاصيل الزراعية، مما سيقلل من كميات الأسمدة التجارية المطلوبة لهذه المحاصيل. ومن المفيد جدا اعتبار هذه النواحي عند تخطيط مشاريع الصرف الصحي للمدن لما لذلك من تأثير على كلفة خطوط نقل المياه وطريقة تنقيتها بالنسبة للأراضي الزراعية التي سيعاد استعمال المياه المعالجة لريها.

وقد استعملت المياه العادمة للزراعة المروية في المناطق الجافة في كل من الولايات المتحدة الأمريكية واستراليا، مما أتاح مصادر مياه اضافية لأغراض الشرب. كما اعتمد اعادة استعمال المياه المعالجة للأغراض الزراعية كسياسة في كل من الأردن ومصر والمملكة العربية السعودية ومعظم دول الخليج العربي. والمياه العادمة تستعمل حاليا بشكل كبير في ري الحدائق والمتنزهات في المدن وكذلك لمشاريع التحريج في كل من الكويت والبحرين وقطر ودولة

الامارات العربية المتحدة وعُمان والعراق. وفي الجمهورية العربية السورية تستعمل المياه العادمة في الري في منطقة غوطة دمشق بعد اختلاطها بمياه نهر بردى كما يتم في البحرين استعمال المياه العادمة المعالجة للدرجة الثلاثية في زراعة الخضروات. ويبين الجدول رقم (٢) كميات المياه العادمة المستعملة في هذه الأقطار.

ومن أهم النواحي التي يجب اعتبارها في برامج اعادة استعمال المياه العادمة المعالجة هي النواحي الصحية والبيئية وكلفة التنقية. والهدف من هذه الورقة ابراز أهمية دور التربة والصخور الحاملة للمياه الجوفية في تنقية هذه المياه الى درجة متقدمة تفوق المرحلة الثلاثية للتنقية بالطرق التقليدية في حالة حسن تخطيط هذه العملية، وبكلفة اقتصادية أقل. وكذلك ابراز أهمية الخزان الجوفي كخزان توازن بين التفاوت الفصلي في الطلب والعرض على هذه المياه، إضافة الى مساهمته في التنقية ودوره كناقل للمياه من موقع التنقية الى مواقع اعادة الاستعمال وأخيرا لتوضيح تفوق استعمال مثل هذه الطريقة على غيرها من طرق اعادة استعمال المياه العادمة.

زاي- امكانات التطبيق في منطقة الإسكوا

تستدعي ظروف شح المياه والعجز في تزويدها في منطقة الإسكوا، وارتفاع كلفة المصادر البديلة بل عدم توفرها أحيانا لأسباب طبيعية أو فنية أو مالية، والحاجة الى وسائل تنقية وصرف للمياه العادمة من أجل حماية البيئة ومصادر المياه الطبيعية من التلوث، والحاجة الى توفير مصادر المياه ذات النوعية الجيدة للاستعمالات التي تتطلب مثل هذه النوعية، وتخفيف الضغط على بعض المصادر المائية الجوفية المستنزفة، مقابل ارتفاع الكميات المنتجة من المياه العادمة، تستدعي كل هذه الظروف اعتماد سياسة مائية تأخذ في الاعتبار تنقية المياه العادمة على أنها مصدر مائي أساسي يجب أن يدخل في الموازنة المائية لكل قطر وفي تخطيط مشاريع الري والمحافظة على استدامتها.

وفي ضوء ارتفاع التنقية الثلاثية المتقدمة للمياه العادمة بالطرق التقليدية، وقدرة مقاطع التربة والطبقات الصخرية الحاملة للمياه الجوفية على تحقيق مثل هذه التنقية بكفاءة عالية وكلفة اقتصادية بسيطة مقارنة بوسائل التنقية التقليدية، وبنجاح وتطبيق مثل هذا الأسلوب في الكثير من بلدان العالم وخاصة الجافة منها، ولميزة هذه الطريقة للتنقية باعتبارها تمثل تكنولوجيا بسيطة وغير معقدة يسهل التعامل معها، ولكن بمراقبة حثيثة، في منطقة الإسكوا، يصبح اعادة استعمال المياه العادمة من خلال تنقيتها بالتغذية الاصطناعية للمياه الجوفية عملية مبررة اقتصاديا وفنيا. ويمكن أن يكون الوفر المالي كبيرا باتباع هذه الطريقة وخاصة في كلفة الانشاء وكلفة التنقية والتشغيل. فلا تحتاج هذه الطريقة الى طاقة كهربائية وأعمال ميكانيكية أو مواد كيماوية قياسا لطرق التنقية التقليدية. وبذلك فيمكن أن تكون هذه الطريقة بديلا منافسا لانشاء أية محطات تنقية جديدة من النوع التقليدي، أو أية توسعات للمحطات القائمة.

وتتوفر ظروف طبيعية مناسبة لاستخدام مثل هذه الطريقة في كافة الأقطار العربية في منطقة الإسكوا. ونحتاج الى دراسات هيدروجيولوجية تفصيلية من أجل اختيار مواقع مناسبة لعملية التغذية الاصطناعية.

الجدول ٢- اعادة استعمال المياه العادمة في منطقة الإسكوا

القطر	كمية المياه العادمة المستعملة (م م٣/السنة)	نوع الاستعمال	ملاحظات
البحرين	٦٥	حدائق عامة ومحاصيل زراعية	تنقية ثلاثية لمياه المزروعات
الكويت	٤٠	حدائق عامة وغابات	
العراق	٩٨	محاصيل زراعية	
عمان	٢٠	حدائق عامة	
قطر	١٢٠	حدائق عامة ومحاصيل زراعية	
المملكة العربية السعودية	٤٠٠	حدائق عامة ومحاصيل زراعية	
الامارات العربية المتحدة	٦٢	حدائق عامة وغابات	
مصر	٦٠٠	زراعة محاصيل	بعد خلطها بمياه نهر النيل
الجمهورية العربية السورية	٨٠	زراعة محاصيل	بعد خلطها بمياه نهر بردى
الأردن	٣٥	زراعة محاصيل	بعد خلطها بمياه سد الملك طلال
المجموع	١٣٤٢		

ويمكن ذكر بعض المناطق على سبيل المثال لا الحصر حيث يمكن تطبيق هذه الطريقة في اعادة استعمال المياه العادمة ومعالجتها في منطقة الإسكوا:

- حوض دمشق المائي/ منطقة الغوطة؛

- المناطق الرملية المحاذية للسهل الفيضي لنهر النيل في جمهورية مصر العربية؛
- منطقة الخربة السمرة ومناطق وادي الأردن ووادي عربه في الأردن؛
- السهول الشمالية الغربية في دولة البحرين؛
- معظم المناطق الشمالية والوسطى في دولة الامارات العربية المتحدة؛
- مناطق الترسيبات الرملية والحصوية الحديثة في المملكة العربية السعودية؛
- مناطق تكشف الرواسب الرملية والحصوية الحديثة في دولة الكويت؛
- المناطق الجنوبية في دولة قطر؛
- مناطق عدن والحديدة في الجمهورية اليمنية؛
- سهل الباطنه وسهل صلاله في سلطنة عـُمان.

ويمكن التعاون بين أقطار المنطقة وبالتعاون مع الإسكوا في البدء بمشاريع ريادية في هذا المجال لتكون نموذجا توضيحيا ومجالا لاكتساب وتعميم الخبرات وتطوير الأبحاث في هذا المجال وخاصة في تكييف هذه التقنية البسيطة والفعالة في خدمة قطاعات المياه والزراعة والصناعة لتتناسب مع الظروف الطبيعية في المنطقة.

المراجـــع

Bouwer H. (1970)	"Groundwater Recharge Design For Renovating Waste Water", Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers.
Bouwer H. (1985)	"Renovation of wastwater with rapid-infiltration land treatment systems".
Bouwer H. (1987)	"Soil-aquifer treatment of sewage". Paper prepared for the Land and Water Development Division, FAO, Rome.
Bouwer H., and Chaney R.L. (1974)	"Land treatment of wastewater". Advances in Agronomy, vol. 26, N.C. Brady (ed). Academic Press, New York.
Iskander, I.K.	"Overview of Existing Land Treatment Systems", Proceedings of the International Symposium on the State of Knowledge in Land Treatment of Wastewater, vol. 1, 1978.
Jewell, W., and Seabrock	"Historical Review of Land Application as an Alternative Treatment Process for Wastewater", U.S. EPA Report No. 43019-77-008, 1978.

XI. REMOTE SENSING TECHNIQUES FOR COMPARATIVE STUDIES OF WATERSHEDS IN SELECTED BASINS IN THE ESCWA REGION*

by

Hamid M.K. Al-Naimy

Introduction

Water is the most important natural resource, and its availability is a major factor controlling the quality of human life.

Water balance dynamics is a topic that has been addressed by remote sensing techniques from the very first satellite missions. Remote sensing literature reports a wide range of experiences in water resources applications concerning precipitation and run-off (Soil Conservation Service 1975; Rango 1990; Meijerink et al. 1994) as well as evaporation and soil moisture (Jackson 1983; Barrett 1990) and groundwater exploration. Potential water resources available in a watershed are linked to the actual water resources effectively usable for human activities and natural needs via some biophysical parameters that characterize the catchment area. Biophysical parameters, derived from remote sensing data, are intended here as quantitative indicators of changes in the surface characteristics of watersheds of either phenological or hydro-climatological nature whose interactions and correlations can be used for modelling and prediction of environmental changing conditions. Evaporation and soil moisture are also important parameters for hydrology and agricultural meteorology, as well as extremely important in agricultural management. They affect the time of seeding, growth and development of crops and many tilling practices. In addition to this, soil moisture is an important factor in irrigation and yield estimation.

Empirical models have been developed for estimating potential evaporation using Landsat MSS data (Idso et al. 1975; Kanemasu et al. 1978; Khorram et al. 1979).

Jackson et al. (1977) found a significant linear relationship between the difference of daily evaporation and net radiation and post-noon canopy-air temperature difference for wheat fields under experimental conditions.

NOAA-AVHRR thermal data are being processed to investigate the spatial and temporal variation in high and low frequency thermal inertia and evapo-transpiration (Jupp et al. 1990). The linking of regional water balance models with remote sensing to monitor soil moisture and drought has been achieved (McVicar et al. 1991, 1992).

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* In the preparation of this document, Mr. Hamid Al-Naimy served as a consultant to the Economic and Social Commission for Western Asia (ESCWA).

The ESCWA region suffers from a shortage of water, since the region's climate is predominantly arid. New technologies are proposed to assess the water resources in the region. The availability of data and maps on surface water and underground water is of great importance in water resources management. Remote sensing techniques can make an important contribution to hydrological studies and monitoring.

Using these techniques is the main objective of the ESCWA project for water resources assessment in the region, which is under execution by the Royal Jordanian Geographic Centre (RJGC). The output of the project will include regional hydrological and hydrogeological maps on a scale of 1/2,500,000, as well as detailed hydrogeological maps on a scale of 1/1,000,000, for three selected shared underground water basins (see annex to this paper).

There will be a workshop for experts from the ESCWA member countries to be held by RJGC. The subject of this workshop will be the use of remote sensing techniques as applied in water resources assessment. This paper contains a short definition of remote sensing techniques, the principles and methodology. The physiography and hydrology of the ESCWA region are reviewed, along with the application of remote sensing techniques in the region.

Finally, a few proposals for future development in the ESCWA region have been suggested in the conclusions section.

A. REMOTE SENSING TECHNIQUES

1. *Principles*

Remote sensing is the science and technology by which the characteristics of objects of interest can be identified, measured or analysed without direct contact (Remote Sensing Note, 1993).

The electromagnetic radiation which is reflected or emitted from an object is the source of remote sensing data. This source can be measured, and this measurement is based on either radiometry or photometry, with different technical terms and physical units. The device of detecting the electromagnetic radiation reflected or emitted from an object on the earth surface is called "sensor" (i.e. cameras or scanners); this should be carried out by aircraft or satellites, which are used as platforms. (Figures 1, 2 and 3 show the principles of these techniques.) All matter reflects, absorbs, penetrates and emits electromagnetic radiation in a unique way. For example, the reason why a leaf looks green is that the chlorophyll absorbs blue and red spectra and reflects the green spectrum. The unique characteristics of the matter are called Spectral-Signature, which can be determined, using reflected or emitted electromagnetic radiation, from the matter, that is, each object or matter has a different characteristic of reflection or emission if the type of object or the environmental condition is different. Remote sensing is a technology for identifying and understanding the objects or the environmental conditions through the uniqueness of the reflection or emission. The reflectance is defined as the ratio of incident flux on a surface to reflected flux from the surface. This concept is illustrated in figures 1, 2 and 3, which show the flow of remote sensing, where three different matters are measured by a sensor in a limited number of bands with respect to their electromagnetic characteristics after various factors have affected the signal.

Figure 1. Data collection by remote sensing

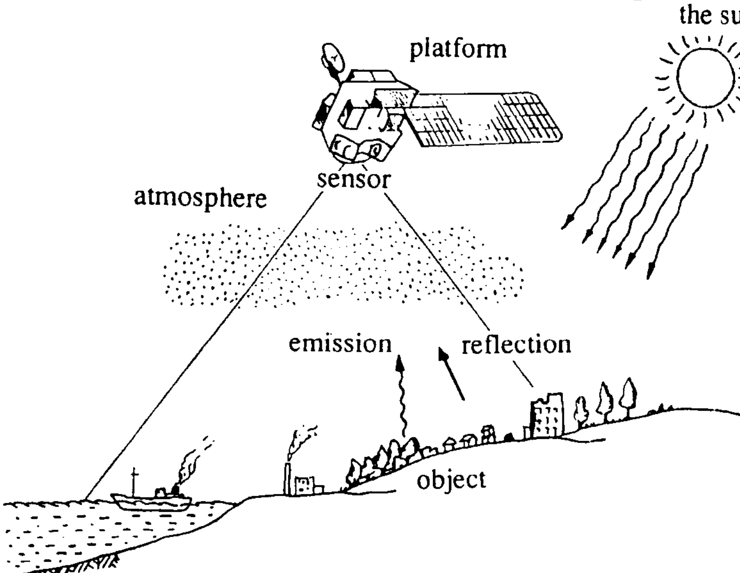


Figure 2. Flow of remote sensing

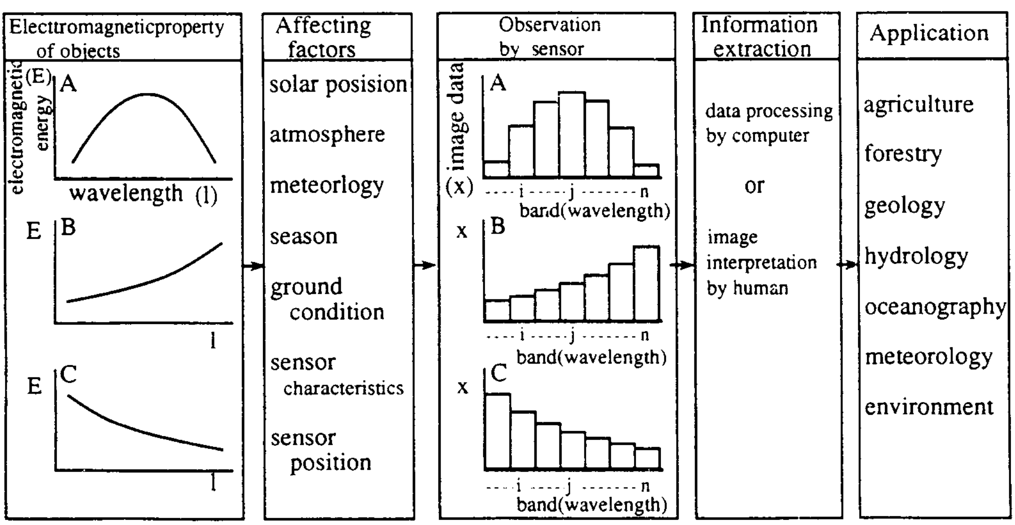
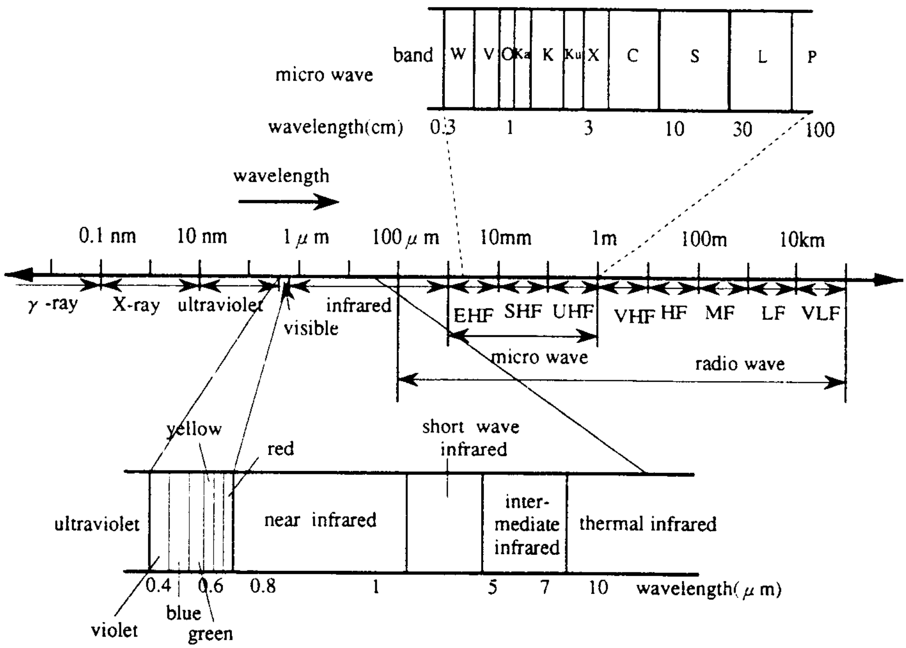


Figure 3. The bands used in remote sensing

class			wavelength	frequency
ultraviolet			100A ~ 0.4 μm	750 ~ 3,000THz
visible			0.4 ~ 0.7 μm	430 ~ 750THz
infrared	near infrared		0.7 ~ 1.3 μm	230 ~ 430THz
	short wave infrared		1.3 ~ 3 μm	100 ~ 230THz
	intermediate infrared		3 ~ 8 μm	38 ~ 100THz
	thermal infrared		8 ~ 14 μm	22 ~ 38THz
	far infrared		14 μm ~ 1mm	0.3 ~ 22THz
radio wave	submillimeter		0.1 ~ 1mm	0.3 ~ 3THz
	micro wave	millimeter (EHF)	1 ~ 10mm	30 ~ 300GHz
		centimeter (SHF)	1 ~ 10cm	3 ~ 30GHz
		decimeter (UHF)	0.1 ~ 1m	0.3 ~ 3GHz
	very short wave (VHF)		1 ~ 10m	30 ~ 300MHz
	short wave (HF)		10 ~ 100m	3 ~ 30MHz
	medium wave (MF)		0.1 ~ 1km	0.3 ~ 3MHz
	long wave (LF)		1 ~ 10km	30 ~ 300kHz
	very long wave (VLF)		10 ~ 100km	3 ~ 30kHz



(a) *Types of remote sensing with respect to wavelength regions*

There are three types of remote sensing with respect to wavelength regions:

(a) Visible and Reflective Infrared Remote Sensing: The sun radiates electro-magnetic energy with a peak wavelength of 0.5 μm. Remote sensing data obtained in the visible and reflective infrared regions mainly depend on the reflectance of objects on the ground surface. Therefore, information about matter/object can be obtained from the spectral reflectance;

(b) Thermal Infrared Remote Sensing: The source of radiant energy used in thermal infrared remote sensing is the object itself, because any object with a normal temperature will emit electro-magnetic radiation with a peak at about 10 μm;

(c) Microwave Remote Sensing: In the microwave region, there are two types of microwave remote sensing: passive microwave remote sensing and active remote sensing. In passive microwave remote sensing, the radiation emitted from an object is detected, while the back scattering coefficient is detected in active microwave remote sensing. The classified three types of remote sensing with respect to wavelength regions are illustrated in figure 4.

(b) *Spectral reflectance of land covers*

The spectral reflectance is different with respect to the type of land cover; this is the principle that in many cases allows the identification of land cover with remote sensing by observing the spectral reflectance or spectral radiance from a remote distance removed from the surface. Figure 5 shows three curves of spectral reflectance for typical land cover; vegetation, soil and water. The vegetation (as seen in figure 5) has a very high reflectance in the near infrared region, though there are three low minima due to absorption. Soil has rather higher values for almost all spectral regions. Water has almost no reflectance in the infrared region. Figure 6 shows two detailed curves of leaf reflectance and water absorption. Chlorophyll, contained in a leaf, has strong absorption at 0.45 μm and 0.67 μm, and high reflectance at near infrared (0.7-0.9 μm). This results in a small peak at 0.5-0.6 μm (green colour band), which makes vegetation look green to the observer. Near infrared is very useful for vegetation surveys and mapping because such a steep gradient at 0.7-0.9 μm is produced only by vegetation.

Because of the water content in a leaf, there are two absorption bands at about 1.5 m and 1.9 m. This is also used for surveying vegetation vigour. Figure 7 shows a comparison of spectral reflectance among different species of vegetation, while figure 8 shows various patterns of spectral reflectance with respect to different rock types in the short wave infrared (1.3-3.0 μm). In order to classify such rock types with different narrow bands of absorption, a multi-band sensor with a narrow wavelength interval is to be developed. Imaging classification and ocean colour mapping.

Figure 4. Three types of remote sensing with respect to wavelength regions

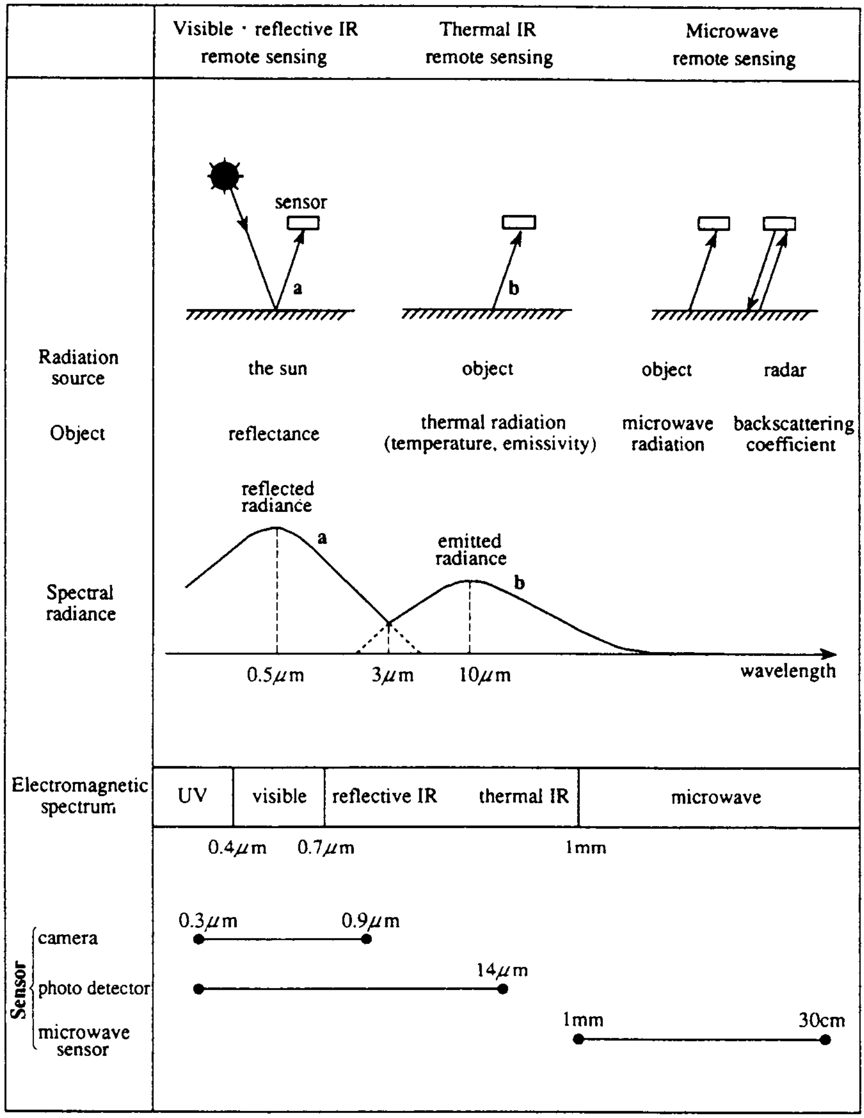


Figure 5. Spectral reflectance of vegetation, soil and water

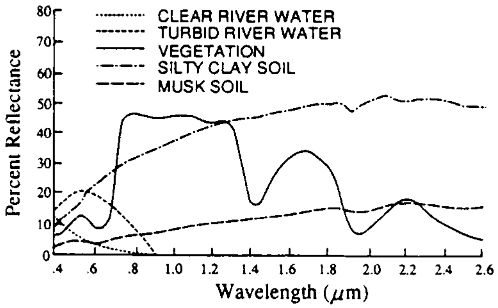
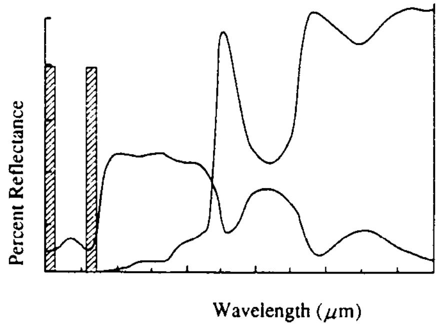


Figure 6. Spectral reflectance of a grean leaf



2. *Methodology*

(a) *General*

Remote Sensing is a multidisciplinary system that combines several techniques such as sensors, platforms computer systems, sources of energy and image processing software, in order to get the optimal quantity of the information about an object by studying the physical characters of the digital response, in the given spectral bands. These spectral data are generated by air or spacecraft, such as Landsat, SPOT or NOAA. These data will be processed automatically by computer and/or manually interpreted and contain information about the surface and sub-surface features of the earth; therefore, they can be utilized in agriculture, land use, forestry, geology, hydrology, oceanography and environment.

(b) *Quick look at hydrology in remote sensing*

In fact the different aerospace missions have made a considerable contribution to hydrology. To understand the hydrology of an area where the data are not sufficient, better insight into the distribution of the physical characteristics of the catchments is needed. By image-processing techniques, we can produce a land cover map which is the basis of the hydrologic response units. Limited attention is given here to the physical measurement of hydrologic variation by remote sensing, which is considered by many to be a challenge to the operational application of remote sensing in hydrology.

(c) *Method of work*

Various types of remote sensing equipment and platforms are available nowadays (some specifically tailored for water problems) to water investigators. The most widely applicable sensors are the Multispectral Scanner Subsystem (MSS) on the Landsat Satellite, and the Very High Resolution Radiometers (VHRR) on the NOAA meteorological satellites.

Observations over watersheds of particular events such as floods are provided at infrequent intervals and on a request basis.

The Landsat MSS observations can be used successfully on watersheds covering areas from 10-20 km^2 in size up to watersheds covering approximately 30,000 km^2. The relatively high spatial resolution (80 m) and the cartographic quality of the imagery from landsat have enhanced the use of satellite data for water resources monitoring.

Figure 7. Spectral reflectance of different kinds of plants

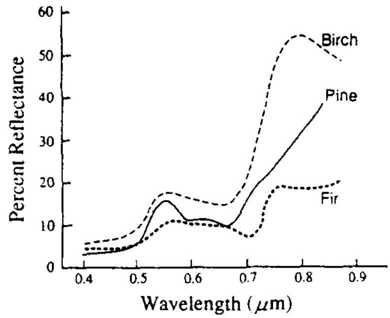
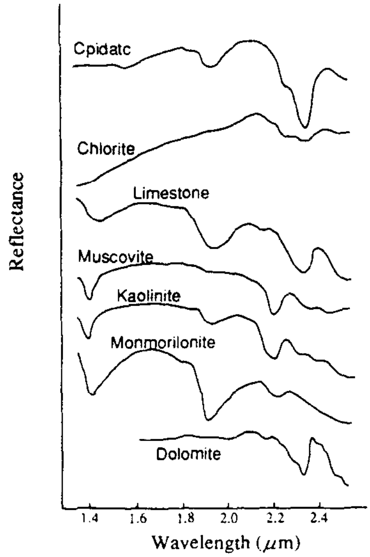


Figure 8. Spectral reflectance of rocks and minerals



In 1972 the National Oceanic and Atmospheric Administration had launched a series of environmental satellites providing daily, 1 km spatial resolution observations. The satellites are in a near-circular, sun-synchronous orbit at nominal altitudes of 850 km. The payload of the NOAA environmental satellites include a number of sensors. One of them is the Advanced Very High Resolution Radiometer (AVHRR). This is a dual-channel scanning radiometer sensitive to energy in the visible spectrum (0.6-0.7 μm) and in the infrared (10.5-12.5 μm). Once a basic knowledge of remote sensing capabilities is acquired, probably the best way to specifically become acquainted with advantages of remote sensing for a particular watershed problem is to obtain some data over the area of interest. These data can be processed and compared with previous knowledge and available data to develop potential uses.

The image database contains several sets of satellite imageries, the main sources for regional and subregional hydrological studies (such as Sopper and Lull, 1970):

(a) Landsat MSS imageries: this multi-spectral scanner sensing system has a resolution of 80 x 80 m^2 for each pixel, 4 spectral bands from visible to near infrared (NIR), and its visiting period is 18 days;

(b) NOAA-AVHRR imageries: this advanced very high radiometric resolution system has a resolution of 1 x 1 km^2 for each pixel, 5 spectral bands from visible to thermal IR, and its visiting period is 24 hours.

For NOAA data, an automatic procedure makes it possible to extract 512 * 512 pixel windows to cover the region of interest. Satellites are then geometrically corrected for the panoramic distortion caused by earth curvature, scan angle and satellite altitude, using navigation parameters, and are transformed into the appropriate projection. Being spread over several months or even years, the digital numbers of the imageries are converted to physical radiances, through a radiometric correction process using calibration coefficient.

As any image involves radiometric errors as well as geometric errors, these errors should be corrected. Radiometric correction is to avoid radiometric errors or distortions, while geometric correction is to remove geometric distortion. The radiometric distortion occurs when the observed energy does not coincide with the energy emitted or reflected from the same object observed from a short distance. The geometric distortion is corrected by establishing a relation between the image coordinate system and the geographic coordinate system.

New synthetic imagery files are then to be derived using appropriate procedures to get vegetation index, soil moisture, land cover, and lineament maps.

3. *Application of remote sensing in hydrology*

The various major environments and components of the hydrologic cycle can be broken down into the atmospheric, surface, and subsurface environment (where water is stored); there are fluxes of precipitation, evapo-transpiration and run-off (run-off is the hydrologic variable that is most often used by hydrologists and water resources planners). The objective most sought by hydrologists is the accurate and timely prediction of run-off rates and run-off volumes at a given point of drainage basin. Another way to view the water deposition and redistribution process is to recognize that the watershed or catchment area responds to the deposition of rainfall by continually adjusting its stream network and surface cover to transport the water out of the watershed via run-off, evapo-transpiration, and groundwater fluxes. As such, the watershed geology, soils and vegetation modulate or control the rate at which rainfall is manifested as run-off or other fluxes (Gray 1979).

Considerable effort and progress have been made in improving the conventional means of observing water resources and associated watershed characteristics. These measurements are made at one point only, or at widely separated points. Thus, it is difficult to monitor adequately the spatial variability in phenomena such as soil moisture or rainfall. In view of these difficulties, there is a need to utilize and understand the advantages offered by remote sensing approaches, which basically offer a capability for repetitively monitoring large areas with high observational density that can accurately depict spatial ánd temporal variability.

(a) *Rainfall*

The climate variation which affects the magnitude and timing of run-off is the amount and distribution in time and space of precipitation. Precipitation serves as the basic input to the drainage basin and is modulated and distributed by the watershed soil and surface cover, geology and drainage character until it is manifested as the basic output parameter—the run-off; precipitation is quite variable in space and time with attendant sharp gradients; therefore, it is difficult to observe with conventional rain gauges.

Considerable effort has been devoted to utilizing the basic advantage of satellite coverage; namely synoptic coverage, to better observe precipitation (Martin and Scherer 1973). All portions of the spectrum can be used to attempt observations of precipitation. The visible observations can be enhanced to delineate the heaviest and most dense clouds such as those associated with cumulonimbus clouds. This kind of work has been accomplished using synchronous meteorological satellite observations, and the results have closely resembled ground-based radar observations (Sikdar, 1972).

The data can be obtained from satellite imageries in two ways:

(a) Estimation of the daily rainfall depth, using the data from weather satellites. In regions with convective rainfall, the gauge density is insufficient to obtain areal rainfall estimates of short periods, such as daily rainfall. This is apparent from the low correlation coefficients between the daily rainfall of stations only, for example, 10 km apart. The spatial resolution of the geostationary METEOSAT is in the order of 5 to 10 km, adequate for estimating rainfall over larger catchments. The advantage of this satellite system is the high temporal resolution required for convective rainfall (Meijerink et al. 1994).

(b) Interpretation of vegetation patterns over longer periods, by interpreting the response to the past rainfall. In regions with annual rainfall of less than 1,500 mm or so, and with strong rainfall gradients, the vegetation patterns as observed on the multi-spectral imagery of the higher spatial resolution sensors, e.g. Landsat, may be related to the spatial rainfall patterns. The method requires interpretation of the areas on the image where the semi-natural and natural vegetation have responded to the past rainfall.

The method is effective where there are not sufficient data (1 rain gauge/several thousand km^2). A much denser vegetation in a certain area corresponds to higher dense vegetation in dark zones, which means high rainfall, taking into account the irrigated and forest areas.

(b) *Evaporation and evapo-transpiration*

The evaporation differed in the loss of the water from the earth's surface in a vapour form. It occurs as evaporation from open water and moist soil surfaces and as transpiration from living plants as part of their respiration and photosynthetic processes. In arid regions, nearly all the input in the form of rain is lost through evaporation; even in humid regions, one half of the water balance can be attributed to evaporation.

Traditionally, the actual evapo-transpiration was recognized as the superior water balance parameter for global productivity estimation. Using an energy balance approach, the actual evapo-transpiration can be moistened using parameters derived from satellite data. Moreover, evapo-transpiration was demonstrated to be a parameter more rapidly responding to changing water conditions, and it can be an alternative to the rainfall parameter.

Evapo-transpiration is the integral to the hydrological and climatic processes of the earth and its atmosphere. The current emphasis on global change research makes it important to understand and measure the evapo-transpiration and its effects on earth processes. Much research has been focused on the microclimatic aspects of evapo-transpiration to develop a theoretical basis for understanding this process. Given the necessity for assessment of large areas in global change research, methods need to be developed that will address regional and global measurements in some quantitative manner.

Remote sensing data are suitable to assess large areas, and considerable effort has been made to characterize vegetation using satellite data. A relationship exists between spectral reflectance and vegetative characteristics. These relationships allow the use of spectral transforms to define biophysical parameters for plants. The Normalized Difference Vegetation Index (NDVI) has been shown to be related to plant canopy variables, which also related to evapo-transpiration. Wiegand et al. (1979), Holben et al. (1980), Weiser et al. (1986), and Seevers and Ottmann (1994), have shown a relationship between NDVI and green leaf area index, photosynthetically active bio-mass.

Bausch and Neale (1987) used a hand-held radiometer, which measured radiance in three bands similar to Landsat thematic mapper (TM) bands 3, 4 and 5, to demonstrate the similarity of a seasonal NDVI curve.

The information of evaporation can be obtained from satellite data by measuring the albedos and surface temperatures in a distributed manner. The change in albedo of arid lands is an indicator of changes in surface soil moisture. In general the darkening of an arid land surface indicates an increase in the land quality due primarily to changes in vegetation. Albedo has been proposed as one of the possible indicators of desertification.

Lagouarde (1991) found a good consistency between the results of an agrometeorological model and satellite derived data. Lagouarde et al. (1993) proposed a simple algorithm, and only one unique value of an empirical constant, for estimating the upward long wave component of the surface measurement derived from NOAA-AVHRR. Bryceson (1993) discussed methods using NOAA-AVHRR data for obtaining an estimate of rainfall surface and of a moisture index, in conjunction with field data in Australia. Because of the importance of soil moisture for both agriculture and hydrology, we should consider the use of remotely sensed data in the visible, thermal and microwave (radar) parts of the spectrum.

(c) *Soil moisture*

This is a temporary storage of precipitation within a shallow layer of the earth that is generally limited to the zone of aeration, which approximately coincides with the root zone. Water temporarily stores as soil moisture; it can be returned to the atmosphere through direct evaporation from soil surface or by the way of plants through transpiration, or it can be a saturated zone as groundwater recharge and eventually transmitted as groundwater flow to stream channels.

Various attempts have been made to apply remote sensing techniques to the determination of the areal distribution of soil-moisture content in the uppermost layers of the ground.

It was originally noted that photography often showed the delineation of regions with very high soil-moisture content. This is because of the change in the absorption or the reflectance spectrum in the visible region, which occurs in soil on the addition of water.

(d) *Water quality*

The remote-sensing methods utilizing photography, radar, and multispectral analysis of both reflected sunlight and infrared emissions have been very useful for the determination of several physical and biological characteristics of bodies of water, such as temperature, colour, algae growth, shape, distribution of oil, and to some extent, dissolved oxygen. These methods, however, have not been fully developed for detecting one of the most important aspects of water quality: its chemical composition.

The chemical composition of water can be measured by collecting samples and subsequently analysing them in a laboratory. The use of remote sensing techniques involving spectrometers or multispectral scanners for identification of the chemical composition of large water areas requires information on such instruments, and on specular reflectance of samples of fresh and saline waters, and of clean aqueous solutions prepared in the laboratory to contain measured amounts of chlorides, sulfates, phosphates or nitrates.

(e) *Vegetation*

The vegetation layer defines the components of the run-off, the evaporation, the soil moisture and the groundwater. As indicator, vegetation cover and its spatial-temporal dynamics are linked to the quality of the rainfalls and their impact on the environment in the catchment area. The key role of the vegetation as indicator in remote sensing has been largely demonstrated in recent years by the broad use of the vegetation indexes in different application contexts. Of course, vegetation has an important effect on water budgets because of the evapo-transpiration losses and rainfall run-off responses. (The rainfall run-off is influenced by the status of the vegetation.) The indicator for this status may be the simple normalized difference vegetation index (NDVI) as mentioned above.

The vegetation indices in remote sensing are combinations of reflectance of two or more bands. All pixel values for each data set were converted to spectral radiance values. The conversion process revealed the raw digital counts by using the calibration coefficients for the specified satellite sensor (Price, 1987). These spectral radiance values were then transformed to the NDVI values, by using the following calculation (Seevers and Ottmann, 1994):

$$\text{NDVI} = \left[\left[\frac{\text{Radiance (infrared band) - Radiance (red band)}}{\text{Radiance (infrared band) + Radiance (red band)}}\right]+1\right]\text{x}100$$

The results of NDVI images can be used in the estimation procedure of the evapo-transpiration; since the application of atmospheric corrections for purposes of data calibration is highly controversial and lacking in acceptable parameters, no corrections were applied.

Usually in the visible red band and the near infrared band, the most common vegetation index is the normalized difference vegetation index:

$$NDVI = \frac{R_{nir} - R_{vis}}{R_{nir} + R_{vis}}$$

where R_{nir} is the reflectance in the near infrared and R_{vis} is the reflectance in the visible spectrum.

While in NOAA-AVHRR imageries

$$NDVI = \frac{Ch_2 - Ch_1}{Ch_2 + Ch_1}$$

where Ch is the digital numbers forming the matrix of the corresponding channel data. NDVI is a bounded ratio ranging in value from -1 to +1. The index was developed by Rouse and others in 1974, Landsat bands 7 and 5, while Townshend (1981) exchanged them for the similar AVHRR Ch_2 (near infrared band), Ch_1 (visible band). From some typical spectral signatures of ground objects, the effects of the difference over the total can be readily noted. Clouds, water, bare soil and low green vegetation density and are associated with negative or low values.

Concerning the Global Vegetation map, NOAA-AVHRR data are very useful for producing such maps, which cover the whole world. NOAA has edited global cloud-free mosaics in the form of GVI (global vegetation index) on a weekly basis. The GVI data include information about NDVI. Though the original resolution of NOAA-AVHRR is 1.1 km per pixel of equation, the GVI has a low resolution of 16 km x 16 km per pixel at the equation. In spite of the low resolution, the GVI is useful for producing a global vegetation map.

(f) *Groundwater*

This term refers to all water stored beneath the surface of the earth in aquifers. In order to use groundwater, it is necessary to locate the aquifer (size, extent and depth), to estimate recharge and discharge rates of water, and to assess the effects of well extraction on its integrity. Through the visual interpretation, Waters et al. (1990) review the applications of remote sensing to groundwater hydrology and, as may be expected, they conclude that imageries have to be used in conjunction with other available ancillary information. The vegetation covers can be mapped and the use of the vegetation can be estimated for water budgets. In particular the clear response of crops to irrigation from groundwater is a valuable means of rapidly assessing the location and extent of areas with groundwater drafts.

Lineament, defined as a line feature or pattern interpreted on a remote sensing image, reflects the geological structure, such as faults, fractures and broken-up flexures. In this sense, lineament extraction is very important for the application of remote sensing to geology. Computer generated lineament would involve all linear features of national terrain as well as artificial structure, which has to be removed by interpretation (lineament extraction is useful for geological analysis in oil exploration in which oil flow is along faults, oil storage with faults).

Lineaments play an important role in groundwater studies, particularly in hard rock regions. For such studies the remote sensing imageries have to be transformed to optimally enhance the surface features of interest. An adequate knowledge of the catchment areas, of water divides and the surface drainage is one of the basic factors in groundwater exploration.

4. *Mapping*

The application of the high resolution imageries is map updating. The panchromatic imageries of the SPOT system with resolution of 10 m is best suited for this aim, in conjunction with color-coded multispectral imageries for discrimination of features which may not be so apparent on the panchromatic imageries. The remote sensing techniques are used to delineate the boundaries of the different surface features, such as the permanent water bodies, rivers, muddy water and soil boundaries. The operation consists of the delineation of boundaries and determination of surfaces of individual features, such as permanent water bodies, shifted rivers, recent water training constructions and so on. The sequence of operation is: image enhancement techniques, geometric corrections of the image using map coordinates, and visual interpretation followed by digitizing.

The ESCWA project consists of two scales mapping one at 1/2,500,000 scale for regional purposes, the other scale is 1/1,000,000 which is more detailed for the shared water resources monitoring and management. In NOAA imageries of 1 km resolution, each pixel represents 0.4 mm on the regional map, so it is suitable for mapping at this level, although it is better if there are 500 m resolution imageries. For the MSS imageries it is suitable to the 1,000,000 scale mapping since each pixel represents approximately 0.1 mm which is adequate for mapping purposes, at this scale.

5. *Modelling of run-off and water balance*

For the last two decades remote sensing data, in the form of multi-spectral aerospace data, have been available for use in hydrology. The potential of remote sensing in the framework of GIS is shown in the use of remote sensing data for rainfall run-off modelling in the lower meso-scale.

Although there have been a large number of scientific publications on the application of remote sensing to hydrology in recent times, practitioners have not accepted remote sensing in the way hoped by its advocates. This may be partially due to overselling of the potential of remote sensing in hydrology in the past. Nevertheless, it can be expected that in the near future remote sensing will play an increasing role in hydrology.

There are several reasons for this:

(a) Large time series of remote sensing data are now available as well as more electromagnetic sensors. GIS are used in hydrology and were valuable for areal representation of relevant parameters and variables;

(b) The near future will provide hydrologists with new types of remote sensing information (new sensors);

(c) The recent tendency in hydrology is towards macro-scale hydrological modelling (regional).

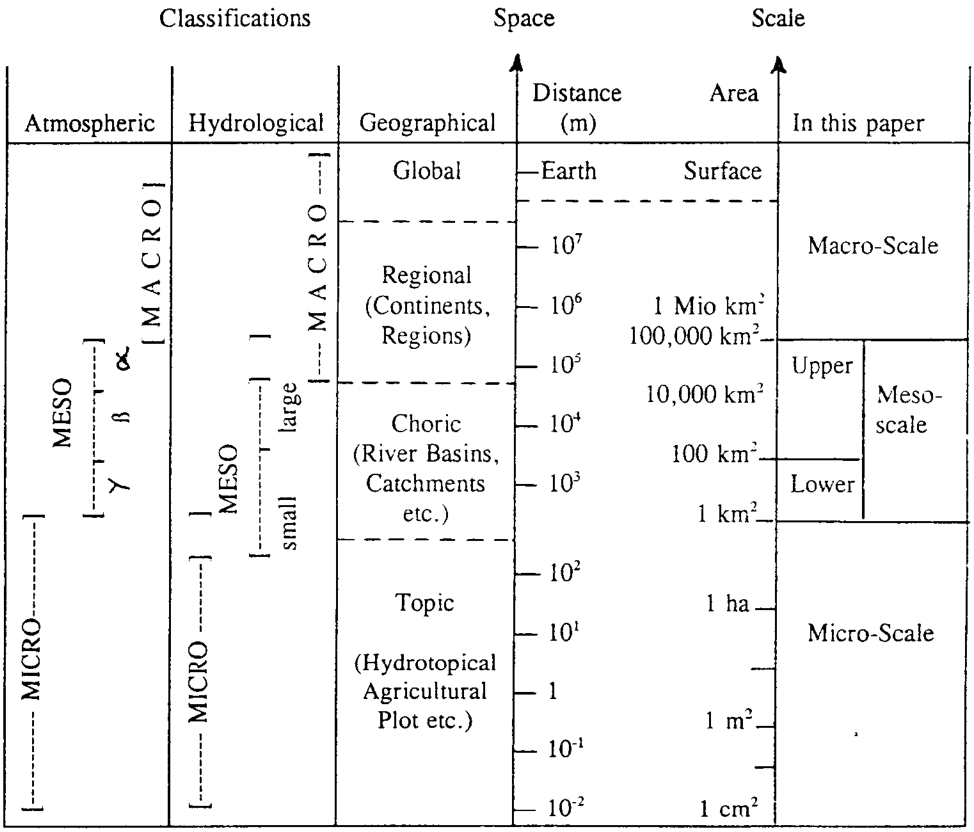
Modelling requires data quantities with temporal and spatial resolution which cannot be provided by conventional observation techniques, particularly not in the remote areas of the world.

The different scales require different types of models. For the micro-scales many hydrological modelling approaches are available. Also for the lower meso-scales there are many modelling tools available, while large-scale hydrological models hardly exist. Figure 9 shows the relevant scales as seen in the fields of atmospheric science, hydrology and geography (Schultz, 1994). Although the allocation of various scales to areas in km^2 varies, it will be assumed that, according to figure 9 micro-scale ranges from 1 cm^2 to 1 km^2, meso-scale from 1 km^2 to 100,000 km^2 and macro-scale starts from 100,000 km^2. For regional purposes, upper meso-scale and macro-scale are considered. The meso-scale is presently subject to the greatest number of hydrological modelling activities, while macro-scale modelling has only recently started. Owing to the resolution in space, remote sensing is particularly suitable for meso-scale modelling.

With the advent of remote sensing data digital elevation models and GIS, it becomes possible to apply distributed model parameters; they allow forecasts of the hydrological effects of land use changes. Hydrological models may use remote sensing data in two distinctly different fashions:

(a) Model for parameter estimation;
(b) Model input.

Figure 9. Classification of scales in hydrology (after Becker and Nemec 1987, modified)



Source: Schultz, 1994.

Scientifically based hydrological models should have a structure that does not change from region to region; only the model parameter values are different in different regions, and the models have to be calibrated for each region separately. As mentioned above, if one deals with physically based distributed system hydrological models, many model parameters depend on the characteristics of the hydrological system, such as catchment characteristics or aquifer characteristics.

Model input data can be estimated with the aid of remote sensing data, covering vegetation status, radiation and temperature values which are relevant for the estimation of evapo-transpiration (as input to rainfall/run-off models).

There is obviously an interdependence between the resolution in time and in space in the hydrological model. A model for flood forecasting in a small catchment area requires high resolution in time and in space model, whereas a low resolution in time (e.g. monthly run-off data) can also cope with coarser resolution in space.

(a) Hydrological model elements derived from remote sensing and other information: Since hydrological model parameters depend to a large extent on catchment characteristics, the parameters may be derived from remote sensing information together with other data, e.g. maps, digital elevation model (DEM) and other GIS data (figure 10).

(b) Macro-scale hydrological modelling: Remote sensing applications on hydrology are mainly found in meso-scale modelling since:

(i) The space and time resolution of most sensors are suitable for this scale;

(ii) Most rivers drain catchments of the meso-scale, often also called "catchment scale".

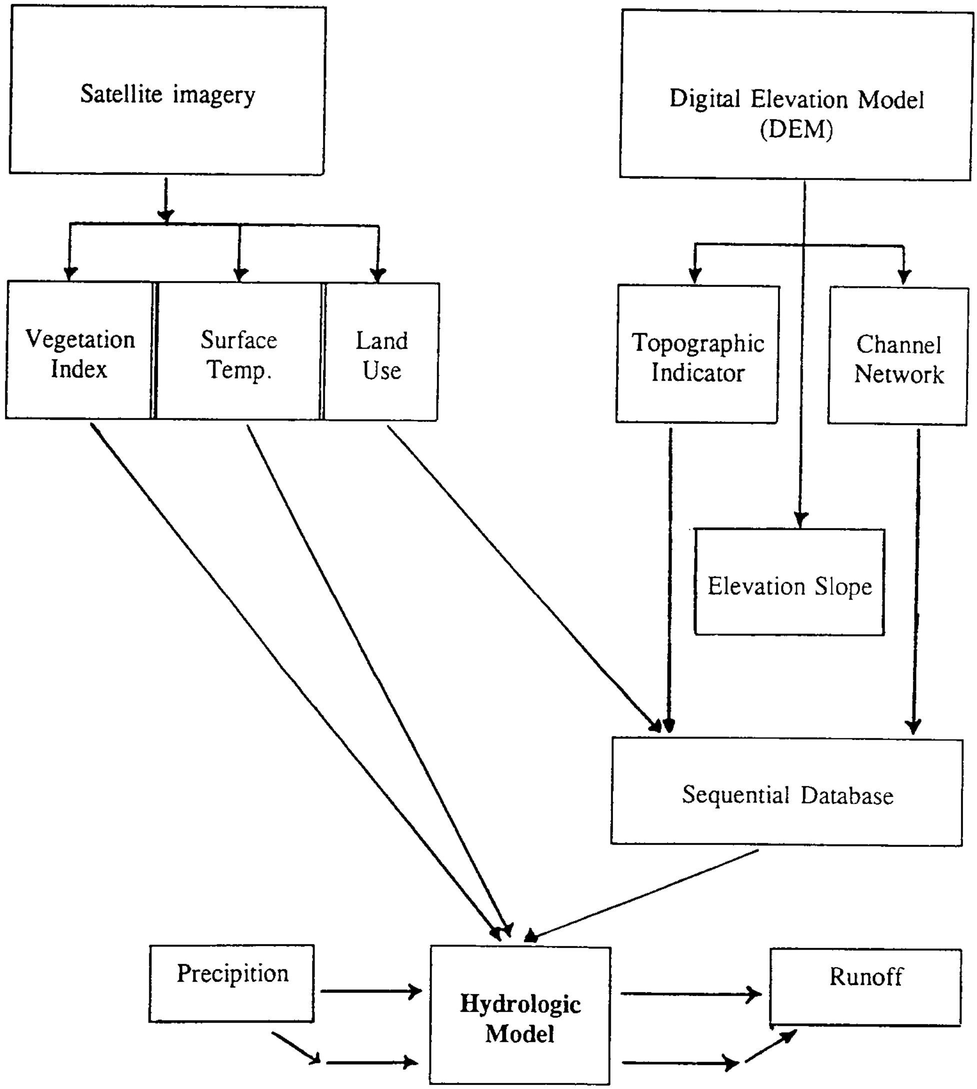
So far macro-scale hydrological models have hardly been developed. Nevertheless there is growing interest in macro-scale hydrological modelling, for the following reasons:

(a) Based on experience obtained so far in meso-scale modelling, there now seems to be enough scientific know-how available for tracking the complex problem of macro-scale modelling;

(b) Modern water resources management requires optimization of integrated river basin systems of medium and large scale;

(c) The data scarcity in large regions, where many large rivers exist, was prohibitive for hydrological modelling. It is hoped that remote sensing will provide a significant quantity of relevant hydrological information.

Figure 10. Distributed system hydrological model using a sequential database (containing satellite and DEM data) for estimation



Source: Schultz, 1994.

Finally, the best use of remote sensing can be made if these data are combined with other modern services of information, e.g. digital terrain models and digitized maps. The handling of all these data can best be done within the framework of GIS.

B. WATERSHEDS

1. *Definition*

A watershed can be defined as a unit of area, which covers all the land which contributes run-off to a common point. Therefore, the watershed is a natural physiographic unit where inherent potential of land and water resources are depicted in a perceptible manner. Each individual watershed has many characteristics which affect its functioning, or the manner in which the incoming precipitation is disposed of. These characteristics are:

(a) *Topography*

Uniformity of slopes, degree and length affect both disposal of water and soil loss. The degree and length of slope also affect the line of concentration and infiltration opportunities.

(b) *Vegetation*

This factor regulates the functioning of watersheds in many ways, including infiltration, retention, run-off, erosion, and sedimentation. The vegetation can be temporary (agricultural crops) or permanent (forests, grasslands and orchards).

(c) *Drainage*

The drainage characteristics depend on topography (characteristics are density, length, width, depth of main and subsidiary channels, main outlet and its size). The drainage pattern will affect the time of concentration.

(d) *Climate*

The climate parameters affect the watershed functioning and its manipulation in two ways:

(a) The regulation of rainfall, temperature, humidity, wind velocity and other factors such as soil and vegetation;

(b) Rain provides incoming precipitation along with its various characteristics including intensity, frequency and the amount of rainfall.

(e) *Geology and soil*

The formation of geology affects the disposition of water erosion, credibility of channel and hill forces, and occurrence of slides. This factor also determines sediment production. For instance some igneous rocks such as quartz and feldspar are hard and do not erode easily, whereas shales and phyllites erode easily and quickly. Physical and chemical properties of soil, especially texture, structure and soil depth, influence to a great extent the degree of disposition of water by way of infiltration, storage and run-off. Erodibility, transportation and deposition of soil are also functions of its properties.

(f) *Land use*

Management of land use, its extent and type are the key factors which affect watershed behaviour. Of course, the land use is essentially under the control of human beings (land users) and hence its judicious management is of vital importance to watershed management and functioning.

(g) *Size and shape*

The size of a watershed determines the quantity of precipitation received, retained and disposed of. The larger the watershed, the more it is likely to be a channel and basin storage.

Generally, land use does not coincide with land cover. A land use class is composed of several land covers. Remote sensing data can provide land cover information rather than land use information.

The watershed may have several shapes. Some common examples are: square, rectangular and triangular. The shape of the watershed determines the length-width ratio, which in turn greatly affects the manner in which the water is disposed.

The drainage basin is the basic areal unit in which physiographic and land use features can be measured and studied. The measurement of these watershed characteristics is important because they are intimately related to water basin and sediment yield. Physiographic observations such as basin area and shape, stream network organization, drainage density and pattern, and specific channel characteristics can enable the investigation to estimate the mean annual discharge and mean annual flood flows from a watershed, as well as the rapidity of watershed response to a particular rainfall event. It is useful for estimating mean streamflow characteristics, physiography and land use data that are required as calibration inputs to numerical watershed models that are commonly used for simulating or estimating daily, weekly, monthly, and annual flows. Physiographic parameters necessary for the operation of most of these models include stream length, drainage density, overland flow length and roughness, watershed area and shape area. Estimates of land use categories, including surface water, forced and watershed imperviousness, are also necessary.

The quality, quantity and timing of watershed run-off are strongly dependent on land use and cover (Environmental Protection Agency, 1973; Novoty and Chesters 1981; Daniel et al. 1982; Ostry 1982). Landsat (MSS) data have been used to identify land use and cover classes relevant to run-off studies (Bondelid et al. 1980; Regan and Jackson 1980; Slack and Welch 1980; Harvey and Soloman 1984; Jackson and Bondelid 1984).

2. *Role of remote sensing*

The advantage of the synoptic view and repetitive coverage provided by space-borne multi-spectral data offers the potential for identification of watershed characteristics such as drainage stream network, land use/land cover, land form, and surface water bodies. The quick assessment of broad composite units of physiography, land degradation and land use could be interpreted visually, using NOAA-AVHRR imageries at the regional level. It was found that by adopting a correlative approach, it appears to be possible to conduct surveys of catchment areas with the help of remote sensing techniques in conjunction with adequate ground truth data and carrying out supervised classification with the help of computers. However, one should be very careful in using the remote sensing techniques, since all depends on the spectral signatures, decoding of which may go completely astray with the slightest mistake or a wrong step. It has been reported that Landsat TM data can be used for characterization of watersheds at 1:50,000.

C. THE ESCWA REGION

1. *Physiography*

Flat, relatively narrow mountain chains extend along the coastlines of the Red Sea, the Mediterranean and the Gulf of Oman. Higher mountains are found in the north-east of Iraq (more than 2.5 km).

The Hamad Plateau extends over extensive areas in the south-east and central part of Bdiet El-Sham; the elevation ranges from 600 m above sea level in the north to 1,000 m in the south.

The north-western Palmyrian chains extend through Lebanon and north of Damascus and in a north-east direction. The basaltic plateau of Hauran and Golan has elevations ranging from 600 m to 1000 m, and it reaches 1,800 m at Jabel El-Arab.

The Lebanon mountains reach a heigh of 3,080 m. The highest altitude in the peninsula is Bani Shaib near Sana'a which reaches 4,260 m. The chain of Taif through Asir to Yemen has an average elevation of 1,800 m.

Egypt is essentially a flat region with average altitude of less than 500 m, but in the south-west, the altitude reaches 2,000 m at Jebel Uweinat, and in the east it reaches 1,800-2,000 m. The Qattara depression as well as Siwa have altitudes below sea level.

2. *Hydrology*

The ESCWA region extends from the Zagros-Turos mountains in the north to the Arab Sea in the south.

The mean annual rainfall is between 100 mm and 150 mm, ranging from about 10 mm to more than 500 mm. The ESCWA region considered a semi-arid zone with 250 mm rainfall in most of the zone. The entire zone suffers from a shortage of water, with clear evidence of land degradation resulting in a decrease in the productivity of the land caused partially by the scarcity of water and arid climate.

The catchment areas of the large rivers—the Nile, the Euphrates and the Tigris—extend beyond the ESCWA region. The low and high irregular precipitation has resulted in an ephemeral drainage system in the region.

(a) *Watersheds in the ESCWA region*

Although some of the surface water in the ESCWA region originated within the region, the greatest rivers originate, outside the region. Rivers originating within the region are mostly associated with the rift as it runs through Jordan and the Syrian Arab Republic. These rivers are the Jordan, the Yarmouk, the Litani and the Orontes; they are fed by springs from limestone and basalt aquifers. In the north of the Syrian Arab Republic, the Khabour arises from the karst spring of Ras-al-Ain. Bank tributaries of the Tigris arise in the Zagros range, more or less on the fringe of the region. There are streams flowing to the Red Sea from the highlands of Yemen and Asir; they are seasonal and are hardly rivers. This also applies to certain rivers flowing out of the Ethiopian mountains, which fail to reach the Nile or the Red Sea, as at Tokar.

The Nile and the Euphrates-Tigris are the great rivers originating in areas of higher precipitation outside the ESCWA region. They bring much water into the region, which in part infiltrates either naturally or as a result of development structures to form groundwater within the region. As their waters become more and more utilized, the amounts reaching the Mediterranean and the Shatt-al-Arab have decreased (Burdon 1982).

Many watersheds in the ESCWA region are catchment areas of major rivers, and are mostly international, shared between two countries or more. The ESCWA region contains 20 regional catchments, as shown in figure 11 and indicated in table 1. The most important are:

Nile catchment area	2,800,000 km^2
Euphrates catchment area	444,000 km^2
Tigris catchment area	258,000 km^2

(b) *Groundwater in the ESCWA region*

Groundwater enters the arid and semi-arid parts of the ESCWA region from regions to the north and south with greater precipitation. Some of this groundwater moves through extensive aquifers, but much enters as surface flow and then recharges the aquifers bordering the major rivers.

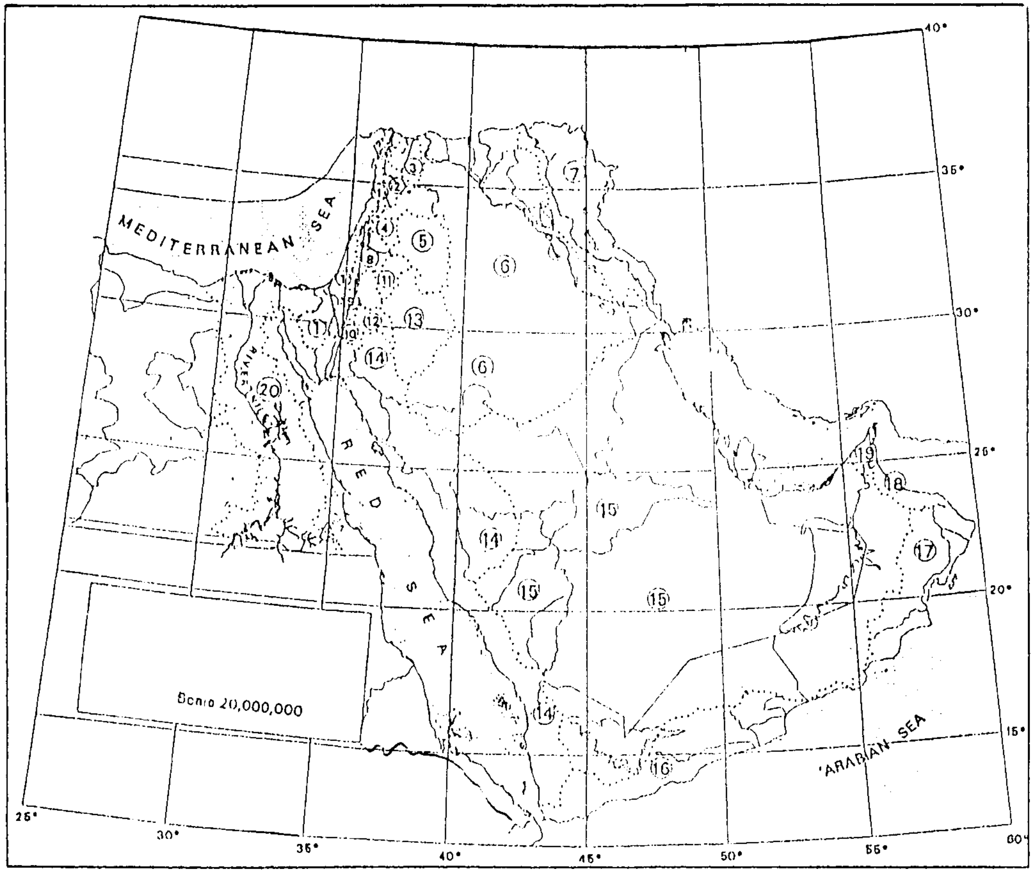
The Nile has an average flow of $180 * 10^6$ m^3/day; a portion of this flow is stored in and regulated by the material filling the larger valley from the older rocks; more of the flow is stored in the Nile Delta.

The Tigris-Euphrates had an average flow of $130 * 10^6$ m^3/day in Baghdad. The Tigris and its tributaries are subject to floods but the Euphrates is more stable, influenced by an almost unvarying flow of some $3.5 * 10^6$ m^3/day from Ras-el-Ain spring feeding its Khabour tributary. These two river systems are now extensively developed, and how much of their floodwater is stored as soil moisture, and how much in surface basins, is uncertain. Almost no surface water from them reaches the Shatt-el-Arab now; it is stored underground or on the surface, and then evapo-transpired, leaving behind a considerable salinization problem.

Freshwater lenses floating on regional groundwater of more saline composition occur in many places but are best investigated on the Egyptian Mediterranean coast and along the Hasa littoral of Saudi Arabia and the adjoining countries. A secondary coastal freshwater lense system—stretching discontinuously along coastal Saudi Arabia, across Bahrain, Qatar and into central Abu Dhabi, with segments in northern Kuwait and the eastern United Arab Emirates—has been identified in an FAO project. This zone of freshwater floating lenses occurs between the zone of *sibakh* evaporation and the coast and is due in part to the peculiar climatic conditions in this coastal desert.

In the Syrian Arab Republic and north-eastern Jordan, dry wadis which once flowed to the Euphrates continue to amass groundwater from time to time; slow underground flow results in a consistent supply of good quality groundwater (Burdon, 1982).

Figure 11. The 20 regional catchment areas of major rivers (most international, shared between two or more countries)



The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Key to figure 11

The regional catchment areas in the ESCWA region

1. Mediterranean Coastal Basin
2. Orontes Basin
3. Aleppo Basin
4. Damascus Basin
5. Syrian Steppe Basin
6. Euphrates River Basin
7. Tigris River Basin
8. Jordan River Basin
9. Dead Sea Basin
10. Wadi Araba Basin
11. Azraq Basin
12. Jafr Basin
13. Wadi Sirhan Basin
14. Tihama Wadi System
15. Eastern Arabia Wadi System
16. South Yemen Wadi System
17. West and South Oman Desert Wadi System
18. East Oman Mountain (Batina) Wadi System
19. United Arab Emirates (UAE) Wadi System
20. Nile River Basin

D. APPLICATION OF REMOTE SENSING TECHNIQUES IN THE ESCWA REGION

1. NOAA-AVHRR imageries

NOAA imageries (of resolution 1 km, applied in the water resources assessment in the ESCWA region at a scale of 1/2,500,000), where each pixel represents 0.4 mm as mentioned above, which is acceptable for hydrological features extraction at this level. RJGC has NOAA-AVHRR imageries for the ESCWA region in two sets, one in the wet season (March-April), the second in the dry season (July-August) of the year 1994. NOAA imageries are useful in the following applications:

(a) Landcover map, showing the vegetation area (irrigated and rainfed), grazing lands, sandy areas and granite areas; a GIS system applied to interesect the satellite data with ground and map data in order to meet the quality requirements;

(b) Vegetation index map;

(c) Major lineaments across the ESCWA region;

(d) Hydrological maps for the major drainage network; major water bodies, rivers, lakes, mud-flats and dams.

Identification and delineation of surface water units: Surface water units or basins at a regional level to be delineated on a regional basis. Water divides for large rivers are well defined.

In arid zones large units which comprise several wadis, originating and ending in the same base level (sea, *sabkha*) are recognized.

(a) Major water bodies: At the regional level, the major surface water bodies such as *sabkhas*, mud-flats and major rivers can be detected. An interpretation of NOAA-AVHRR imageries leads to the production of a regional hydrological map, as shown in figures 12a, 12b and 12c.

(b) Vegetation Index: The water in its hydrological cycle intercepts the vegetation canopy, which acts both as interface and as indicator. Among several vegetation indices proposed to monitor the environmental changes, NDVI was used as mentioned above. NDVI reaches its maximum at about heading, which is the beginning of the reproductive stage. The ESCWA vegetation index maps can be divided into two main classes: irrigated and non-irrigated vegetation, this will give an indication of the abstraction from the surface water and groundwater, and consequently the water budgets, as shown in figure 13.

(c) Land cover: NOAA imageries are a major contribution to this type of map at the regional level. From NOAA imageries and other databases and maps, we can extract the following features:

(i) Major rangelands;
(ii) Major basaltic and granite areas;
(iii) High dense vegetation areas;
(iv) Sandy areas;
(v) Major water bodies.

This map is helpful in monitoring and managing the water resources, as well as a source of GIS for any further analysis (figure 14).

2. *Landsat, MSS imageries*

The Landsat Multispectral Scanner MSS imageries (80 x 80 m^2, 4 bands and 64 radiometric level) are an important source of hydrological details. RJGC collected

Figure 12 (a)

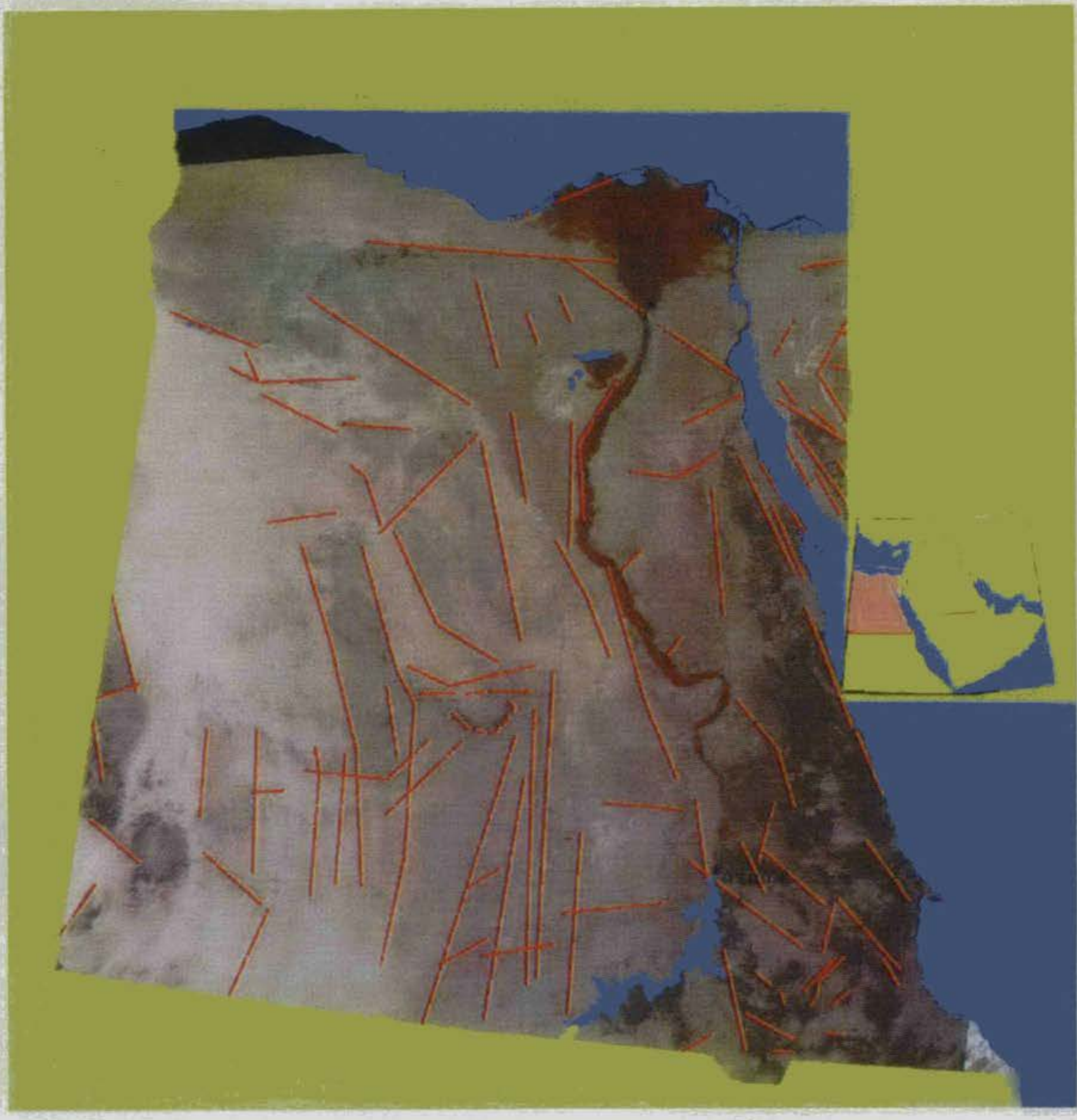


Figure 12(b)

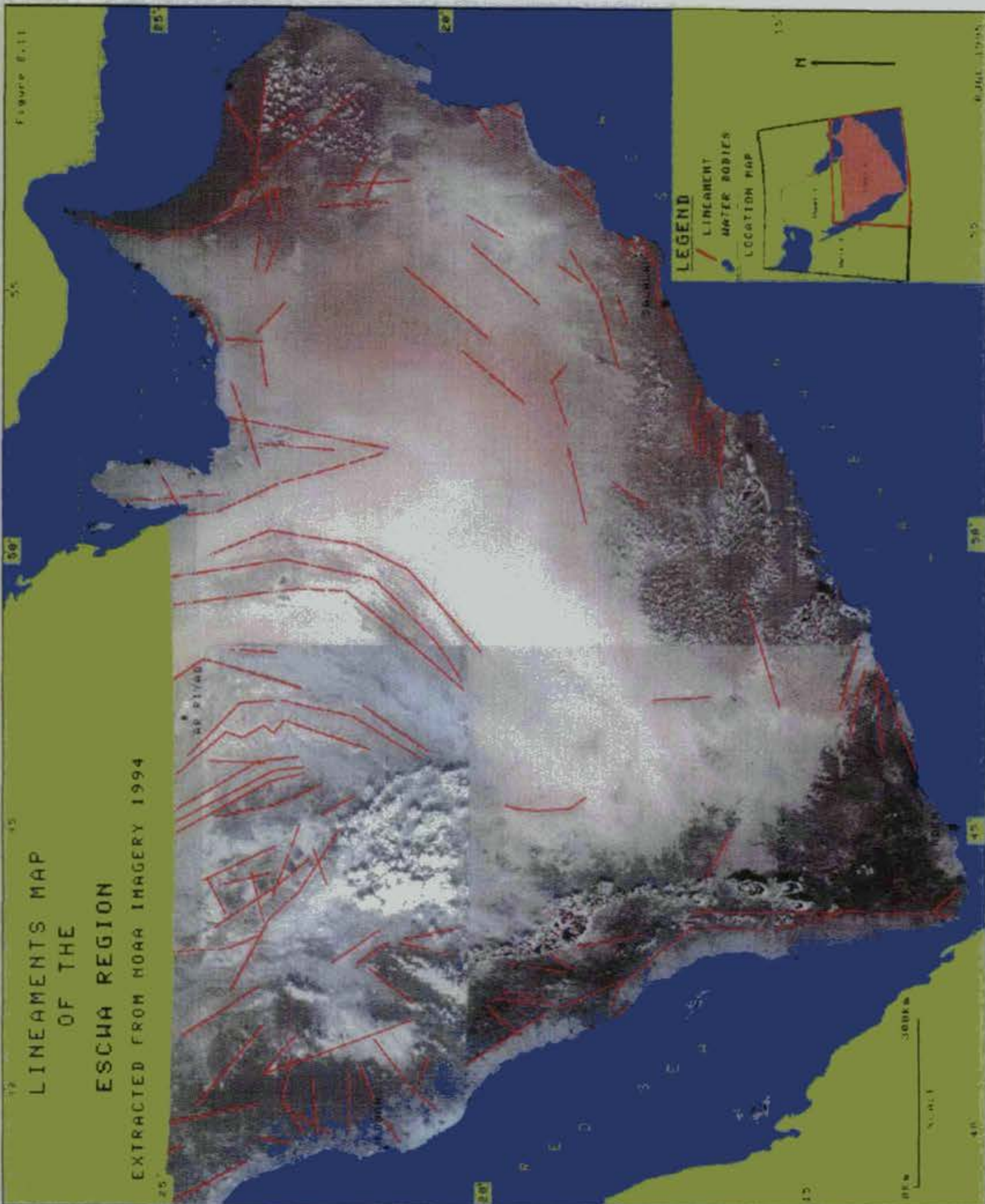

LINEAMENTS MAP
OF THE
ESCWA REGION
EXTRACTED FROM NOAA IMAGERY 1994
LEGEND
LINEAMENT
WATER BODIES
LOCATION MAP

Figure 12(c)

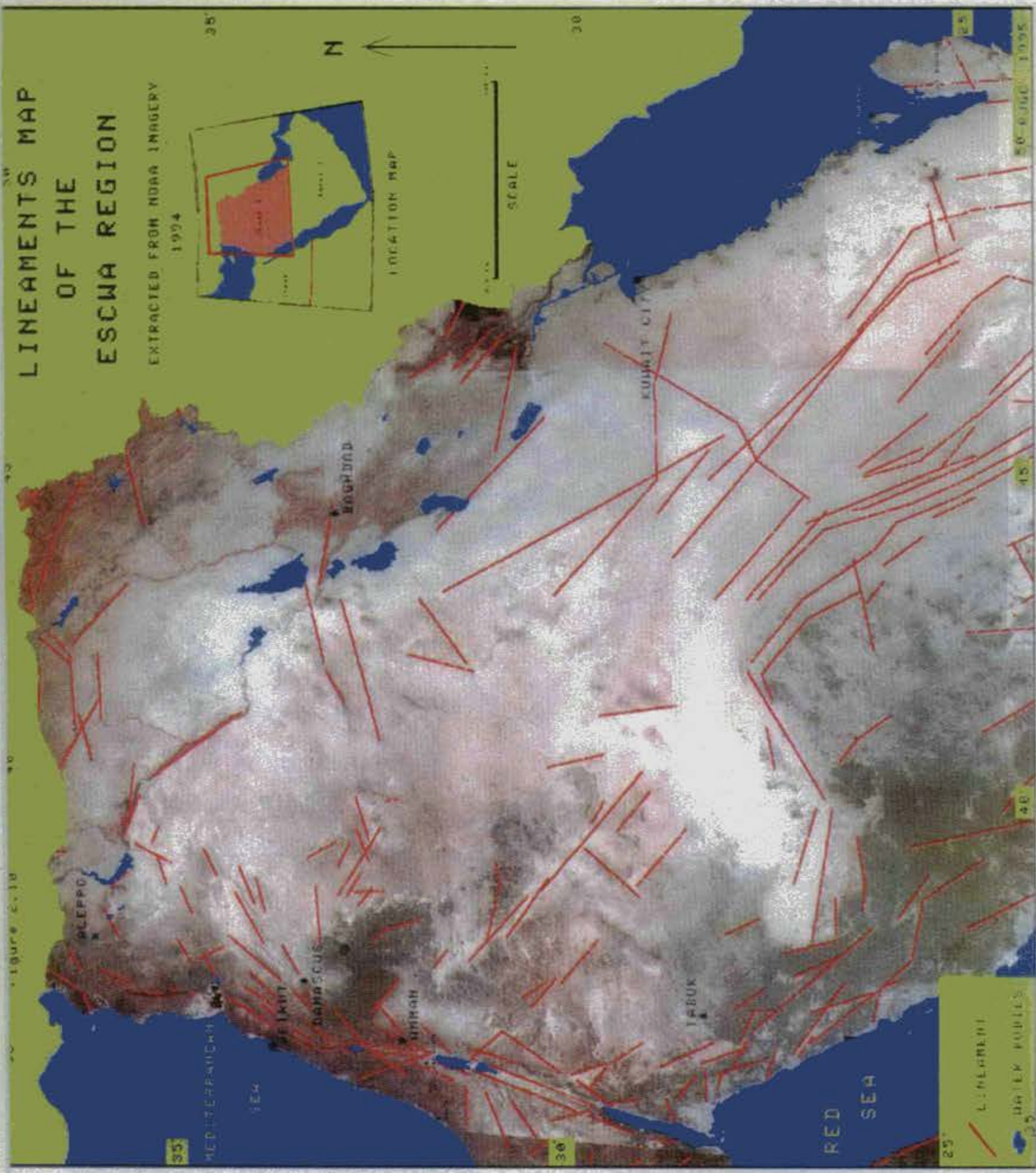
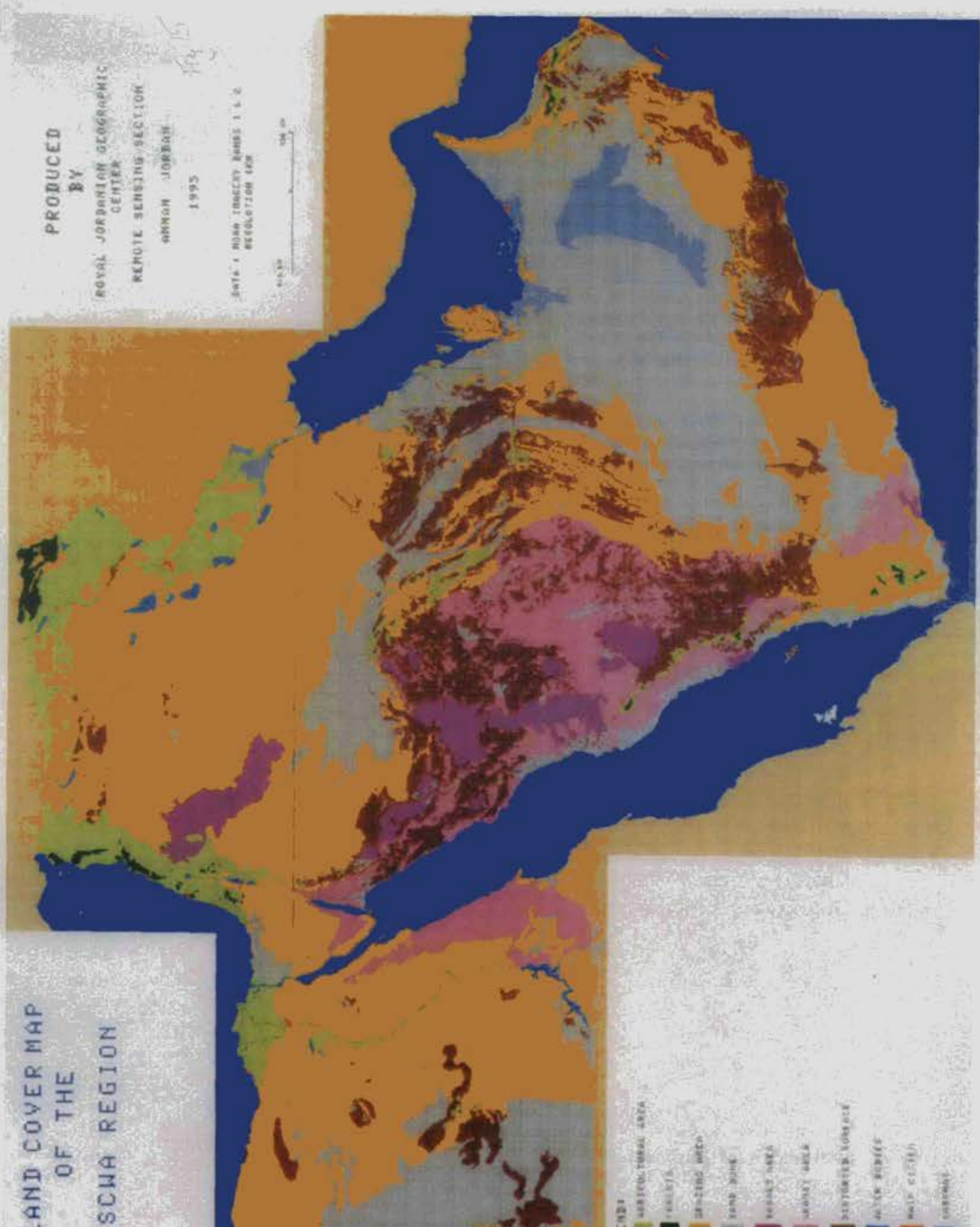

LINEAMENTS MAP
OF THE
ESCWA REGION
EXTRACTED FROM NOAA IMAGERY
1994
LOCATION MAP
SCALE
N
ALEPPO
BAGHDAD
BEIRUT
DAMASCUS
AMMAN
TABUK
MEDITERRANEAN
SEA
RED
SEA
LINEAMENT
WATER BODIES

Figure 13. General view of the ESCWA region from NOAA imageries

Figure 14



LAND COVER MAP
OF THE
ESCWA REGION
PRODUCED
BY
ROYAL JORDANIAN GEOGRAPHIC
CENTER
REMOTE SENSING SECTION
AMMAN JORDAN
1995
LEGEND:

these imageries in such a way that they cover the shared aquifer basins, and are used to obtain accurate lineament, land cover and irrigation maps.

(a) Lineaments: We should note that the lineament analysis, referred to as a fracture analysis, consists essentially of the study of all the linear features observed on photographic images, that is, all the features which have in common the characteristic of intersecting the ground surface with a straight, or slightly curved, line.

Lineament analysis helps to reveal zones of fracture concentrations and, through a proper interpretation, helps in reconstructing the structural deformations occurring in a given region, defining the character of surface structure and locating buried structural features.

More detailed lineaments can be extracted from the visible band after using the different types of filters. The lineaments play a key role in the groundwater studies, particularly in the absence of hydrologic data for the zone under study (as shown in figures 15a and 15b).

(b) Irrigated area: Delineation of the irrigated areas is very helpful in this type of imageries, for estimating the water budget, particularly the irrigation based on groundwater. This can be used for estimating the water consumption from underground water;

(c) Land cover: A detailed land cover map can be extracted from MSS imageries; this is helpful for detailed study of the area.

Note: I have not seen any soil moisture map, perhaps because of the poor quality of available data, or it might cover different data not homogeneously, and of course that will affect the quality of the output.

Finally, a digital chart of the world (DCW) has been used by RJGC for extraction of many items such as:

Drainage network
Land cover
Rivers
Lakes
Dams
Main roads
Boundaries
Wet and mud-fault areas
Annotations.

This information is checked and corrected using NOAA-AVHRR imageries, ONC maps (1/1,000,000) and the available data and maps.

Figure 15 (a)

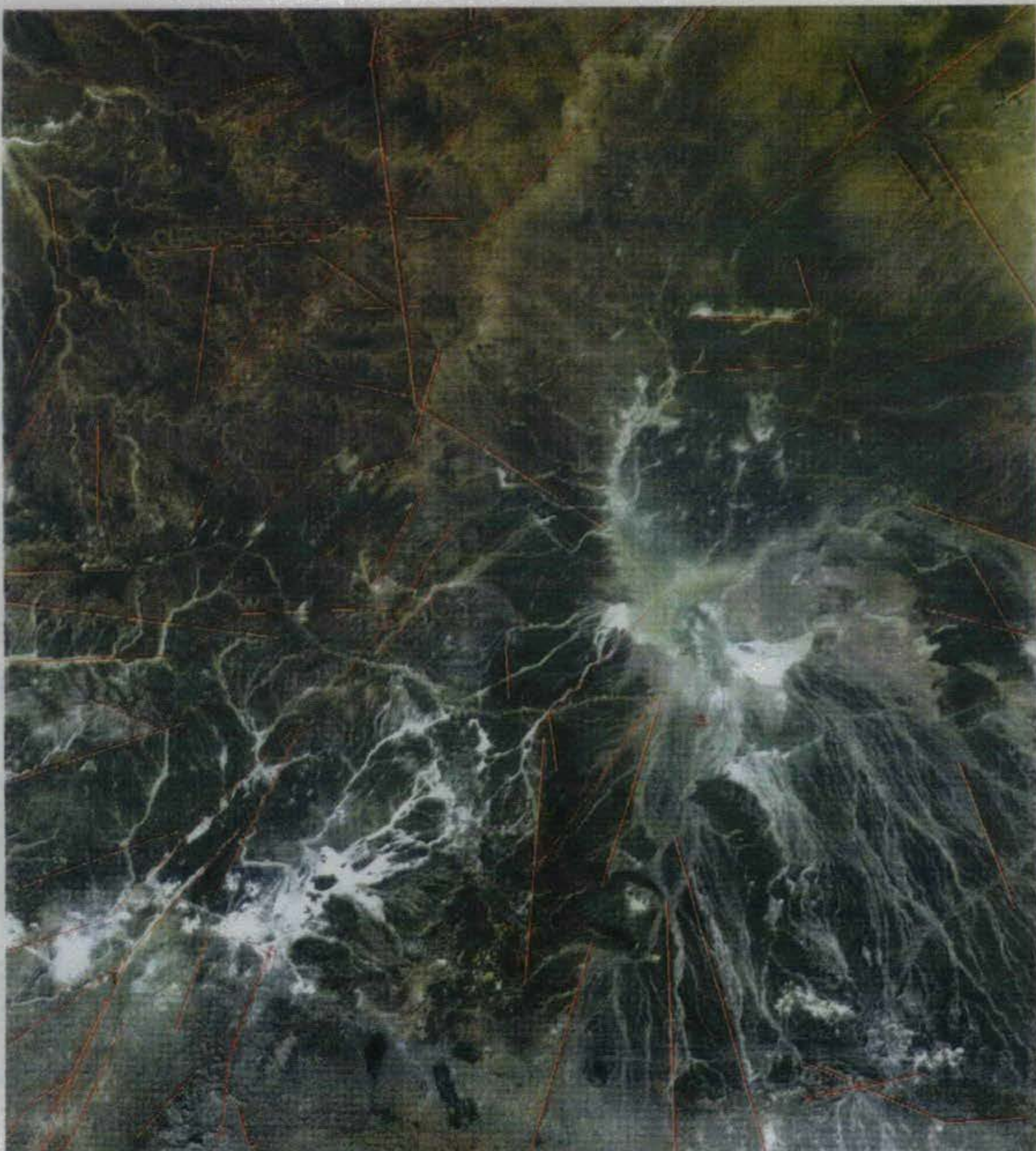
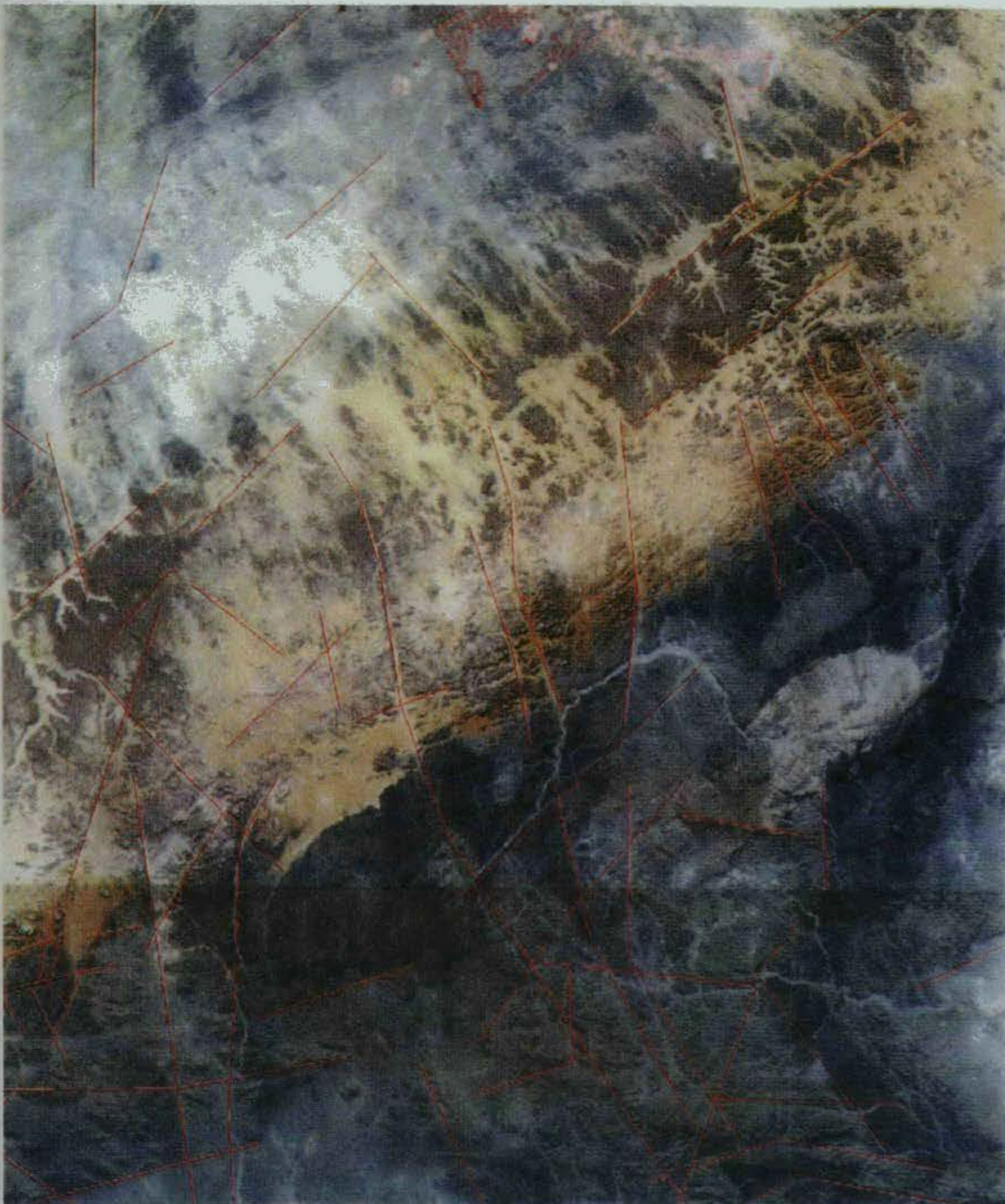


Figure 15 (b)



E. CONCLUSIONS AND PROPOSALS

1. In arid and semi-arid lands, such as the ESCWA region, hydrological implications of environmental changes can be deduced from certain indicators of changes on a regional scale based on remote sensing.

2. The methodological aspects proposed for the ESCWA region show the great potential of satellite data, with different resolution, for monitoring the water resources.

3. More efforts have to be made:

(a) To understand the complex interaction between land surface characteristics, meteorology and water process at the surface on a regional scale. In terms of remote sensing, this permits an assessment of desertification and control;

(b) To build databases on a regional level on surface parameters, based on satellite derived information and compatible with modelling in the hydro-climatological field. This information must be presented in a multi-level structure, the final layer on watersheds, intended as land scape units, and not on satellite imageries as is usually the case. Small-scale hydrological, hydrogeological and geological information should be implemented in the system to ensure legitimate data collection;

(c) To integrate regional studies in international programmes of a more global nature, in order to evaluate the results in terms of possible input for climate changes;

(d) To advertise the regional studies as well as to integrate them into a regional database in the form of conferences or workshops held at two-year intervals.

4. In the last three decades, there has been a gradual evolution of remote sensing of the earth from space technology, which has introduced a new dimension into the collections, analysis and utilization of earth resources data. Such data are finding wide applications in regional socio-economic development projects. It is now possible to carry out effectively a continuous operation of surveys of the earth (or the ESCWA region) from space, on a continuing basis with the aid of the Landsat (United States of America), SPOT (France), MOS (Japan), IRS and INSAT (India), and METEOR and ALMAZ (former USSR) series of satellites, and the various sun-synchronous and geostationary meteorological satellites. The radar satellites, which include ERS, JERS (Japan) and RADARSAT (Canada) will enhance the earth's environment.

Landsat MSS imageries used in the ESCWA project by the contractor RJGC (about 50 imageries), and NOAA-AVHRR imageries (6 images covering the ESCWA region), are sufficient to achieve the present goal of the project. It is essential now to obtain more precise and coherent information about the natural resources in the region through:

(a) Either covering the region with new Landsat MSS imageries; if possible, this needs about (200-250) imageries (although, it will cost about US$ 250,000);

(b) Or by using the Russian imageries, which started to be distributed in the last two years; these imageries have resolution of the order of 170 m for each pixel, or if there are any similar available data up to 500 m resolution. The advantage of this is that the number of imageries required is limited, which imply a decrease in the cost, as well as an increase in quality.

5. The actual project covers the hydrological activities in the region. It is proposed to extend this study to a wider range of natural resources assessment, including desertification, detection and monitoring by preparing maps locating the different aspects of this subject using remote sensing techniques.

Deserts make up more than 60% of the total area in the ESCWA region. These deserts are strategic areas with scarce water resources. Owing to the tremendous increase in population, and the growth rate coupled with rapid development, it is of prime importance that these areas be utilized. Furthermore, the resources of these deserts are to be used, and desertification measures should be implemented. To achieve this goal, careful investigation and understanding of groundwater resources and related hydrological parameters must be carried out. Remote sensing techniques can help in covering the huge areas under investigation. Therefore, complete desertification maps and details from satellite imageries for the ESCWA region are needed.

6. Natural resources have an important role in the problems of our environment. Individual ecosystems are usually affected by abnormal changes in our natural resources. To control and investigate the behaviour of these resources, remote sensing techniques should be used. The implementation of these remote sensing techniques will help in using environmental impact assessment techniques. We believe that now is the right time to develop a section devoted to remote sensing, with the ESCWA Natural Resources Section to serve this purpose.

7. The ESCWA region needs continuous follow-up of environmental changes, either natural or artificial, which may be undertaken by technical teams within the region, in collaboration with specialized scientific organizations. Management of the work will necessitate local experts to execute such a project, in order to build up a good and firm base of scientists dealing with these essential problems in the region. Such a base will serve future projects and train junior scientists for further development of the resources of the ESCWA region.

8. The use of this kind of regional investigation should not hold up local research programmes; such programmes form a base of sound and reliable information.

9. A proposal should be prepared to establish a space agency for the countries of the ESCWA region, which will be helpful in developing related activities such as:

(a) Natural resources assessment using remote sensing techniques;

(b) Communication technology;

(c) Geodesy of the region;

(d) Navigation;

(e) Any other activities for space applications which are useful for the region.

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REFERENCES*

- Barrett, E.C., 1990. The use of satellites in rainfall monitoring -39-42. In: International Symposium Remote Sensing and Water Resources, Enschede, The Netherlands, August (IAH/NSRS).

- Bausch, W.C., and C.M.U. Neale, (1987). Crop coefficients derived from reflected canopy radiation: a concept. Tran. Am. Soc. Agrie. Engrs 30, 703-709.

- Becker, A. and J. Nemec (1987). Macroscale hydrologic models in support to climate research. In: The Influence of climate change and climate variability on the Hydrological region and water resources, ed. S.I. Solomon, M. Bevan and H. Hogg (Proceedings of Vancouver Symposium), August 1987, pp. 431-445. IAHS, Publ. No. 168.

- Bondelid, T.R., T.J. Jackson, and R.H. McCuen, 1980. Comparison of conventional and remotely sensed estimates of run-off curve numbers in southeastern Pennsylvania. Proc. 46th Ann. Mtg. Amer. Soc. Photogram, A.S.P., Falls Church, Va., pp. 81-96.

- Brivio, P.A., 1993. Case Study for Managing Water Resources in the Sahel Areas. UN/IAF Workshop on Organizing Space Activities in Developing Countries: Resources and Mechanisms-Environmental and Resources Management. Graz (Austria).

- Bryceson K.P., 1993. Locust survey and drought monitoring - two case studies of the operational use of satellite data in Australian government agencies, ITC Journal, 1993, 3, 267-275.

- Burdon, D.J., 1982. Hydrogeological conditions in the Middle East, O.J. eng. Geol. London, 1982, vol. 15, pp. 71-82.

- Daniel, T.C., R.C. Wendt, P.E. McGuire, and D. Stoffel, 1982. Nonpoint source loading rates from selected land uses. Amer. Water Res. Assoc. Water Resources Bulletin 18:1:117-120.

- Environmental Protection Agency, 1973. Methods for identifying and evaluating the nature and extent of nonpoint sources of pollutants. Office of Air and Water Programmes. EPA-430/9-73014. EPA, Washington, D.C.

- Gray, D.M., 1979. Principles of hydrology: Port Washington, N.Y., Water Information Center, Inc., 560P.

* Issued as submitted.

- Holben, B.N., C.J. Tucker, and C. Fan, 1980. Spectral Assessment of Soybean leaf area and leaf biomass photogramm. Eng. and Remote Sensing 46, 651-656.

- Harvey, K.D., and S.I. Solomon, 1984. Satellite remotely sensed Land-use Land-cover data for hydrologic modelling. Canadian Jour of Remote Sensing. 10:1:68-91.

- Idso, S.B., R.D. Jackson, and R.J. Reginato, 1975. Estimating Evaporation: A Technique Adaptable to Remote Sensing; Science 189: 991-992.

- Jackson, T.J., and T.R. Bondelid, 1984. Run-off curve numbers from Landsat data. Proceeding, 1983, RNRF Symposium on Application of remote sensing to water resources management. A.S.P. Falls Church, Va. pp.543-573.

- Jackson, R.D., R.J. Reginato, and S.B. Idso, 1977. Wheat canopy temperature: A Practical Tool for Evaluating Water Requirements, Water Resour. Res. 13: 651-656.

- Jackson, R.D., 1982. Soil Moisture Inferences from Thermal-Infrared Measurements of Vegetation Temperatures; IEEE Transaction on Geoscience and Remote Sensing, vol. GE-20, No. 3, 282-286.

- Jackson, R.D., 1983. Spectral indices in N-space. Remote Sensing at the Environment 25, 295-309.

- Jupp, D.L.B., J. Walker, J.D. Kalma, and T.R. McVicar, 1990. Using Thermal Remote Sensing to Monitor Land Degradation and Salinization in the Murray-Darling Basin of Australia, Proc. 23rd Int. Symp. on Remote Sensing of the Environment, Bangkok, Thailand, April 18-25, 1011-1021.

- Kanemasu, E.T., J.L. Heilman, J.O. Bagley, and W.L. Powers, 1978. Using Landsat Data to Estimate Evapotranspiration of Winter Wheat; Environmental Management, 6:515-520.

- Khorram, S., and H.G. Smith, 1979. Use of Landsat and Environmental Satellite Data in Evapotranspiration. Estimation from a Wildland Area, Proc., 13th Intl. Symp. On Remote Sensing of Environ., Ann Arbor, Michigan, 1445-1453.

- Khouri, J. (1991). Hydrology and Hydrogeology of the Major Basins and Aquifer Systems in the Mashrek, Arabian Peninsula and Nile Valley (ACSAD 1991).

- Lagouarde J.P., 1991. Use of the NOAA-AVHRR data combined with anagrometeorological mode of evaporation mapping. International Journal of Remote Sensing, 12,9 1853-1864.

- Lagouarde J.P., and Y. Brunet, 1993. A simple model for estimating the daily upward longwave surface radiation flux from NOAA-AVHRR data. International Journal of Remote Sensing, 14,2. 907-925.

- Martin, D.W., and W.D. Scherer, 1973. Review of satellite rainfall estimation methods; Bull American Meteorological Soc., V. 54, pp. 661-674.

- McVicar, T.R., D.L.B. Jupp, J. Walker, and G. Tian, 1991. Remote Sensing with Physical Models of Soil Moisture Status to Monitor Land Degradation and Drought, Proc. 12th Asian Conf. on Remote Sensing, Singapore, 30 November.

- McVicar, T.R., D.L.B. Jupp, X. Yang, and G. Tian, 1992. Linking Regional Water Balance Models with Remote Sensing, Proc. 13th Asian Conf. on Remote Sensing, Mongolia, October 7-11.

- Meijerink, A.M.J., H.A.M. de Brouwer, C.M. Mannarts, and C.R. Valenzuela, 1994. Introduction to the use of geographic information systems for practical hydrology, the International Institute for Aerospace Survey and Earth Sciences (ITC), UNESCO and Ministry of Education and Science, P.N.23.

- Murai, S., 1991. Applications of Remote Sensing in Asia and Oceania/Environmental Change Monitoring/Asian Association on Remote Sensing.

- Novoty, V., and G. Chesters, 1981. Handbook of Nonpoint Pollution. Sources and Management. Van Nostrand Rein-hold Co., New York, 555P.

- Ostry, R.C., 1982. Relationship of water quality and pollutant loads to land uses in adjoining watersheds. AWRA Water Resources Bulletin 18:1:99-104.

- Price, J.C. (1987). Calibration of Satellite radiometers and the comparison of vegetation indices. Remote Sensing Environment 21. 15-27.

- Regan, R.M., and T.J. Jackson, 1980. Run-off synthesis using landsat and the SCS model-ASCE Journal of the Hydraulics Div., 106(H45) = 667-678.

- Rango, A., 1990. Remote Sensing of Water Resources, accomplishments, challenges and relevance to global monitoring. 3-16 In: International Symposium Remote Sensing and Water Resources, Enschede, The Netherlands, August 1990 (IAH/NSRS).

- Remote Sensing Note: 1993. Japan Association on Remote Sensing.

- Royal Jordanian Geographic Center (1995): As a Contractor for the ESCWA Project on Water Resources Assessment in the ESCWA Region Using Remote Sensing Techniques.

- Schultz, G.A., 1994. Meso-Scale modelling of run-off and water balances using remote sensing and other GIS data. Hydrological Sciences-Journal des Sciences Hydrologiques, 39,2. p.121.

- Seevers, P.M., and R.W. Ottmann, 1994. Evapotranspiration estimation using a normalized difference vegetation index transformation of satellite data. Hydrological Sciences- Journal-des Sciences Hydrologiques 39,4, p.333.

- Sikdar, D.N., 1972. ATS-3 observed cloud brightness field related to meso-lo-synoptic scale rainfall pattern: Tellus, V.24, pp.400-413.

- Slack, R.B., and R. Welch, 1980. Soil Conservation Service run-off curve number estimates from Landsat data. AWRA Water Resources Bulletin, 16:5:887-893.

- Soil Conservation Service, 1975. Urban hydrology for small watersheds, Technical Release No. 55, Engineering Division, U.S. Department of Agriculture. 48P.

- Sopper, W.F., and H.W. Lull, 1970. Streamflow characteristics of the northeastern United States: Pennsylvania State University, Agricultural Experiment Station, Bull 766, 129P.

- Townshend, J.R.G., 1981. Regionalization of terrain and remotely sensed data. In: Terrain Analysis and Remote Sensing, J.R.G. Townshend (ed.), Urwin, pp. 109-132.

- Waters, P.D., Greenbaum, P.L. Smart, and H. Osmaston, 1990. Application of Remote Sensing to groundwater hydrology. Remote Sensing Reviews, vol. 4 (2), 232-264.

- Weiser, R.L., G. Asrar, G.P. Miller, and E.T. Kanemasu (1986). Assessing grassland biophysical characteristics from spectral measurements. Remote Sensing Envir. 20, 141-152.

- Wiegand, C.L., A.J. Richardson, and E.T. Kanemasu (1979). Leaf area index estimates for wheat from Landsat and their implication for evapo-transpiration and crop modelling. Agron. J. 71-336-342.

Annex

SCOPE OF WORK ASSIGNMENT

1. Provide Remote Sensing (RS) data (photos, tapes) with adequate areal and seasonal cloud coverage, and adequate scales to fulfil the project objectives.

2. Obtain hydrological, hydrogeological, and land-use data for the ESCWA region, as required for the project. In this regard, ESCWA will provide all relevant "conventional hydrogeological/hydrological data".

3. Analyse and interpret, in an integrated manner, using the Geographic Information System (GIS) technology, the RS data and the ground information in order to produce the necessary maps of water resources and related natural resources as follows:

(a) ESCWA regional hydrological map, scale 1/2,500,000 showing the major catchment areas, drainage lines, major rivers, lakes, dams, and other major water bodies;

(b) ESCWA regional hydrogeological map, scale 1/2,500,000 showing the major aquifers, flow patterns and other hydrogeologically relevant features;

(c) Detailed hydrogeological maps, scale 1/1,000,000 for the following three major shared groundwater basins;

(i) Ordovician groundwater basin shared between Jordan and Saudi Arabia;

(ii) Dammam aquifer shared between Saudi Arabia, United Arab Emirates, Iraq and Bahrain;

(iii) Carbonate Rock aquifer (upper Cretaceous-Paleocene) shared between Jordan, Saudi Arabia, Iraq and Syrian Arab Republic.

These maps should show details on: groundwater flow patterns, water quality, water table (wherever available), aquifer boundaries, existing development areas, potential areas for future development.

4. Formulate options for development and management of major water resources focusing on shared water resources with special emphasis on the shared water resources given under item 3 (ii) above.

5. Prepare and submit to ESCWA progress and technical reports as follows:

(a) RJGC will report to ESCWA quarterly on the progress of the work;

(b) RJGC will submit to ESCWA for review, three months before the expiry date of the contract, a draft final report containing all outputs and maps as outlined above;

(c) One month before the expiry date of the contract, RJGC will submit to ESCWA the final report (the original and two copies) incorporating ESCWA, Islamic Development Bank (IDB), and UNEP comments on the draft final report;

(d) The final report will be accompanied by maps, input and output files for the various maps created, images and tapes, and shall include a proposed programme for joint monitoring and investigations of the shared water resources;

(e) It is understood that UNEP, ESCWA and the IDB hold the copyright of the final report and all maps and materials produced and compiled under the project;

(f) UNEP's Grid is entitled to use all RS tapes disks and images (after the completion of the consultant's contract) for its own purposes.

6. The outcome of the project activities shall be presented to an expert group meeting for evaluation purposes.

7. RJGC shall make available the facilities required, including lecturing for a 10-day training workshop on the RS and GIS technologies as applied in the project. The ESCWA secretariat will defray the cost of travel and daily subsistence allowances of the trainees.

PART TWO

COUNTRY PAPERS

XII. WATER RESOURCES IN THE STATE OF BAHRAIN

by

*Khalifa Ibrahim Al-Mansour**

A. Early history

Until about 1930, Bahrain depended largely on natural surface-springs for meeting its domestic and agricultural water needs. These springs were found on the northern half of the main island and to some extent in other smaller islands. Surplus water in the springs used to find its way to the sea through narrow streams. Dug wells were also in common use in some areas.

When the oil exploration commenced in the 1930s, water demand rose to a large extent, and this in turn necessitated the exploration and tapping of groundwater which was present in artesian conditions. At the beginning, the community was supplied through public water stand-pipes strategically positioned to serve a cluster of houses.

In 1940, further improvements were made to the mode of distribution in urban areas by introducing a piped water supply system and providing service connections to housing units. The system consisted essentially of a borewell, a pump, a small storage reservoir and a very limited network of distribution pipelines. As the urban area grew larger and larger, more and more borewells were added, together with a more or less similar distribution arrangement.

B. Background and current status

1. *Groundwater*

The water supply in Bahrain for domestic and agricultural purposes depended traditionally on groundwater abstracted from two freshwater aquifers—the Alat and Al Khobar (otherwise known as Aquifers A and B). These aquifers are extensions of geological structures under the eastern part of Saudi Arabia which also abstracts considerable quantities of water from them. There is a third aquifer below Khobar which is known as Umm Er Radhuma (Aquifer C). The salinity of water in this aquifer varies between 10,000 and 33,000 mg/litre.

Together with agricultural requirements, the groundwater abstraction began to spiral upward and reached a level of about 150 million m^3/year in 1980. This had an adverse effect on groundwater quality. The total dissolved solids (TDS) in water rose to something in excess of 3,000 mg/litre in the western region. In some areas like Sitra, Hidd and Tubli, the TDS reached an alarming level in excess of 5,000 mg/litre. There were isolated cases where TDS was found to be around 10,000 mg/litre. A

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groundwater modelling study conducted in 1982 showed that a progressive reduction in total groundwater abstraction is vital to arrest salinization of freshwater aquifers and create an environment for recovery of quality. The safe limit set for abstraction was 90 million m^3/annum. The effect of restricting groundwater abstraction is an increase in the demand for desalinated water far in excess of what was previously envisaged.

2. *System development*

The strategy set in the early 1970s for the system development of the domestic supply was to increase the total production of water to meet the accelerated demand and to improve reliability and the quality standard of water so supplied. Three major elements in the development plan were:

(a) Construction of sufficient capacity desalination plants;

(b) Construction of new and upgrading of existing transmission mains, trunk mains, pumping and blending stations and storage tanks;

(c) Modernizing the distribution system and extending it to all areas with built-in flexibility in operation. Now Distribution networks cover all developed areas in Bahrain.

The first desalination plant (multi-stage flash distillation plant) was constructed in 1975 at Sitra as part of a long-term policy to provide a blended supply of acceptable chemical quality complying with WHO drinking water standards. The capacity of the plant was 5 mgd (22,725 m^3/day) initially. The capacity was increased to 25 mgd (113,625 m^3/day) by 1985. A reverse osmosis plant was also constructed on the east coast at Ras Abu Jarjur with groundwater from aquifer C as the raw water source with a capacity of 10 mgd (45,450 m^3/day) by 1984. Another reverse osmosis plant of 10 mgd capacity was constructed at Ad Dur, again on the east coast, which started up in 1992.

Despite the introduction of the desalination plants, groundwater abstraction continued to rise for all purposes, including domestic and irrigation, to levels far in excess of the ceiling considered safe. It now stands at 200 million m^3/annum, i.e. more than double the safe limit. This has resulted in further deterioration of groundwater quality and the fear that the aquifer will be lost completely by the turn of the century if no drastic measures to curb abstraction are taken.

3. *Water quality*

Maintaining good water quality is of prime concern to the Ministry of Works, Power and Water. However, owing to the low contribution of desalinated water to the overall domestic water supply (about 50%), some areas are still receiving pure groundwater with a TDS of 2,500 - 3,000 mg/litre. It is anticipated that the construction of the desalination plants as planned will allow all the distributed water salinity to be within the WHO guidelines values.

Disinfection by chlorine covers 100% of the water supply since 1986. Residual chlorine monitoring and bacteriological test results fall in line with WHO guidelines set for drinking water. Tests are regularly carried out to check for most likely contaminants.

C. Activities and programmes

In facing these challenges which are basically to reduce dependency on groundwater to avoid further deterioration of water quality and have better control of high consumption levels, the Ministry has commenced a programme that would:

1. Increase desalinated water production by the construction of new desalination plants. It is envisaged that plants of a capacity of 30 million to 45 million gallons per day are to be added by 1998/99. This will help reduce dependence on groundwater and improve the quality of distributed water.

2. Adopt a demand-management policy which would curb the excessive high consumption. The policy encompasses a number of elements as listed below:

(a) Implement a leak detection/reduction and system renewal programme. This has reduced the level of leaks from the distribution system from about 25% of the total demand in the late 1980s to about 15% now, and is expected to be lowered to about 5%-6% by the end of 1997 if the implementation of the programme is continued;

(b) Apply metres on all services and implement a progressive water tariff. The result has been very positive. The rate of increase in consumption was reduced from about 12% in the period 1980-1985 to less than 5% in the period 1986-1990 after it was applied;

(c) Enforce water plumbing regulations for all internal plumbing systems. This was found necessary to curb wastes arising from substandard plumbing materials and workmanship and wasteful water appliances. Elements of such regulations have already been applied, and full implementation is expected in 1996-1997;

(d) Implement a public educational programme in association with the relevant authorities, such as the Ministry of Education, Ministry of Information, and Youth and Sports, to enhance public awareness of water issues and water conservation practices. This includes among other things water audits and distribution of water conservation devices.

3. Since the agricultural sector makes up about 70% of total groundwater consumption and is the main cause for the deterioration of its quality, the Government is considering a number of steps that would help alleviate the problem, such as:

(a) Expansion of the use of treated sewage effluent for irrigation, first to make use of what is available now and then arrange to utilize fully the 70 million m^3/year expected to be available from sewage plants by the year 2000;

(b) Expand the use of efficient irrigation systems. It is estimated that about 20% of the irrigation area is covered with such systems;

(c) Reconsider the crop mix. At present there is no proper selection of crop mix, and a lot of water-demanding crops, such as alfalfa, are grown;

(d) Consider the application of a tariff on groundwater consumption used for irrigation. This has already been agreed by the Cabinet and will soon be applied;

(e) Regulate the abstraction from private groundwater wells. No regulation or control at present of water abstraction is enforced, but it is strongly perceived among decision makers that such a regulation is necessary. An Amiri Decree (No. 12) was issued in 1980 to limit the drilling of wells to public use only. Such a decree was a positive step in the preservation of the groundwater resources at that time, but strict re-enforcement is needed.

D. Issues of importance

1. *Fragmentation of institutional responsibilities*

Integrated management of water resources is still a formidable task though there have been steps taken towards the establishment and/or improvement of the legislative and institutional set-up over the past few years. The lack of clear policy on water resource utilization has made it difficult to engage in the proper planning and management of water resources.

It is well recognized among decision makers that a formulation of clear policy is vital to face the present and future challenges of dwindling water resources and the expanding demand of various sectors. This policy should set the framework for proper resource conservation, development, and management along with the prioritization of water use, taking into consideration basic human needs and the economic return of other sectors' use. This policy most notably should address agricultural water use, which is considered excessive and without a significant economic return.

The recent government reorganization has led to very positive development on the institutional level, as far as water resources management is concerned. Instead of the earlier fragmentation among different agencies, at present some responsibilities, such as groundwater resources development and control; treated sewage effluent (TSE), and agriculture, are all under the Ministry of Works and Agriculture. This will certainly ease the management and utilization of TSE for agricultural use and help programme groundwater demand reduction for this purpose. The responsibility of municipal water production and distribution is still under the Ministry of Electricity and Water. Another positive development on the road to integrated management is the establishment of a committee of concerned government ministries to expedite the development and utilization of treated sewage effluent. The formation of this committee has been so far instrumental in the expansion of TSE production and utilization, and also the completion of the study of the second phase of the programme, which would allow the full utilization of TSE production. Implementation will begin once the financing is allocated.

2. *Legal framework*

Certainly the legal framework can in no way be considered complete, or at the least up to the challenges of the current or the future critical situation. Nevertheless, available legislation allows for some controls that are vital for the preservation of water resources. However, the non-adherence to the requirements and lack of enforcement of such legislation has been the pattern for some years (in particular in regard to drilling of groundwater wells), leading to the unfortunate situation of today. Some changes in, and strict observance of, existing legislation and the development of new legislation taking into account the present and future situation is recognized by the authorities to be essential.

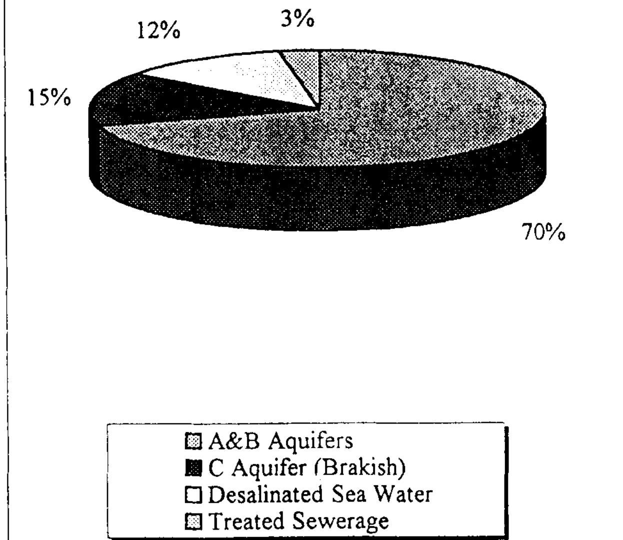
3. *Financial constraints*

The limited natural resources available have forced the authorities to consider the development of costly non-conventional sources, such as desalination for drinking purposes and TSE for irrigation. Limited financial resources have forced the deferment of many vital projects, most notably the 30 mgd desalination plant, which was supposed to be operational by 1993. As a result the Government is seriously considering allowing the private sector to undertake the building of water and power production plants.

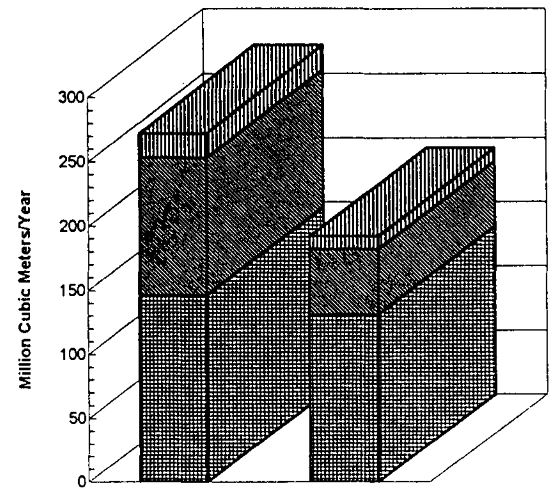
4. *Tariff*

It is recognized that a suitable tariff application is important if the authorities need to overcome the ever increasing financial burden, which is likely to grow in the future. More important, the authorities realize the vital role of the tariff as a conservation tool. The experience so far in the municipal sector has been positive in curbing the rate of increase in demand when the tariff was introduced. Though the gap between cost and tariff is considerable, development and introduction of more effective tariffs may be necessary in the near future to enhance water conservation behaviour, and help ease the financial burden. The first application of a tariff on groundwater for irrigation and other uses is expected shortly. If well managed and developed, this tariff will have a major impact on groundwater abstraction, which has doubly exceeded the safe limits.

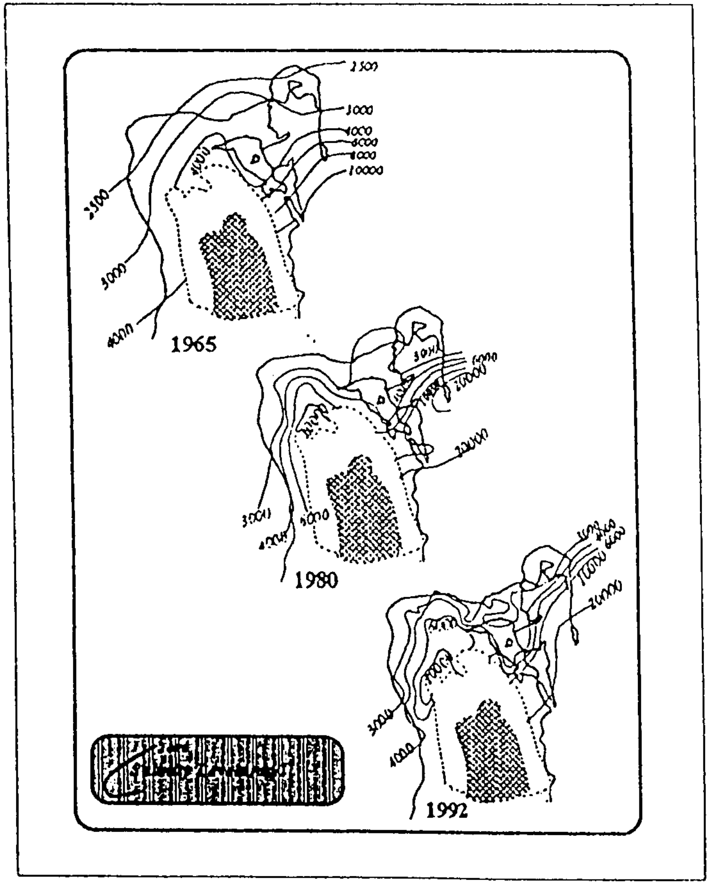
Percentage breakdown of water sources used



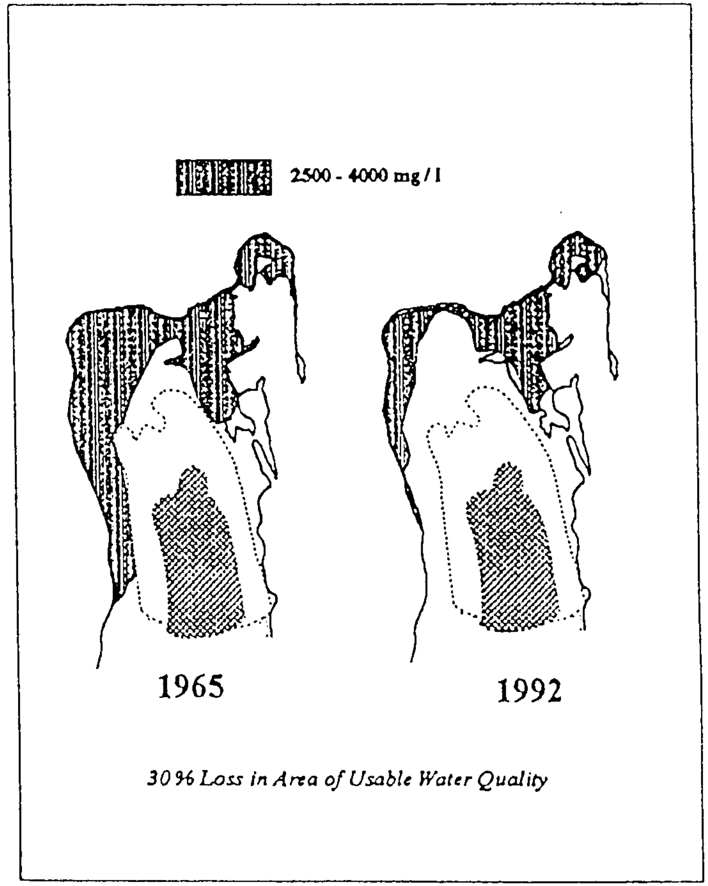
Water resources utilization according to consumer sectors

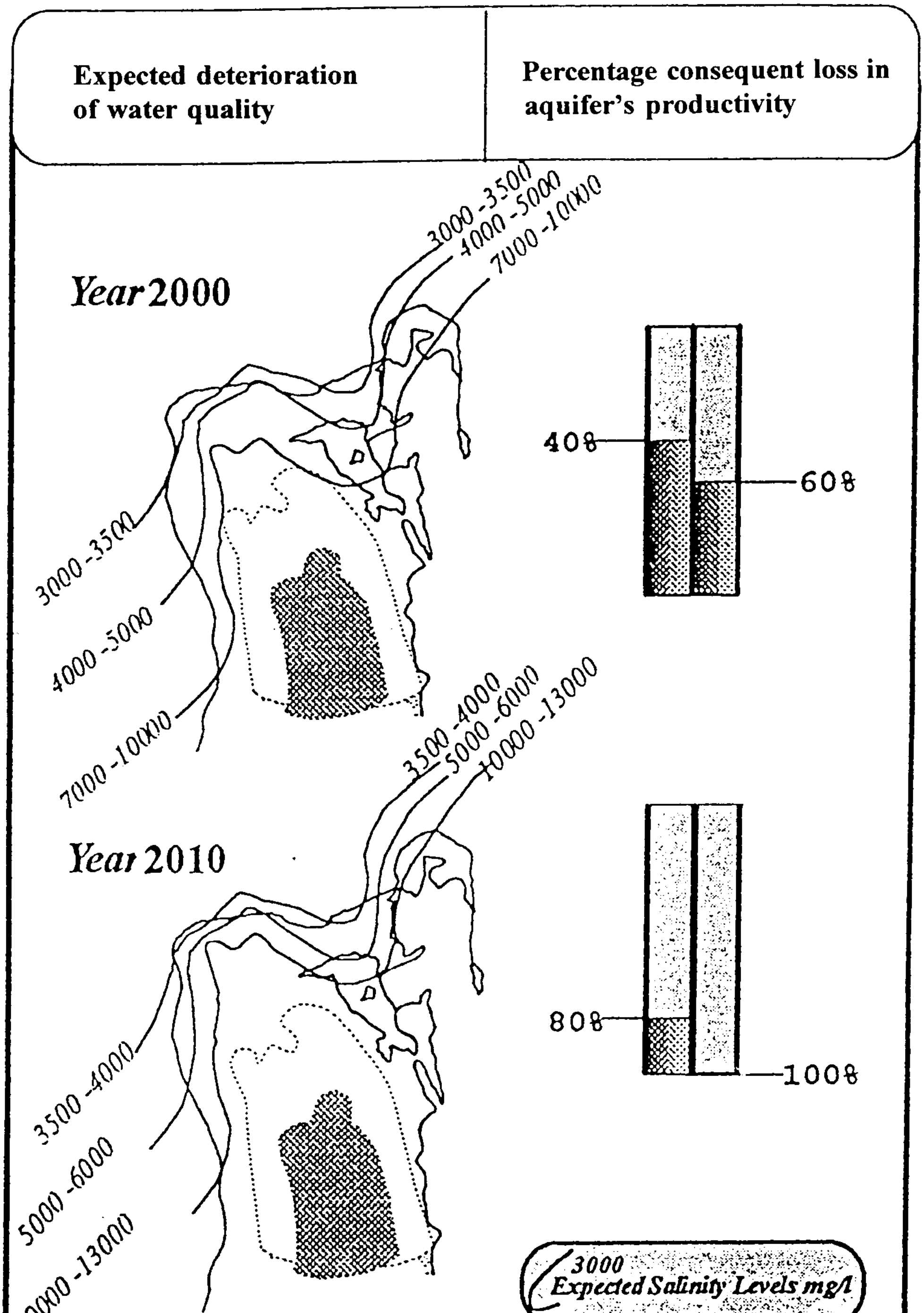


	Usage Of Water		
	Total	GW	%
Agricultural	146	131	90
Municipal	107	51	47
Industrial	19	10	53

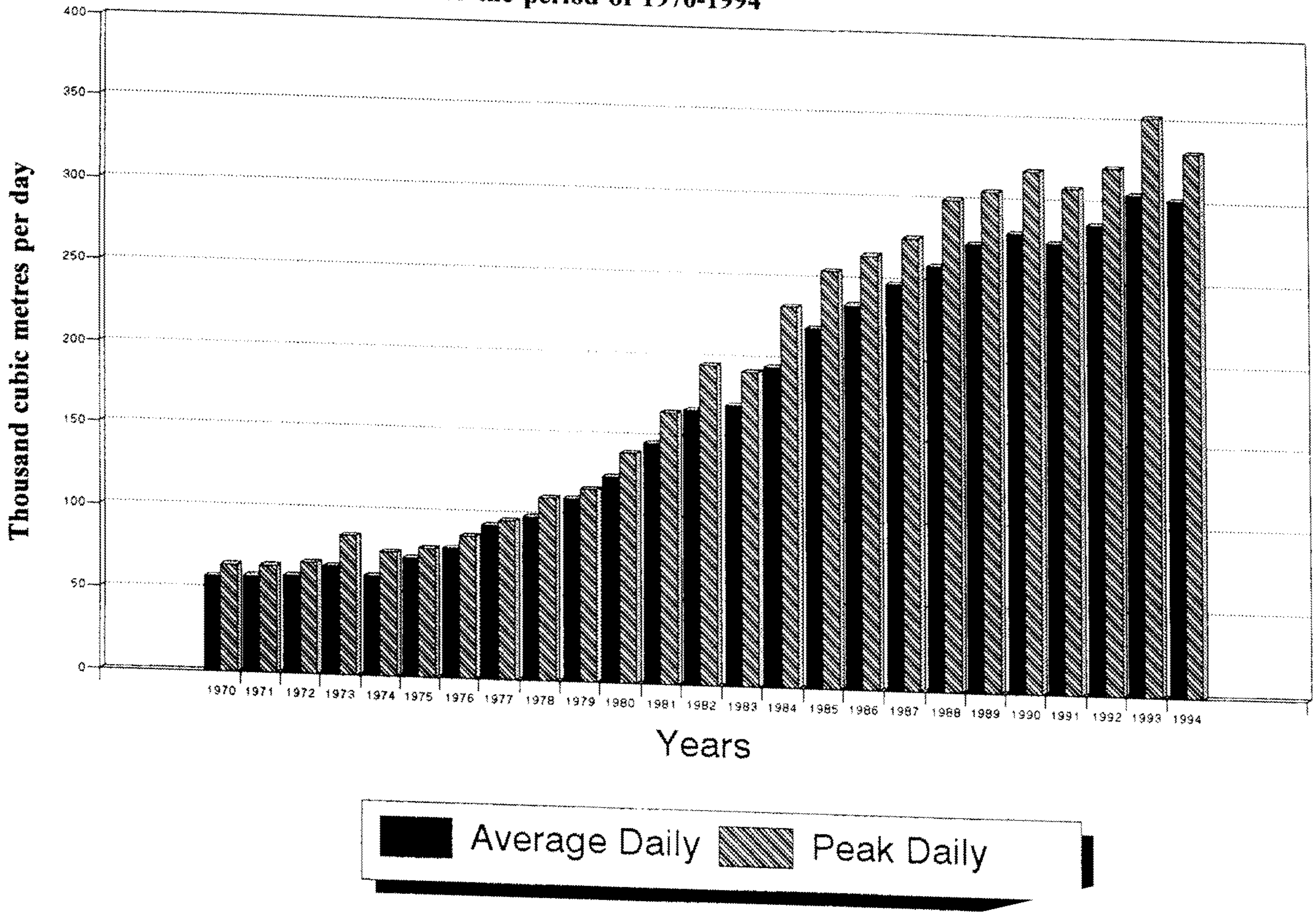


Inland retreat of usable water quality
1965 - 1992

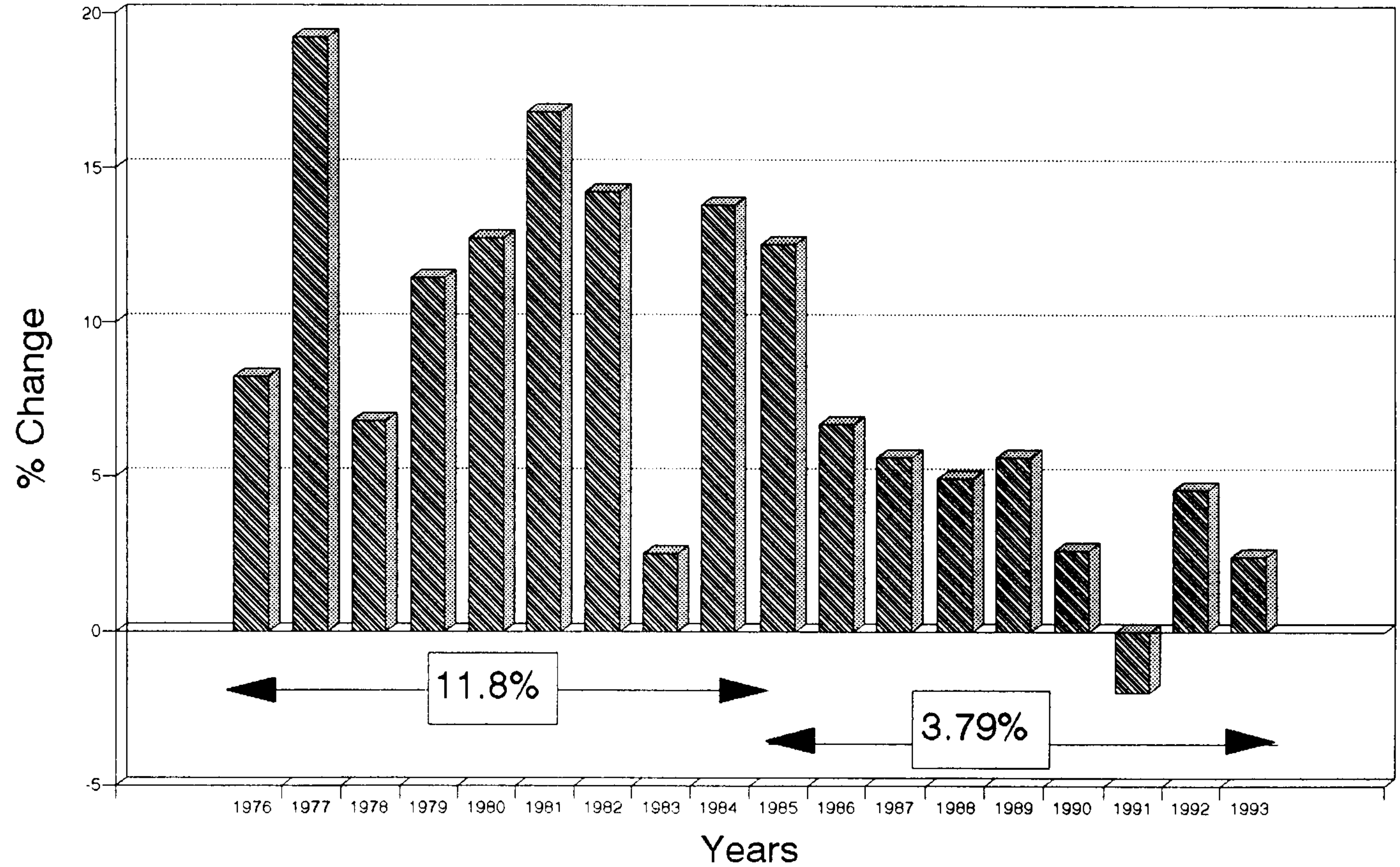



Expected deterioration of water quality
Percentage consequent loss in aquifer's productivity
Year 2000
3000-3500
4000-5000
7000-10000
40%
60%
Year 2010
3500-4000
5000-6000
10000-13000
80%
100%
3000
Expected Salinity Levels mg/l

Average/peak daily water consumption (Municipal) for the period of 1970-1994



Annual percentage increase in total Municipal consumption



XIII. TOWARDS AGENDA 21 - CHAPTER 18: EGYPTIAN POLICY FOR IMPLEMENTATION

by
A. Fahmy, B. Attia,* M.B.A. Saad***

Introduction

Egypt covers an area of about 1 million km^2 of the arid belt of North Africa. Only 3.4% of this area is occupied by its population of nearly 60 million, of which 99% is concentrated in the Delta zone. The Nile Valley consists of flood plain, bordered by flat terraces, most of which are suitable for land reclamation. Prime quality arable land surrounds the two Nile branches in the Delta, Rosetta and Damietta. Cultivated areas occupy nearly 7.37 million feddans (1993), mostly confined to the flood plain and the Delta of the Nile. A few oases and some arable land in Sinai are irrigated by irrecoverable groundwater.

Rainfall in the Mediterranean coastal strip decreases from 200 mm/yr in the west and drops dramatically inland to some 20 mm/yr near Cairo, 200 km from the coast. Rainfall in Egypt only occurs in winter in the form of scattered showers. Rainfall is utilized only in the northern part of the Delta as a supplement to irrigation diversions in the winter closure period, but cannot be considered a dependable source for extensive agricultural production. A reliable supply of water for irrigation is therefore mandatory for the development of agriculture in Egypt.

The socio-economic development of Egypt has been, and will remain, greatly dependent upon the development of its agriculture sector. However, water demands in Egypt have increased not only parallel with the agriculture horizontal expansion plan set by the Government, but also in relation to industrial development, the increase in population, and the rise in living standards. The share of water per person was estimated as 950 m^3/year, which is considered under the water poverty levels; it is anticipated that this amount will be reduced to about 500 m^3/year by the year 2025.

A. EGYPT'S WATER RESOURCES: CURRENT AND POTENTIAL DEVELOPMENT

1. *The Nile River as the main water resource of Egypt*

The main and almost exclusive source of water is the Nile River. Nearly 85% of the Nile water originates from the Ethiopian highlands through the Sobat River, the

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Blue Nile River, and the Atbara River; the remainder originates from the Equatorial Lakes highlands (through Bahar El-Jebel and Bahar El-Ghazal). The highest annual river flow at Aswan was 150 billion m^3 (1878/1879), the lowest 42 billion m^3 (1913/1914). The average annual natural flow at Aswan for the period 1900-1955 was estimated as 84 billion m^3/yr where abstraction in the Sudanese part of the river are estimated at about 14 billion m^3/yr.

The regulatory capacity provided by the High Aswan Dam has given stability to Egypt's water resources despite the wide range in annual flows recorded in the last 100 years (which limits the use of statistical forecasting of flows for planning purposes). The storage capacity of Lake Nasser (live storage 90 billion m^3) can safeguard downstream water requirements in years of less than average inflow to the lake. The recent African drought (1984-1987), while devastating to many parts of Africa, had a limited impact on Egypt. Water reserves of the High Aswan Dam were seriously reduced, but the high inflows during 1988 have restored reserves to near the 1983-1984 levels. Egypt is now putting more effort into water management and forecasting, to improve the utilization of its water resources in order to be abe to meet future increasing demands.

The Nile water agreement of 1959 with the Sudan was based on the average Nile flow at Aswan during the period 1900-1995 (84 billion m^3/yr) and estimated average annual evaporation and other losses in Lake Nasser (nearly 10 billion m^3/yr). The agreement allocates 7.5 billion m^3/yr to Egypt and 14.5 billion m^3/yr to the Sudan.

Egypt's share from Nile water is fixed by the above agreement to 55.5 billion m^3/year. It is worth noting that the different other uses such as the reuse of drainage water, groundwater in the valley and delta and wastewater reuse are not considered as independent sources, but rather as a factor helping in increasing the efficiency of the overall system.

2. *Groundwater*

(a) *The Nile aquifer*

Groundwater in the Nile aquifer cannot be considered a separate source of water. The aquifer is renewed only by seepage losses from the Nile, the irrigation canals and drains and percolation losses from irrigated lands. Its yield may therefore not be added to Egypt's total water resources without taking into account salinity build-up due to groundwater abstraction/recharge cycles. The potentially recoverable abstraction rate (safe yield) of this aquifer is estimated at 7.5 billion m^3/yr; further abstraction may result in a significant lowering of the groundwater table and an increase in sea-water intrusion in the northern part of the Nile Delta. Hence, this aquifer can only be seen as a small reservoir in the Nile River system with a limited-rechargeable-life storage compared with its total volume which is estimated at 500 billion m^3/yr. The current rate of abstraction from the Nile aquifer is estimated at 4.1 billion m^3/yr.

(b) *Groundwater in the Western Desert*

There is groundwater in the Western Desert in the aquifer of the New Valley and region east of Owaynat. The total groundwater volume in these areas has been estimated at 40,000 billion m^3, with salinity varying between 200 and 700 ppm (Abu-Zeid and Rady, 1991). The groundwater occurs, however, at great depths and is generally considered to be non-renewable. Use of this water, as adopted in the water policy of Egypt, depends on pumping cost and depletion rate versus potential economic return. A study has indicated (Abu-Zeid and Rady, 1991) that 125,000 feddans can be irrigated (by 1 billion m^3/yr of groundwater) in the New Valley; another 180,000 feddans can be irrigated in the East Owaynat area by groundwater from the deep Nubian Sandstone.

(c) *Groundwater in Sinai*

In Sinai, there are numerous smaller groundwater aquifers, for example the shallow aquifers along the Northern coast, the Northern and Central Sinai that are recharged by rainstorm floods and the aquifers in South Sinai, which are mostly deep and non-renewable. Present groundwater abstraction in Sinai and the Western Desert is estimated at 0.57 billion m^3/yr, which could be increased to 3.5 billion m^3/yr.

3. *Reuse of agriculture drainage water*

Drainage flows stem from three sources, all of which depend upon Nile inputs; namely, tail-end losses from canals, surface flow from irrigated fields, and percolation. Intrusion of saline groundwater contributes greatly to the salt load, in particular in the northern part of the Nile Delta, where 80% of the salinity of the drainage water is added by upward seepage of saline groundwater. Lower salinity is found further southward, where it remains below a critical level (estimated at 1,000 ppm TDS). Studies have indicated that drainage water can be reused directly for irrigation if the salinity level is low or mixed with fresh canal water when the salinity is high. An example is El-Salam Canal, which uses drainage water of Bahar Hadous and El-Serow drains mixed with freshwater in a ratio of 1:1; the total amount which can be reused is estimated at about 7.5 billion m^3/yr. However, for the time being, about 3.7 billion m^3/yr is being used.

4. *Desalination*

Desalination is being applied only to a few areas along the Red Sea coast, especially in tourist resorts, where water consumption is relatively small. However, desalination in Egypt has been given low priority compared with other non-conventional water resource options, mainly in view of its relatively high cost.

5. *Improvement of the irrigation system*

Field water application, agronomic water use, and field canal conveyance efficiencies determine the overall efficiency of the irrigation system, which is in the order of 70% at present (Planning Sector, 1994). There is an ongoing project within the Ministry of Public Works and Water Resources to implement a plan designed by the National Water Research Centre to improve the irrigation efficiency in the old lands. The project comprises the improvement of control structures application of modern methods in land levelling/tillage and on-farm development, and the rehabilitation of main canals, branch canals, and *mesqas* (field canals). Owing to a reduction in water losses that are not returned to the system, the project is expected to yield savings of 0.5, 1.5 and 5 billion m^3/year in the years 2000, 2012 and 2025 respectively.

6. *Reuse of wastewater*

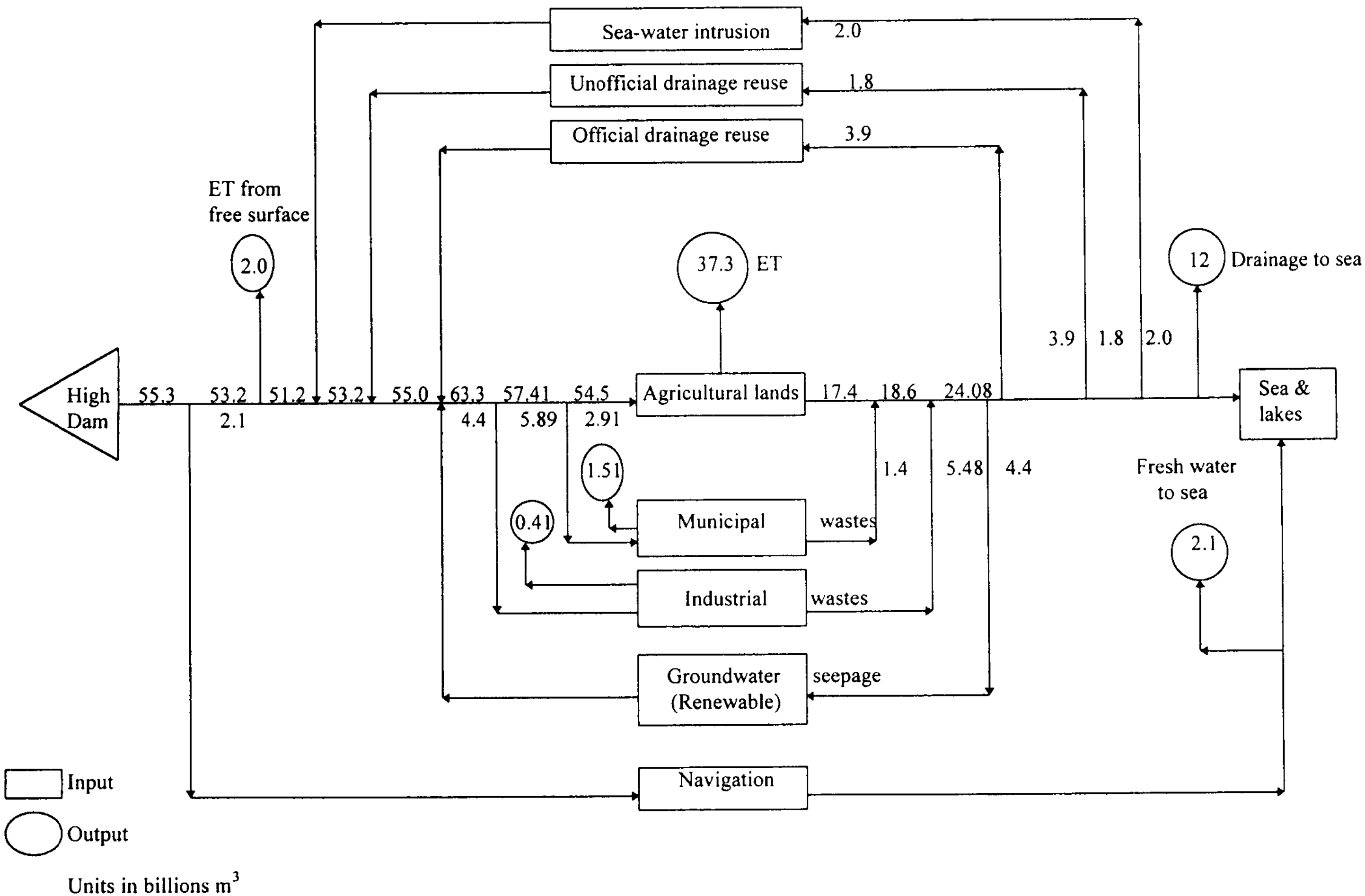
Wastewater reuse has been applied in Egypt for centuries, but was formally used in 1915 at Gable El-Asfar (north-east of Cairo), after primary treatment, for cultivation of 2,500 feddans. As new wastewater treatment plants—using secondary treatment—are being built in some cities, the reuse of treated wastewater could be increased from the present amount (estimated at 0.6 mm^3/yr) to 1.67 mm^3/yr in the year 2000 and to 2.4 mm^3/yr in the year 2010.

7. *Water quality aspects*

(a) *Salt water balance over Egypt*

The water balance for Egypt is presented in figure 1. Components in the figure are given as gross supply and net consumption. In figure 1, it is indicated that at present, some 12 billion m^3 of drainage water is being spilled annually into the sea, some of which is to maintain the salt balance and to flush the high salinity water in the northern Delta, where salt intrusion from the sea takes place. However, the amount of lost drainage water seems to be inaccurately estimated, as part of this water (possibly 2.0 billion m^3/yr) is the drainage of sea water intruded in the northern part of the Delta, which affects the water and salt balance. Another uncertainty in the estimation of the "net" amount of spilled water is due to the salt from leaching soils of newly reclaimed northern lands. This may indicate that the actual drainage water produced from agriculture is about 10 billion m^3.

Figure 1. National water balance 1992/1993



The non-recoverable volume of drainage water that has to be spilled to the sea to allow sufficient leaching of the soils and to counteract sea-water intrusion is estimated at 8 billion m^3/yr (6 from agriculture lands + 2 from sea-water intrusion) at a minimum. Therefore, drainage reuse projects in the near future may use about 4.0 billion m^3/yr, of the presently spilled drainage water. Water pollution hazards as well as ecological considerations are, however, expected to limit this objective.

A thorough investigation into the use of brackish or highly saline water on sandy desert soils under modern irrigation techniques might reveal increased possibilities for the use of this water.

(b) *Water quality and environmental aspects*

Water quality parameters in Egypt can be grouped according to their constituents as follows:

(a) Salts, which have been extensively studied;

(b) Organic pollutants from industrial, domestic and agriculture wastes, which can be removed by natural processes (bio-degradation);

(c) Pathogens and bacteria;

(d) Nutrients resulting from the application of manure and fertilizers of the bio-degradation of wastes;

(e) Other organic/inorganic chemicals (e.g. heavy metals) stemming from industrial and domestic wastewater or pesticide applications in agriculture.

The first category of pollutants is most harmful to agriculture, whereas the others form a danger for humans, fisheries and the environment in general.

A relatively clear picture exists in terms of water salinity; information and data on other water quality parameters are limited. The limited data available do, however, suggest that “black spots” are still of a local nature. Pollutants loading results from untreated/semi-treated municipal and industrial wastewater discharges into drains (sometimes also directly into the Nile River or canals in the case of industrial wastewater discharges), from drainage water discharging into the Nile River in Upper Egypt, and from the leaching of fertilizers and pesticides from agriculture.

Generally, in most of the irrigation canals, the water is still relatively clean, in contrast with that in the drains, where most of the wastes are dumped.

The almost stagnant bottom waters in Lake Nasser lack adequate oxygen. After the water has been released into the river, it soon regains its natural content, however. Large organic pollution loads from urban areas and industries in Upper and Middle Egypt cause local "black spots" but the self-purifying capacity of the Nile River still results in reasonable levels of organic pollutants downstream. The levels of BOD, as a measure of degradable organic matter, are still satisfactory up to the Delta barrages (table 1).

Fertilizer use has increased almost fourfold during the past four decades. Groundwater contamination from fertilizer use requires attention, as groundwater is used widely for drinking water and is considered more vulnerable than surface water. Pesticide use has also increased but at a lower rate. In 1991, herbicides were used to control aquatic weeds, of which 13,000 km of canals/drains were infested, but their use was eliminated as a result of political and public concern. On the other hand, alternative means have disadvantages as well; manual weed control may cause an increase in bilharzia, while the use of mechanical and biological means may require extensive investment. The best solution for weed control would probably be to use integrated means on the basis of an optimization study.

Water pollution from industrial and domestic wastes in the Nile Delta is likely to cause degradation of land/soil and water resources. Degradation of natural resources is widespread in Egypt as a result of the adverse impacts of development; the problem received limited attention in the past. This impact can be considered as a drain on the national economy. However, the impact on human resources is of greater concern since it represents a cost to the national economy. However, the impact on human resources is of greater concern since it represents a cost to health and the economy. A legal basis for controlling water pollution, especially by municipal and industrial effluents, already exists through Law 48 of 1982. A nationwide water quality monitoring programme has been proposed as part of the implementation of Egypt's Environmental Action Plan.

B. EGYPT'S WATER DEMANDS: PRESENT AND FUTURE SITUATION

1. *Agriculture water requirements*

Water requirements of the agriculture sector represent the largest component relative to other uses. Gross water demand from irrigation is in the order of 54.5 billion m^3/yr, including all application, distribution and conveyance losses. Irrigation is applied to 7.37 million feddans of arable land, whereby the annually cropped area is 14.7 million feddans (i.e., a cropping intensity of nearly 200%).

TABLE 1. WATER QUALITY STATUS IN THE NILE RIVER
IDENTIFICATION OF BLACK SPOTS BY COMPARING PARAMETER STANDARDS AND EXISTING VALUES

Parameters/constitutes (Units)		TDS (ppm)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Total Coliform (No./100m)	Organic Nitrogen (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	Turbidity (mg/l)	PH
Appropriate standards											
For Nile main reach (Source Law 48/WHO)		500	min 5			3000					7 to 8.5
For discharges to Northern lakes (Law 48/Art 66)		650	min 4	6	10	5000	1	0.5	10	50	7 to 8.5
Nile Reach (Node)	Km from Aswan										
Aswan	1.4	135	DET 3.15	3	9	12000	0.04	0.02	0.55	3	7.4
	21	150	DET 3.77	2	5	1500	0.02	0.02	0.35	3	7.35
	53.8	155	DET 4.5	4	8	2000	0.01	0.45	0.52	3	7.25
	83.4	160	DET 5.45	2	9	18500	0.02	0.42	0.46	3	7.25
Idfu	114.5	154	DET 6.0	1	9	800	0.015	0.42	0.42	255	7.3
	143.05	160	DET 6.23	1.3	7	1500	0.02	0.13	0.26	260	7.35
Esna (Barrage)	167.65	163	8.5	1	9	6000	0.02	0.5	0.54	5	7.4
	206.9	166	8.4	1	8	1000	0.017	0.6	0.44	4	7.45
	236.8	170	IMP 9.2	3	7	1000	0.015	0.25	0.54	4	7.5
Naga Hammadi Barrage	268.15	167	DET 9.3	3	9	2000	0.01	0.13	0.7	3	7.55
	299.2	173	IMP 9.1	3	7	3000	0.07	0.02	0.38	5	7.6
	331.1	178	IMP 9.15	3	10.5	1900	0.03	0.05	0.24	5	7.65
	361	176	IMP 8.4	3	10.5	53000	0.06	0.02	0.28	7	7.5
	397	180	IMP 9.0	3	9	50000	0.02	0.02	0.32	6	7.5
Sohag	438.55	186	IMP 9.57	3	7.5	5000	0.04	0.02	0.26	9	7.65

TABLE 1. *(continued)*

Parameters/constitutes (Units)		TDS (ppm)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Total Coliform (No./100m)	Organic Nitrogen (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	Turbidity (mg/l)	PH
Appropriate standards											
For Nile main reach (Source Law 48/WHO)		500	min 5			3000					7 to 8.5
For discharges to Northern lakes (Law 48/Art 66)		650	min 4	6	10	5000	1	0.5	10	50	7 to 8.5
Nile Reach (Node)	Km from Aswan										
	472	182	IMP 8.6	3.5	13.5	1500	0.055	0.02	0.8	7	7.7
	512	180	IMP 9.12	3	13.5	500	0.06	0.01	0.27	10	7.6
Assuit Barrage	547.4	180	IMP 9.72	4	15	2500	0.02	0.01	0.24	13	7.55
	587	183	IMP 8.75	3.5	14	1000	0.08	0.008	0.87	16	7.7
	618.65	186	IMP 8.6	4.5	25	2700	0.015	0.008	0.45	12	7.75
	646	189	IMP 9.25	3.5	15	2000	0.03	0.008	0.42	12	7.7
Minya	686.05	183	7.85	3.7	9	5500	0.015	0.008	0.3	20	7.65
	716.6	186	IMP 8.4	3.2	16	5500	0.035	0.008	0.2	17	7.6
	748	182	IMP 8.55	3.2	10.5	2000	0.025	0.008	0.2	14	7.65
	792.4	188	IMP 7.17	3	16	2000	0.01	0.008	0.64	37	7.35
Beni Suef	807.8	187	IMP 7.55	2	8	2000	0.01	0.02	0.52	42	7.5
	862	196	DET 7.2	3	10.5	1000	0.01	0.07	0.44	40	7.4
	887.95	200	DET 7.45	3.2	10	500	0.01	0.08	0.25	41	7.5
Cairo	921.8	205	DET 6.5	3.7	5.5	6000	0.01	0.02	0.51	20	6.8

TABLE 1. *(continued)*

Parameters/constitutes (Units)		Km from Aswan	TDS (ppm)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Total Coliform (No./100m)	Organic Nitrogen (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	Turbidity (mg/l)	PH
Appropriate standards												
For Nile main reach (Source Law 48/WHO)			500	min 5			3000					7 to 8.5
For discharges to Northern lakes (Law 48/Art 66)			650	min 4	6	10	5000	1	0.5	10	50	7 to 8.5
Nile Reach (Node)												
U.S. of Delta Barrage		947	208	DET 5.8	3.2	16.5	4000	0.03	0.02	0.78	25	6.9
Damietta Branch Zifta Barrage		1166	350	DET 4.65	7.6	46	4500	0.03	0.31	0.94	10	7.5
Damietta (At Outflow to Manzala Lake)		1180	375	IMP 6.0	6.5	13	5000	0.03	0.24	0.76	7	7.5
	Rosseta Br.	10.5	320	4.7	8.5	15	20000	0.025	1	2		7.5
	Edfina	1156.5	345	DET 5.65	6.5	15	1500	0.025	0.2	2.5		7.5
General Trend of Parameter Status with time			Improving		Improving	NA	NA	NA	NA	NA	NA	NA

The Land Reclamation Plan, developed by the Ministry of Agriculture together with the Ministry of Public Works and Water Resources, aims at reclaiming more that 2.2 million feddans from 1993/94 to the year 2000. The plan includes the reclamations of:

(a) 1.7 million feddans through improved efficiency in use of surface water, i.e. through projects to conserve winter closure losses (mainly for navigation) and by improved reuse of drainage water and groundwater (figures 2 and 3);

(b) 0.2 million feddans with water provided by sewage treatment projects;

(c) 0.3 million feddans with unrecoverable groundwater in the New Valley (Western Desert) and Sinai.

The implementation of this ambitious plan faces several obstacles, such as resistance against the storage of losses during the winter closure period in the coastal lakes due to adverse impact on fisheries and the environment and the constraints in the reuse of drainage water by the increasing pollution of the drains. Moreover, the salt balance in the Delta necessitates the 8 billion m^3/yr (at a minimum) of the drainage water has to be flushed to the sea, which could also limit the future increase of reuse.

Figure 2. Horizontal expansion future

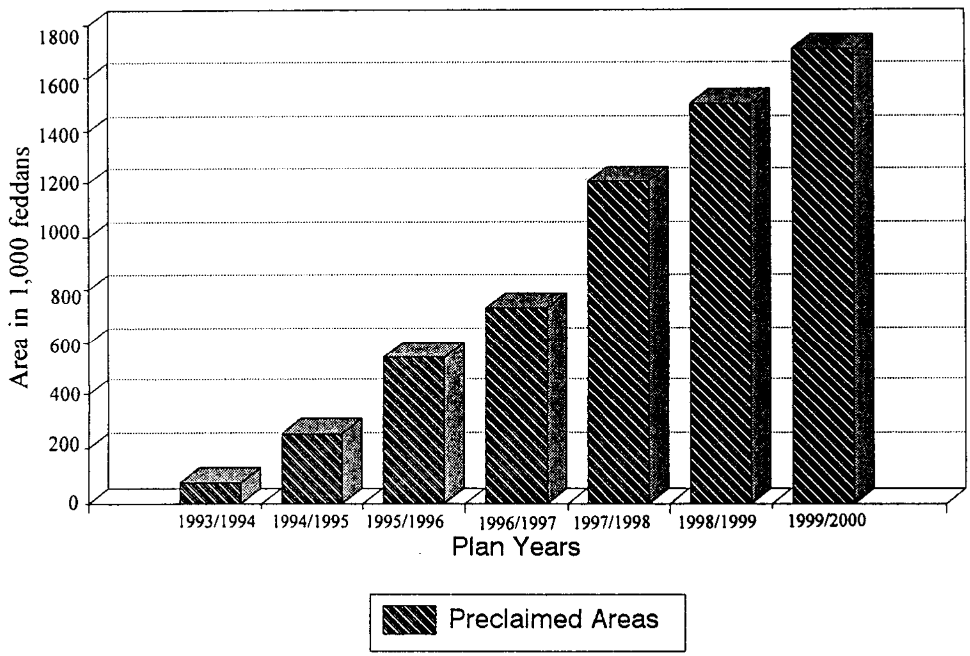
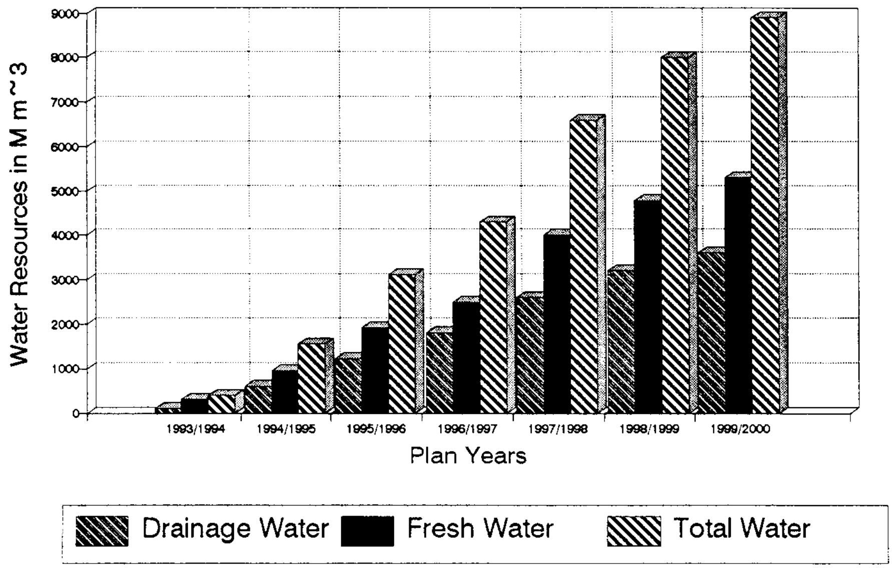


Figure 3. Water resources plans to cope with reclamation



Due to these obstacles, horizontal expansion might be limited. In order to reach the target of the plan, the following measures have to be taken (Planning Sector, 1994):

1. Implementation of a strict scheme for protecting waterways from pollution (although there is good cooperation between the Ministry of Public Works and Water Resources and the Egyptian Environmental Affairs Agency);

2. Reduction of areas planted in rice;

3. Modification of the current cropping pattern to incorporate less water-consuming crops, by replacing sugar-cane with beets, which consume less water;

4. Modification of the winter closure (to make it more flexible) and conservation of the freshwater losses to the sea (see the section on navigation water requirements);

5. Calculation of crop water requirements at the field level in a more accurate way by using new methods for the computation of evapo-transpiration losses and aerial photogrammetry or satellite imaging techniques to obtain actual cropping patterns;

6. Eradication of aquatic weeds to reduce evapo-transpiration loss from canals and lakes;

7. Drainage reuse at the potential capacity to minimize the spilling of drainage water to the sea beyond the amount needed to maintain the salt balance.

For the period from the year 2000 until 2010, additional areas of about 0.3 million feddans can be reclaimed only if the Jonglei Canal Project is implemented. This would add almost 2 billion m^3/yr to the annual water budget of Egypt.

2. *Navigation*

Since the construction of the High Aswan Dam, the water released for irrigation and municipal and industrial demand for the period from February to September is sufficient to maintain adequate depth for navigation on the Nile. However, from October until January, irrigation water demands are relatively low (also many regions in the Northern Delta utilize winter rainfall to supplement irrigation), particularly during the winter closure (three weeks in January/February), and the Nile water discharges become too low to provide the minimum drafts reburied for navigation.

In the Aswan-Luxor section (where a minimum draft of about 1.5 m is required, navigation bottlenecks may occur in winter, when there is a peak in tourism activities. The Luxor-Cairo section is hardly sailed by tourist boats and may only have navigational bottlenecks during the closure period. The normal Nile flows—without extra releases—during this period will be sufficient for partially loaded tourist boats and for cargo ships operation with a lower efficiency. To overcome the navigational bottlenecks in the Aswan-Luxor section, extra water is being released from the High Aswan Dam—mostly during the closure period—in addition to the requirements for municipal and industrial supply. As this water is not required for any of the other demands, it is being spilled to the sea.

This amount of freshwater annually spilled to the sea was about 1.8 billion m^3 in 1990/91, 3.8 billion m^3 in 1991/92, 2.08 billion m^3 in 1992/93, and 1.15 billion m^3 in 1993/94. Most of this water is spilled at Edfina (end of the Rosetta branch). Around 0.2 billion m^3/yr is being spilled into Lake Manzala at Damietta; the latter amount is used to flush silt and rubbish from the Damietta branch. For the conservation of this water, various alternatives have been considered, such as storage in the pools upstream of the Nile River barrages, artificial groundwater recharge, increased winter irrigation, storage in the coastal lakes and staggering or eliminating the winter closure period, an option which is being tried this year.

However, all proposals do seem to have adverse impacts on water quality, fisheries, human activities and the environment in general. Detailed studies have to be carried out to determine these impacts which may lead to the discarding of some or all of the proposals. Currently, the Esna and Naga Hammadi barrages are being renewed, which will guarantee better control of the Nile levels in Upper and Middle Egypt. The extra releases of freshwater could therefore be reduced in the near future to an estimated 0.35 to 0.4 billion m^3/yr (figure 4).

3. *Municipal and industrial water demand*

(a) *Municipal water demand*

Municipal water requirements are being assessed all over Egypt. The requirements per governorate are estimated on the basis of three factors: population and population increase; consumption per capita (in litres per capita per day); and water distribution efficiency. In the recent past, municipal water demand did not play a major part relative to other water uses (in the order of 2.70 mm^3/yr with a net consumption of about 1.51 mm^3/yr), but it will require a considerable part of the national water resources in the future because of population growth as well as the rise in living standards, which generally increases per capita demand.

For planning purposes, future municipal demands are estimated by considering different permutations of the three principal factors given above.

(b) *Industrial water demand*

Industrial water demand also constitutes a considerable part of the total water demand in Egypt. The total demand was estimated at 5.89 billion m^3/yr with a net consumption of about 0.41 billion m^3/yr. Use of the return flow from industry is hampered by the low level of treatment and consequently low quality of the wastewater. Future industrial water requirements are estimated by taking into account planned growth rates of the different industrial subsectors, proposals to reduce water requirements by, for example, using sea water for cooling of new power stations, improvement of industrial processes and reuse of industrial wastewater.

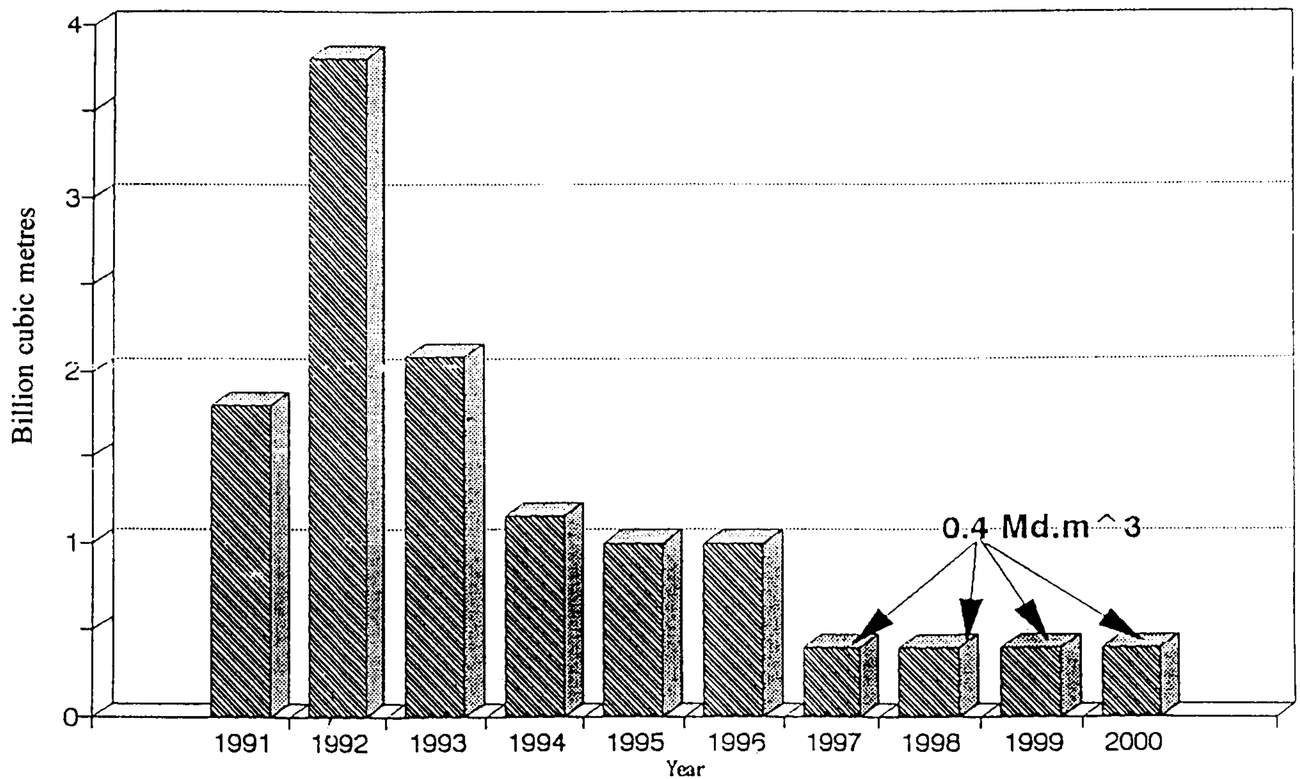
The analysis of future demands for municipal and industrial uses for the year 2000 is estimated at 1.0 billion m^3/yr and for the year 2025 at 6 billion m^3/yr.

The current figures on yearly demand are:

Agriculture for an area of 7.37 million feddans	54.5 billion m^3/year
Municipal	2.7 billion m^3/year
Industries	5.9 billion m^3/year
Total	63.1 billion m^3/year

It is obviously clear that Egypt's share in the Nile waters is completely exhausted.

Figure 4. Volume of freshwater annually spilled into the sea



C. Future conceived programmes

The features of the conceived programmes till the year 2000 are presented:

1. *Drainage reuse*

The potential of the drainage water which could be used was estimated at 7.5 billion m^3/yr with a reasonable water quality constraint, out of which 3.7 billion m^3/yr is being used. However, 3.8 billion m^3/yr are available to be reused.

2. *Groundwater*

The groundwater potential in the valley and delta was estimated at 7.5 billion m^3/yr as safe yield, out of which 4.1 billion m^3/yr is being used. Thus, the balance of 3.4 billion m^3/yr could be used.

3. *Irrigation improvement*

By improving irrigation projects' conveyance efficiency, and on-farm irrigation as well, studies have shown that 0.5 billion m^3/yr could be saved.

4. *Limitation of high-consumption crops*

Rice and sugar cane are considered very high consumers of water. It was noted that about 1.6 million feddans of these crops were cultivated rice recently. It is planned to reduce that area to 0.7 million feddans only. This reduction of area would save about 3.0 billion m^3/yr.

The estimates of the additional demand in the year 2000 are:

New land cultivation (1.6 million feddans) (infrastructures are being completed)	9.0 billion m^3/yr
Municipal and industrial uses	1.0 billion m^3/yr
Total	10.0 billion m^3/yr

5. *Estimation of the required additional water demand for the year 2025*

The additional demand up to the year 2025 could be stated in billion m^3/yr as follows:

New land cultivation (about 1 million feddans)	5.6 billion m^3/yr
Municipal and industrial uses	6.0 billion m^3/yr
Total	11.6 billion m^3/yr

The required resources, which could satisfy the above demand up to the year 2025, could be saved through better integrated management of existing water resources, i.e. reuse of drainage water, groundwater, reduction of municipal and industrial losses, reduction of high-water-consuming cropped areas as well as reduction of irrigation and drainage system losses.

D. Water master plan project

In the year 1977, the water master plan project was established. Through two phases, 30 technical reports were produced. The project was interested in collecting different relevant data: hydrological, meteorological, agricultural, municipal, industrial, economic, physical, quality, demographic and ecological data, as well as data on the irrigation and drainage and administrative systems. The project was also interested in designing an information database system where all irrigation, drainage, agriculture and economic data could be stored. Many mathematical models were developed: groundwater, Lake Nasser simulation, upper Nile, agro-economic, forecasting, dynamic policy, and operational distribution mathematical models.

Several studies were conducted in relevant fields, using the above data as a tool, and three alternative plans were formulated.

Table 2 lists all the technical reports published for the water master plan of Egypt. The project was terminated in 1990.

E. Achievements towards the implementation of recommendations of chapter 18-Agenda 21

1. *Institutional capacity-building*

Many water institutions were established in order to improve water policy and water management such as the National Water Research Centre, which was established in 1975 and involves the following research institutes:

Water Management Research Institute
Waterways Maintenance Research Institute
Drainage Research Institute
Groundwater Research Institute
Water Resources Development Research Institute
Nile Research Institute
Survey Research Institute
Hydraulics Research Institute
Construction Research Institute
Mechanical and Electrical Research Institute
Coastal Research Institute
Research Institute on Climatic Changes and their Impact on Water Resources.

TABLE 2. LIST OF TECHNICAL REPORTS PUBLISHED FOR THE WATER MASTER PLAN OF EGYPT

REPORT NO.	NAME
Technical report 1	Water planning: methods and three alternative plans
Technical report 2	Water demands
Technical report 3	Water supply
Technical report 4	Groundwater
Technical report 5	Regulation studies
Technical report 6	Projects information system
Technical report 7	Water quality
Technical report 8	The organization, administration, and legal framework for water planning
Technical report 9	Water and wastewater studies municipal and industrial sectors
Technical report 10	Industrial water use and wastewater production
Technical report 11	Water management capabilities of the alluvial aquifer system of the Nile Valley, Egypt.
Technical report 12	Sediment processes in the Nile River
Technical report 13	Fisheries, ecology, health and fish farming
Technical report 14	Hydrological simulation for Lake Nasser
Technical report 15	Mathematical model for the Upper Nile
Technical report 16	Agro-economic model
Technical report 17	Consumptive use of water by major field crops in Egypt
Technical report 18	Hydrological evaluation of environs of Lake Nasser
Technical report 19	Economic evaluation of land reclamation
Technical report 20	The irrigation system
Technical report 21	Multi-lead forecasting of River Nile streamflows

TABLE 2. *(continued)*

REPORT NO.	NAME
Technical report 22	Adaptive closed-loop operation of the High Aswan Dam
Technical report 23	Water resources planning guidelines
Technical report 24 (vol.I)	An economic evaluation of new lands projects in the national five plan (1982/1983-1986/1987)
Technical report 24 (vol.II)	Appendix 1: Shadow prices Appendix 2: Mechanization
Technical report 24 (vol.III)	Appendix 3: Crop patterns
Technical report 24 (vol.IV)	Appendix 4: Costs and benefit stream
Technical report 25	Nile River irrigation data collection system/background and feasibility
Technical report 26	The operational distribution model
Technical report 27	Vertical development of "Old Lands"
Technical report 28	Loss of agricultural land
Technical report 29	Detailed examination of existing land reclamation projects
Technical report 30 (vol. I)	Present and future operating scenario for the High Aswan Dam
Technical report 30 (vol. II)	Report appendices

The National Water Research Centre has 193 research Engineers, 50 of whom are Ph.D holders. The objectives of the National Water Research Centre are to outline and implement long-term policies for managing water resources in Egypt in order to cope with national demands, to solve the technical and applied problems associated with the general policy for irrigation and drainage, and to conduct investigations and research work connected with the extension of agricultural and land water resource assessment both surface water and groundwater.

The Ministry of Public Works and Water Resources in Egypt established an Information Centre which serves all its organizations and assists decision makers in making the right decision at the right time.

A National Training Centre within the Ministry of Public Works and Water Resources was established and is responsible for the development and strengthening of skills for the Ministry's staff in accordance with its policies. The training centre is located at 6 October City near Cairo and contains classrooms and laboratory facilities to accommodate over 2,500 trainees per year. It offers the most modern learning technologies and methods.

In addition to serving the manpower development needs of the Ministry of Public Works and Water Resources, the training centre offers its facilities and services to other ministries within Egypt and to government and private students from countries within the region. The new facility has a complete dormitory for 250 students and on-campus dining and recreation facilities. Training for outside agencies is offered on a tuition basis.

The Training Centre's objectives are:

(a) Training a cadre of senior supervisory executive and middle managers with comprehensive knowledge on how to plan and direct the Ministry's technical, financial and manpower resources;

(b) Training engineers and other professional staff of the Ministry for their present responsibilities and for future goals;

(c) Providing management and training resources for continuing professional self-development of engineers and other graduated staff;

(d) Creating and executing training programmes for para-professional personnel to develop in them the needed range of practical skills;

(e) Facilitating training opportunities for African, Arab and Mediterranean countries in the fields of irrigation, drainage, water resources development and management, according to their needs.

2. *Satisfying freshwater needs in line with sustainable development*

The implementation of this goal will involve the following:

(a) Construction of the Al-Salam canal, which will allow for cultivation of 600,000 feddans to help in producing food for the Egyptian population;

(b) Construction of the new navigation lock at the Naga Hammadi barrage, saving 1 billion m^3/yr, to be utilized in irrigation of new lands and in increasing efficiency of river transport;

(c) Construction of new pumping stations on the Al-Naser Canal to irrigate 130,000 feddans in the Nobaria area west of Alexandria;

(d) Construction of the New Esna barrage on the Nile River for providing efficiently the required irrigation water to the upstream canals and for power generation and improving navigation conditions on the Nile;

(e) Establishment of a telemetry system covering the length of the Nile River in Egypt and the irrigation and drainage networks. This system allows for best water control and management and facilitates communication between the Ministry of Public Works and Water Resources and its organization;

(f) Establishment of a Forecasting Centre at the Ministry's building which helps in estimating the Nile yearly flood in order to set future plans for water resources management;

(g) Establishment of a public awareness unit at the Ministry headquarters to promote public awareness of water quantity and quality issues and the importance of water for sustainable development;

(h) Widening of the Ismailia Canal to provide irrigation water or 900,000 feddans to be added to the cultivated area of Egypt;

(i) 200 deep wells, which have been dug to increase utilization of deep groundwater, expand the cultivated areas in the desert and increase the conjunctive use of surface water and groundwater;

(j) Construction of some small dams in Sinai to enable utilization of water from the flash-floods which sometimes occur in winter in order to provide drinking and irrigation water;

(k) Implementation of the National Irrigation Improvement Project which will decrease water losses through earth field ditches;

(l) Extending the tile drainage system to cover all old cultivated land. This system of drainage will help in increasing the productivity of the cultivated land and improve the soil structure;

(m) Using modern techniques for conducting an areal survey to assess land and water resources;

(n) Developing work plans for the various water-related issues, which allows for a systematic approach in resolving these issues, and preparing technical reports on planning and water-related issues;

(o) Improving and modernizing the present system by introducing several new and innovative measures and practices;

(p) Combining available technical data and suggesting the recording of additional data in order to carry out hydrological as well as operational studies;

(q) Improving the control of the Nile water for all uses and, particularly, its optimal allocation to and within agriculture as a means for helping increase agricultural production and productivity;

(r) Outlining and implementing long-term policies for managing water resources in Egypt in order to cope with national demands;

(s) Determining crop water requirements for different regions and studying evaporation and seepage losses from waterways, lakes and reservoirs;

(t) Developing and improving the design, planning and execution of drainage projects in Egypt and determining the drainage water quantities and qualities that can be reused for irrigating purposes;

(u) Protecting and maintaining the High Aswan Dam. Studying earthquakes' effects on the Dam, sedimentation in Lake Nasser, and earthquake activity and earth movement in the area around Lake Nasser. Protecting the critical areas along the Mediterranean, especially within the Delta area;

(v) Studying the operations of all types of pumps and conducting tests checking their safety range and calibration;

(w) Producing, maintaining and distributing current and accurate geographic data describing the Egyptian land mass, the cultural features thereon and its ownership.

3. *Towards protection of water resources, water quality and aquatic ecosystem*

This goal will involve the following:

(a) Establishing a monitoring network to cover the Nile River and its two branches within Egypt, Lake Nasser and also the drainage network as long as it is being used for irrigation;

(b) Starting a national project for preventing raw industrial waste from being discharged into the Nile or any other waterway. This is only allowed after preliminary treatment. Therefore, constriction of some treatment units at the different factories has been started and will continue;

(c) Investigating theoretically and experimentally the characteristics of sediment materials and the mechanics of its movement in the Nile River;

(d) Monitoring and evaluating the sedimentation in Lake Nasser and its effect on the reservoir storage capacity and the Aswan Dam's operation;

(e) Carrying out aquatic weed control manually, mechanically and biologically;

(f) Providing studies and recommendations to protect the heavily populated northern coast of Egypt, with its valuable agricultural establishment and infrastructure.

4. *Towards a safe drinking-water supply and sanitation*

A comprehensive plan was set up to provide all Egyptians, whether living in megacities, cities, or the countryside with drinking-water. This plan has been implemented. However, the treatment plants must be renovated and new ones constructed to cope with the rapid increase in public demand. The Ministry of Health is responsible for monitoring potable water quality, and it has a plan to ensure that the supply of potable water for drinking avoids any health risk for the nation.

F. CONCLUSIONS AND RECOMMENDATIONS

Water is a vital element and is the main element of sustainable development of all nations. Therefore, maintaining its quantity and its quality at an acceptable level is a must.

The water balance of Egypt, as shown above, will result in a deficit by the year 2025. This can be changed only if more water resources are developed and if the water quality of Nile waters, groundwater and drainage water is maintained at acceptable levels with no detrimental effect on the environment.

All the proposed plans relate to the reuse of drainage water and shallow groundwater and are necessary to secure the required water balance. In the meantime, progress in the implementation of National Irrigation Improvement is required not only to save water but also to increase the productivity of the cultivated land.

The strengthening of the telemetry system, a public awareness unit, and an information centre are all important.

The shortage of funds available for implementing the plans and projects, especially those projects related to water quality issues, should be overcome in view of the consequences for public health. This can be solved by increasing international participation in funding such plans and projects.

REFERENCES

M. A. Abu-Zeid, and M.A. Rady, 1991. Egypt's Water Resources Management and Policies in Egypt. Paper presented to a Policy Workshop on Comprehensive Water Resources Management, June 1991. Washington, D.C., World Bank.

———. 1992. Water Resources Management and Policies in Egypt. In: G Le Moigne et al. (eds.), "Country Experiences with Water Resource Management". Economic, Institutional, Technological and Environmental Issues. Washington, D.C., World Bank.

Attia, Bayoumi B., M. El-Moattasem, and G. Mahmood, 1990. Egypt's Water Balance for the Year 2000. In: "National Seminar on Physical Response of the River Nile to Interventions". El Qanater (NRI/SNC/NHC/ECG), 25 October 1990.

Planning Sector. 1994. Water Policy of the Egyptian Ministry of Public Works and Water Resources till the Year 2000. Cairo, Planning Sector, MPWWR, July 1994.

XIV. الورقة القطرية - جمهورية العراق(*)

إعداد
مؤيد جواد عبد الغني العبيدي

ألف- مقدمـــة

تقع جمهورية العراق ضمن المناطق الجافة وشبه الجافة، وتتراوح معدلات سقوط الأمطار فيها بين ١٢٧٠ ملم/سنويا في المناطق الشمالية الشرقية و ١٠٠ ملم/سنويا وأقل في المناطق الجنوبية والغربية من البلاد.

ان معدلات التبخر في العراق عالية وتزداد كمية التبخر خلال فصل الصيف لتصل الى حوالي (٥ر١) ملم/يوميا، أما الرياح السائدة فهي شمالية غربية.

ان معظم ترب العراق رسوبية وخاصة في المناطق الوسطى والجنوبية منه وتتراوح نسجتها من متوسطة قرب ضفاف الأنهر الى ناعمة في الأحواض والأراضي المنخفضة.

تتمثل الموارد المائية السطحية للعراق في نهر دجلة وروافده ونهر الفرات ويشترك في حوضي التغذية لهذين النهرين كل من تركيا والجمهورية العربية السورية وايران. يبلغ المعدل العام للايرادات المائية السنوية لحوض دجلة وروافده ٤٨ر٤٩ مليار متر مكعب، أما بالنسبة لحوض الفرات فإن معدل الايراد السنوي الطبيعي للعراق المسجل للفترة من ١٩٣٠-١٩٧٢ بلغ (٣ر٣٠) مليار متر مكعب سنويا وانخفض هذا الايراد خلال فترة إملاء سدي كيبان في تركيا والطبقة في الجمهورية العربية السورية الى (٩ر٢٣) مليار متر مكعب/سنويا للأعوام ١٩٧٤ ١٩٧٥ والى (٣٧ر١١) مليار متر مكعب خلال فترة إملاء سد أتاتورك في تركيا للأعوام ١٩٩٠ ١٩٩٣، علما بأن معدل ايراد نهر الفرات للفترة ما بين إملاء سدي كيبان والطبقة وإملاء سد أتاتورك قد بلغ (٤٠ر٢٧) مليار متر مكعب.

تتسم تصاريف نهري دجلة والفرات بتغيرات كبيرة على مدار السنة حيث تزداد التصاريف خلال مواسم الفيضان وتنخفض خلال مواسم الصيف وقد تم تسجيل حدوث أكثر من (٣٠) فيضانا كبيرا للفترة الممتدة بين القرن الثامن عشر والقرن العشرين، وسببت تلك الفيضانات أضراراً كبيرة بالأراضي الزراعية والمساكن والطرق في العراق.

بهدف السيطرة والتشغيل الأمثل للموارد المائية للعراق تم انشاء العديد من السدود والخزانات الكبرى والنواظم القاطعة الرئيسية ونواظم توزيع المياه ويتم وضع خطط سنوية للتشغيل تستند الى مؤشرات السنة المائية وتستهدف تخزين المياه اللازمة للايفاء بالاحتياجات المائية المختلفة على مدار السنة.

(*) صدرت كما وردت من الجهة المعنية.

باء- إدارة وتطوير الموارد المائية

تتولى وزارة الري في جمهورية العراق مهمة إدارة وتطوير وتنمية الموارد المائية وحصرها وتحديد مصادرها واستخداماتها وتشغيل وصيانة المشاريع الإروائية ووضع الخطط لدرء أخطار الفيضان ومواجهة مواسم الشحة في المياه، كما وتتولى الوزارة مهمة التخطيط الشامل للموارد المائية في القطر وانشاء السدود التخزينية والتحويلية ونواظم الضبط على الأنهر والروافد وانشاء المشاريع الاروائية وتنفيذ مشاريع استصلاح الأراضي وإدخال نظم الري الحديثة والمكننة وبما يؤمن استغلال وتطوير الموارد المائية واستخداماتها بشكل أمثل، ويتم اجراء دراسات الجدوى الفنية - الاقتصادية الخاصة بالمشاريع الاروائية وإعداد التصاميم ومستندات التنفيذ وتقييم المشاريع المنفذة ومن قِبَل المراكز الاستشارية والدوائر التابعة للوزارة.

يجري العمل حاليا باستكمال دراسة التخطيط الشامل للموارد المائية وتطوير الأراضي في العراق وتشمل دراسة الظروف الطبيعية من مناخ ومصادر مائية وظروف جيولوجية وهيدروجيولوجية وظروف استصلاح التربة ومصادر الأعشاب والعلف الطبيعي ودراسة الانتاج الزراعي الحالي وتطوير الزراعة على المدى البعيد ودراسة تجهيز الموارد المائية بضمنها دراسة الزراعة المروية وتجهيز المياه الى المدن والقصبات والصناعة وتجهيز المياه للزراعة ولأغراض الصرف الصحي وسقي المراعي والغابات ودراسة هندسة الطاقة وتجهيز الطاقة والنقل المائي وتطوير الثروة السمكية، كما وتشمل الدراسة السيطرة على الجريان في الأنهار واستخدام المياه والسيطرة على فيضانات نهري دجلة والفرات وخطط السيطرة المركزية على المشاريع المائية والاروائية بضمنها مشاريع الحفاظ على الموارد المائية وتدابير السيطرة على تعرية الأراضي والهياكل الخاصة بالانشاءات والاستثمارات المتعلقة بالموارد المائية.

إن الموارد المائية للعراق تتأثر بشكل كبير كمـًا ونوعاً بالمشاريع التخزينية والاروائية التي تقام في الدول المتشاطئة مع العراق وأية خطط مستقبلية لتطوير وتنمية هذه الموارد واستخداماتها لا يمكن ضمنا نجاحها دون توفير الحد الأدنى المقبول من المياه والذي يؤمن الاحتياجات المائية المختلفة لكلا الحوضين.

ان احتمالات نقص الموارد المائية الواصلة الى العراق ستزداد بعد استكمال المشاريع الاروائية المخطط تنفيذها في دول أعالي حوضي دجلة والفرات، كما وأن احتمالات تردي نوعيتها ستزداد هي الأخرى بسبب تلك المشاريع حيث تسعى تركيا والجمهورية العربية السورية الى استزراع أكثر من (٤٠ر٢) مليون هكتار من الأراضي في حوض الفرات وأكثر من (٩٥٠) ألف هكتار من الأراضي التي تروى من حوض دجلة.

ان عدم التوصل الى اتفاق حول قسمة المياه وتحديد حصة كل بلد من البلدان المشاركة في حوض دجلة والفرات يشكِّل عائقا يحول دون إقرار الخطط النهائية الخاصة بتنمية وتطوير الموارد المائية للعراق.

جيم- تقييم الموارد المائية

تعاني الدول النامية بوجه عام بضمنها العراق من العراقيل التي تضعها الدول المتقدمة بوجه عمليات نقل التكنولوجيا وعلى الأخص التكنولوجيات التي تتسم بتطورها من النواحي ذات

العلاقة بالبيئة أي تلك التي لا تنتج عنها ملوثات كبيرة وكذلك التكنولوجيات المتطورة لمعالجة هذه الملوثات بكلف مناسبة.

لقد لجأت العديد من الدول المتقدمة الى نقل الصناعات الملوثة للبيئة من أراضيها وإقامتها في أراضي الدول النامية كأسلوب من أساليب المنافسة الاقتصادية حيث أن تطبيق المحددات البيئية المعمول بها في الدول المتقدمة تضيف الى كلف الانتاج مصاريف باهظة تجعل من السلعة المنتجة غير منافسة في الأسواق العالمية.

بالاضافة الى ذلك فإن الدول المتقدمة تلجأ الى وضع صعوبات كبيرة أمام تمويل المشاريع الصناعية ذات التكنولوجيات الملائمة من الناحية البيئية عندما ترغب الدول النامية بإقامة مثل هذه المشاريع لديها كما وتعمل على رفع نسب الفائدة مما يرهق كاهل الدول النامية ويجعل كلف تلك المشاريع غير اقتصادية.

وبالنظر للطبيعة المتقدمة للتكنولوجيات ذات العلاقة فإن إدارتها وتشغيلها وصيانتها من قِبَل الدول النامية يعتبر معضلة كبيرة حيث تعاني تلك الدول من مشكلة توفير الخبراء لهذا الغرض وتفرض الدول المتقدمة شروط مجحفة لقاء توفير الخبرة اللازمة في مثل هذه المجالات ويشمل ذلك الأجور العالية ومزايا يصعب على الكثير من الدول تأمينها ويشمل ذلك المشاريع الجديدة والمشاريع القائمة التي تحتاج الى عمليات تطوير وتحسين.

وقدر تعلُّق الأمر بتقييم المواد المائية من النواحي البيئية فهناك بعض النقص لدى العراق في المستلزمات المطلوبة للتقييم والرصد المستمر للموارد المائية لتأمين انشاء نظم معلومات متكاملة تَسخَّر لأغراض تطوير برامج وسياسات إدارة المياه حيث تحول ظروف الحصار دون تحقيق التطوير المطلوب في هذا المجال.

ان العراق يسعى كهدف نهائي الى انشاء شبكة مراقبة تدار مركزيا للسيطرة على الموارد المائية للقطر، علما بأن الامكانيات المتاحة حاليا تؤمن قراءة مناسيب الخزانات وعدد من المواقع على الأنهر والروافد الرئيسية كما ويجري قياس تصاريف ونمذجة عدد من تلك المواقع دوريا .

دال- حماية الموارد المائية ونوعية المياه ونظم البيئة المائية والتطور المائي

بتسارع وتائر التنمية الاقتصادية والاجتماعية في العراق بعد ثورة تموز/يوليو ١٩٦٨ ودخول حلقات التصنيع الأساسية وزيادة التحضر خلال العقدين الماضيين برزت الحاجة الى تطوير السياسات التنموية التي تقي البيئة العراقية من التدهور وخاصة ما يتعلق بالموارد المائية.

إن إقرار أهمية الاعتبارات البيئية في خطط التنمية القومية برز بشكل واضح اعتبارا من خطة التنمية القومية للأعوام ١٩٧٦- ١٩٨٠ وما بعدها والتي أقرت مسألة العناية بحماية الصحة البشرية والثروة النباتية والحيوانية من أخطار تلوث البيئة الهوائية والمائية والتربة والتي أكدت أهمية إعداد دراسات تقدير حجم التلوث ومعدلات زيادته السنوية وتحديد أسبابه ومصادره

المختلفة وسُبُل معالجته، وقد عمَّقت خطط التنمية القومية اللاحقة مسألة الاهتمام بالجانب البيئي ضمن سياساتها وأُعتبرت حماية وتحسين البيئة وتطويرها والحفاظ على مقوماتها والعمل على منع تلوثها إحدى مهماتها الأساسية.

كنتيجة لهذه السياسات التنموية تم تحسين الظروف البيئية لكل من المناطق الحضرية والريفية في العراق حيث تم تغطيتها بالمياه الصالحة للشرب كما وأن تنظيم المدن والقصبات وفق أسس تخطيطية علمية لاستعمالات الأرض وتم تخصيص مواقع مناسبة من الناحية البيئية للطمر الصحي أُتبعت فيها الضوابط والشروط البيئية المناسبة، كما وأن سياسة الموقع الصناعي في العراق اعتبرت الجانب البيئي أحد الشروط الأساسية لقبول الموقع الصناعي واتخذت مجموعة من الاجراءات التي تضمن انشاء وحدات لمعالجة المياه المتخلفة والمرشحات في المصانع التي شُيِّدت في الفترات السابقة إلا أن استمرار الحصار الاقتصادي الجائر على العراق جعل إمكانية تحقيق هذا الهدف البيئي مستحيلاً لما يتطلبه من أجهزة ومعدات ومختبرات يجب توفيرها بالعملات الصعبة، إلا أن السعي بهذا المجال استمر بالنسبة للمشاريع التي أمكن تنفيذها بالامكانات المتاحة محليا فقد أقرت خطة التنمية القومية الأخيرة استكمال مشروع (المصب العام) لمياه البزل والمسمى بنهر صدام والذي تم انجازه في عام ١٩٩٢ وذلك لأهميته في تخليص مشاريع وسط وجنوب العراق من مياه البزل التي تؤدي الى تغدق الترب والتي كان يصرف معظمها الى الأنهار الرئيسية مسببا تردي نوعية مياهها.

لقد انعكس الاهتمام بالاعتبارات البيئية ضمن خطط التنمية القومية على تطوير أساليب دراسة وتقييم الأثر البيئي في دراسات الجدوى الفنية والاقتصادية لمختلف المشاريع الجديدة سواء كانت صناعية أو زراعية أو خدمية أو بُنى ارتكازية حيث لا يتم إقرار أي مشروع جديد ضمن الخطط الاستثمارية السنوية إلا بعد ثبوت جدواه الفنية والاقتصادية التي تجري وفق معايير تأخذ بنظر الاعتبار الأثر البيئي ومدى تأثير المشروع على تحسين أو تخريب البيئة المحيطة (مياه، هواء، تربة) واحتساب الكلف الاقتصادية والاجتماعية المترتبة على معالجة الأثر البيئي السلبي للمشروع وتأثير ذلك على مجمل الجدوى الفنية والاقتصادية للمشروع.

ان السياسات البيئية في العراق تؤكد على الاستغلال الأمثل والعقلاني للموارد الطبيعية وبما يؤمن تحقيق التنمية القومية المضطردة وعدم التخريب بالبيئة الطبيعية نتيجة لهذا الاستغلال باعتبار أن الموارد الطبيعية واستغلالها حق للجيل الحالي والأجيال القادمة، وتؤكد السياسات البيئية على معالجة المشاكل البيئية للمشاريع القائمة وتبني سياسات موقعية للمشاريع تنسجم مع المتطلبات والمحددات البيئية، كما وتهدف تلك السياسات الى زيادة الرقعة الخضراء والحد من عمليات الزحف الصحراوي والعمراني على الأراضي الزراعية والى الحد من مشكلة زيادة ملوحة تربة الأراضي الزراعية ومعالجة ملوحة مياه نهري دجلة والفرات والى التوسع في مشاريع معالجة المياه الثقيلة في المدن والقصبات العراقية.

ان تحقيق الاتساق بين السياسات التنموية والبيئية قد لا يكون بالشيء العسير إلا أن ترجمة هذه السياسات الى أهداف قد يولد نوع من التعارض بين الأهداف التنموية والبيئية حيث أن استمرارية الحفاظ على بيئة نظيفة ومقبولة مع تسارع معدلات التنمية القومية وخاصة في المجال الصناعي معناه صرف مبالغ استثمارية كبيرة تكون على حساب تحقيق معدلات تنموية اقتصادية معيَّنة على المدى القصير، وعليه لا بد من تحقيق درجة عالية من التنسيق بين

الأجهزة التخطيطية والأجهزة البيئية ولا بد من إصدار التشريعات الضرورية التي تحكم عملية الحفاظ على بيئة نظيفة ومقبولة، وفي العراق تم قطع خطوات جيدة على طريق تعميق التشريعات البيئية ودعم التنسيق المؤسسي بين الأجهزة التنموية والبيئية على المستويين المركزي، القطاعي والمكاني (المحافظات)، ففي مجال التشريعات البيئية صدرت العديد من القوانين والأنظمة والقرارات التي تنظم وتدعم العمل البيئي لضمان المراقبة والسيطرة على الملوثات الناجمة عن مختلف الأنشطة الاقتصادية والحضرية (الصناعية والزراعية والخدمية) ومن أبرزها قانون لحماية وتحسين البيئة ونظام لصيانة الأنهار والمياه العمومية من التلوث وضوابط ومحددات بيئية للمشاريع الصناعية والزراعية والخدمية تم بموجبها تصنيف الأنشطة حسب درجة تلويثها للعناصر الطبيعية (تربة وهواء ومياه). إضافة الى ما تقدم هناك بعض التشريعات والتعليمات البيئية التي تنظم حالات بيئية معينة كقانون منع الضوضاء ونظام الرقابة الصحية للمعامل ونظام تنظيف الطرق والتخلص من الفضلات ومواصفات للدفن الصحي للنفايات وقانون تنظيم استثمار المقالع.

في مجال التطوير والتكامل المؤسسي للأجهزة البيئية والتنموية تم تحقيق خطوات مهمة على طريق تحقيق التكامل والاتساق بين الأهداف البيئية والتنموية والقطاعية من خلال قنوات تتمثل بمجلس لحماية وتحسين البيئة ومجالس فرعية لحماية وتحسين البيئة في المحافظات ولجنة لتخصيص الأراضي لمشاريع الدولة ويتم من خلال الأجهزة التنسيقية العمل على تنسيق السياسات والاجراءات التنموية والبيئية، ولا بد هنا من الاشارة الى أنه وبعد تحويل العديد من الأنشطة المهمة في القطاعين الصناعي والزراعي الاشتراكي الى القطاع الخاص توسع وبشكل ملحوظ دور واهتمام القطاع بالجوانب البيئية، كما وجرى اهتمام بنشر التوعية البيئية بين مختلف شرائح المجتمع وعبر كافة وسائل الاعلام المتاحة.

هاء- المياه اللازمة لانتاج الغذاء والتنمية الوطنية

بهدف تأمين الغذاء وتحقيق تنمية زراعية قابلة للاستمرار وباعتبار أن القطاع الزراعي هو المستهلك الأول للمياه في العراق لذا يتم ايلاء موضوع إدارة موارد المياه وضمان كفاءة استخدامها أهمية كبيرة حيث جرى إدخال نظم الادارة المحسَّنة في تصميم شبكات الري والبزل وبنائها وتشغيلها وصيانتها بحيث يمكن استخدام موارد المياه بكفاءة عالية والمحافظة على انتاجية التربة على أسس قابلة للاستمرار وكذلك اعتماد طرق الري الحديثة كالري بالرش أو التنقيط والسعي لتقليل ضائعات النقل وفواقد التبخر.

لقد قطع العراق شوطاً كبيرا في إدارة المياه والسيطرة على الموارد المائية عن طريق انشاء السدود والخزانات ومنشآت السيطرة على مناسيب مياه الأنهر (كالسدات والنواظم)، كما وتم تحسين الشبكات الاروائية للمشاريع القائمة ويجري تطهير الأنهر والجداول سنويا ويتم العمل على تبطين قنوات الري واستصلاح الأراضي وانشاء شبكات البزل والمصبات الرئيسية لها.

ان تأمين المياه اللازمة للزراعة يجري وفق أسلوب تخزين سنوي في السدود والخزانات القائمة على نهر دجلة وروافده ونهر الفرات للوصول في نهاية موسم الخزن الى أقصى ما يمكن خزنه وفقا لمؤشرات السنة المائية ومتغيرات الظرف المناخي لتأمين المياه اللازمة للأغراض

المختلفة وعلى وجه الخصوص الزراعية منها، أما استعمالات المصادر المائية في الأنشطة الاقتصادية الوطنية الأخرى فإنها تعتمد بدرجة كبيرة على نوعية المياه.

ان التنمية الصناعية المكثَّفة والزيادة السكانية الكبيرة تؤدي الى زيادة في المياه المتخلفة عن النشاطات الصناعية والبلدية، كما وأن التطور الزراعي والتوسع في استعمال الأسمدة الكيماوية والمبيدات الخاصة بمكافحة الآفات الزراعية جميعها تؤثر على نوعية مياه المصادر المائية التي تصرف اليها تلك المخلفات وهذا يتطلب اجراءات للحد من تصريف المياه المتخلفة دون معالجتها وايجاد البدائل لتصريف مياه البزل بعيدا عن مياه الأنهار، وتحد الامكانيات المتاحة محليا من تطبيق التعليمات والضوابط التي تستهدف نظام رقابة صارم بهذا الصدد لعدم توفر الأجهزة اللازمة لمعالجة المياه المتخلفة عن تلك النشاطات، أما بالنسبة لمياه البزل فإن نهر صدام المنجز عام ١٩٩٢ يستهدف تخليص المصادر المائية في وسط وجنوب العراق من مياه البزل ويتطلب استكمال شبكات البزل وربط مصباتها به وهذا يصعب تنفيذه في الظروف الحالية للعراق بسبب ظروف الحصار. ان لنهر صدام فوائد بيئية عديدة حيث يتم من خلاله نقل مياه البزل من الأراضي المتملحة للمشاريع الاروائية الواقعة في سهل وادي الرافدين الى الخليج العربي وذلك بدلاً من تصريفها الى نهري دجلة والفرات وتلويث مياهها (حيث تقدر كمية الأملاح التي سيتم التخلص منها عن طريق المشروع بحوالي (٨٠ مليون طن/سنويا) والحفاظ على مياه النهرين بنوعية ملائمة صالحة للارواء وللاستخدامات البلدية والصناعية وغيرها. ان مجموع الأراضي التي يخدمها هذا النهر تقدر بحوالي (٥ر١) مليون هكتار حيث أن غسل الأملاح والاستصلاح في تلك الأراضي ونقلها خارج الأرض الزراعية يؤديان الى زيادة الانتاجية بدرجة كبيرة والمساهمة في الأمن الغذائي للسكان وتطويره. ولهذا النهر فوائد أخرى منها تطوير الثروة السمكية وتثبيت الكثبان الرملية في المناطق التي يمر فيها المشروع لايقاف الزحف الصحراوي على المشاريع الزراعية في وسط وجنوب العراق إضافة الى الاستفادة منه في النقل النهري وايجاد فرص عمل كثيرة للسكان وخلق تجمعات سكانية على طول المسار.
ان نهر صدام قد حسَّن جذريا مياه شط العرب التي تخدم مدينة البصرة وذلك بتقليص المياه الراجعة من المبازل فبدلاً من رميها في نهري دجلة والفرات اللذان يشكلان شط العرب أصبحت تذهب الى الخليج العربي مباشرة.

إن لإدارة الموارد المائية في العراق علاقة وثيقة بالظروف المناخية والعلاقات الزراعية التقليدية السائدة وطبيعة الأراضي حيث تتميز أراضي العراق بوجود تباين كبير فيما بينها من النواحي المتعلقة بخصائصها أو طبيعتها ومشاكلها وقابلياتها الانتاجية الزراعية كما وأن للثقافة الفلاحية أهمية في الالتزام بترشيد استعمال المياه ويتم بهذا الصدد تثقيف وإرشاد المستفيدين من المياه بأهميتها وضرورة ترشيدها.

تعد الموارد المائية الداخلية المتاحة في القطر المصدر الأساسي للانتاج السمكي، وقد قامت الجهات المختصة في العراق بانشاء ممرات للأسماك في المنشآت الهيدروليكية المقامة على مجاري المياه.

واو- التوصيات

١- قيام الدول المتقدمة باتاحة التقنيات المتطورة في النواحي البيئية والغاء كافة القيود والشروط والعقبات التي تضعها تلك الدول أمام الحصول على تلك التقنيات.

٢- اقتراح تشكيل صندوق دولي يُمول من قِبَل الدول المتقدمة لتقديم المساعدات للدول النامية في مجال الحصول على التكنولوجيا النظيفة من الناحية البيئية.

٣- تبسيط اجراءات الحصول على المساعدات الفنية والمادية من المنظمات الدولية ومنح الدول النامية فرص أكبر في مجال تطوير الكوادر العاملة في النشاطات البيئية.

٤- قيام دول أعالي الأنهر بمراقبة نوعية مياهها واتخاذ الاجراءات الكفيلة بالحد من تلويثها وبما يضمن ورود مياه ذات نوعية جيدة لدول أسفل أحواض الأنهر المتشاطئة معها، مع ضرورة توصل الدول المتشاطئة الى اتفاق حول قسمة عادلة للمياه تحدد بموجبها حصة كل من المياه (كماً ونوعاً) ليتسنى لكل بلد التخطيط بشكل واضح لتنمية وتطوير موارده المائية واتخاذ الاجراءات الكفيلة بالحفاظ على تلك الموارد.

XV. THE HASHEMITE KINGDOM OF JORDAN

by

*Boulos E. Kefaya**

Introduction

Jordan is a semi-arid land; 90% of the country receives annual rainfall of less than 200 mm per year. The population of Jordan was 4,095 million as of 1994, and the growth rate is 3.4% and falling continuously owing to higher education and family planning. The population is concentrated in the northern and western highlands, with about 75% in the Amman-Zarqa zone.

Jordan is one of the scarce-water-resources countries where the annual renewable water resources per capita is less than 200 cubic metres. The strain on water quantity is closely associated with the growing water quality problems, and the country's water resources are becoming more vulnerable to different sorts of pollution. Jordan currently faces water shortages, and the renewable water resources are not enough to satisfy the potential water demands. This serious gap is expected to widen in the near future, since there are no economically affordable solutions to close the gap.

The scarcity of water resources in Jordan contributes to the supply-driven management approaches, which aggravates the situation and causes damage to the environment. The main water-related problems in Jordan stem from water shortage and quality deterioration. The population expansion and the rapid development put high strains on the resources and the management tools, necessitating a restructuring of management practices, the legal framework, and the institutional set-up.

Jordan was among the first signatory countries of the Rio Declaration on Environment and Development, which approved Agenda 21. The main emphasis of Agenda 21 is to integrate environmental considerations into the development process to achieve a sustainable course of development. The hallmark of Rio is that it injected development into the environmental debate in terms of programmes: for sustainable agriculture, human settlement, cleaner production technologies and freshwater. Another characteristic of Agenda 21 is that it addresses the means of implementation. The two key issues are finance—providing assistance to developing countries to implement the commitments that were included in the Agenda—and technology transfer.

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Agenda 21 considered water resources as limited and as a fundamental part of all terrestrial ecosystems. These resources are not only very important in supporting all kinds of life on our planet, but for future prosperity and economic growth. The multisectoral nature of the resources created fierce competition among the different users to satisfy their demands in the face of ignorance of the needs of the ecosystem and the sustainability of the resources.

Agenda 21's view of water resources as a limited and scare commodity altered the old practices that had underestimated the resource for so long. The past perception of the abundancy of water resources contributed to mismanagement and severe consequences for the environment.

A. JORDAN'S WATER RESOURCES AND THEIR CURRENT MANAGEMENT

Water resources in Jordan are divided into conventional and non-conventional resources. The contribution of the non-conventional resources is considered minor in the overall water resources budget.

1. *Conventional water resources*

(a) *Surface water resources*

Surface water includes water that flows in rivers, water resulting from flood flows, and water from springs. The long-term average annual base flow is 328 MCM and flood flow is about 334 MCM. An estimated 555 MCM can be economically developed, yet the environmental impact of this exploitation of resources on the ecosystem has to be investigated. The Yarmouk Basin, the major tributary of the King Abdullah Canal, accounts for 40% of the total surface water in Jordan. The Canal is considered the backbone of development in the Jordan Valley. Other major basins include Zarqa, Jordan River side wadis, Mujib, Dead Sea, Hasa, and Wadi Araba.

(b) *Groundwater resources*

Jordan's groundwater is distributed among 12 basins. The groundwater is divided into renewable and non-renewable resources:

Renewable groundwater resources: In Jordan, the safe yield of renewable groundwater resources is estimated at 277 MCM/year (National Water Master Plan, 1977).

Non-renewable groundwater resources: In Jordan, the main non-renewable groundwater resource presently exploited is the Disi sandstone fossil aquifer in the south. It is estimated that the safe yield of this aquifer is 125 MCM/year over 100 years. Other non-renewable groundwater resources are found in the Jafer Basin in Shidiya, with an annual safe yield of 18 MCM.

2. *Non-conventional water resources*

These water supplies are developed in Jordan to satisfy the ever-increasing demands that could not be met by the traditional water resources (surface water and groundwater).

(a) *Treated domestic wastewater*

Currently Jordan utilizes about 56 MCM of treated wastewater annually. The reclaimed wastewater is projected to constitute a major part of the irrigation water in the Jordan Valley (237 MCM in the year 2020).

(b) *Potential desalination of brackish water*

Aquifers having brackish waters are as follows: Disi sandstone (2,712 MCM), Krnub sandstone (75 MCM), Amman Wadi Sir (104 MCM), Rijam (15 MCM) and Wadi Arab Alluvials (13 MCM). A total of 67 brackish springs have been identified; 64 are in the Jordan Valley, the Dead Sea and the Wadi Arab areas. The combined flow of these springs is estimated at 96 MCM/year.

The costs of desalting are considered the only constraint. This process should be further investigated and pilot plants should be built in the area for research purposes.

(c) *Water harvesting*

This is a small-scale method which involves collecting rain in water drainage areas, constructing dams, or collecting it from rooftops. Estimates of water contributing to the water budget is in the range of 10 MCM.

(d) *Groundwater recharge*

This practice could be utilized to enhance the groundwater reserves in the aquifers. The Ministry of Water and Irrigation has embarked on a comprehensive study in Amman-Zarqa Basin to study this option.

3. *Possibilities to use shared international water resources*

Jordan shares its main surface water resources in the north with its neighbours. The Yarmouk River is shared with the Syrian Arab Republic, where most of the catchment area is located. The Jordan River originates from Lebanon and flows to Lake Tiberias before most of its water is transferred for municipal and irrigation use via the Israeli National Water Carrier. Water quality has deteriorated in the Jordan River because of several factors. The irrigation and urban activities, diversion of saline springs into the river, and insufficiently treated wastewater discharged into the river are major problems preventing the utilization of the river flow for municipal and irrigation uses.

(a) *Consequences from the peace process*

In October 1994, Jordan and Israel signed the Peace Treaty agreement. The water issue was a principal subject of the provisions of the Treaty. Annex 2 of the Treaty puts forth regional schemes to be studied and investigated. An additional 215 MCM is expected to become available to Jordan as a result of this Treaty. Several storage dams on the Yarmouk and Jordan rivers will be constructed, and a desalination plant to treat 20 MCM of saline springs, currently diverted to the Jordan River, will be built to supply Jordan with 10 MCM of drinking water quality. Other regional arrangements were agreed on. This included storing water in Lake Tiberias in winter and supplying it to Jordan in summertime, and exploring new possibilities to supply Jordan with 50 MCM of potable water.

4. *Supply demand imbalance*

(a) *Sectoral demand analysis*

(i) *Municipal demand*

Municipal consumption accounted for about 21% (214 MCM) of the total water use in 1993. Average water consumption per capita is 145 litres, yet the demand cannot be met in most of the urban settlements in summer. The water consumption is rationed by a quota system, rotating supplies and intermittent pumping. This practice has several consequences: reduced quality with the potential risk of serious contamination; loss of metering accuracy; and loss of consumer confidence.

(ii) *Agricultural demand*

Agricultural crops are irrigated in the Jordan Valley and in the highlands. The agricultural sector accounts almost for 74% of the whole use in the Kingdom. The privately owned farms in the highlands are irrigated by groundwater from private wells. These farms use about 350 MCM of groundwater (renewable groundwater is about 277 MCM) for low-value crops. The estimated areas under irrigation in the highlands are 33,000 ha.

The publicly owned irrigation system in the Valley utilizes mainly surface water resources (Yarmouk River and the side wadis), and the effluent of the wastewater treatment plants (almost 300 MCM/yr). This irrigation scheme was developed by the Jordan Valley Authority (JVA), which still operates it. The main scheme was 26,000 ha; however, the 14-km extension of the King Abdallah Canal irrigates about 6,000 ha off the south valley north of the Dead Sea in winter only. In the southern Ghors, south of the Dead Sea, only 4,850 ha are under irrigation. The JVA is continuing with its ambitious programme to increase the efficiency of the conveyance and the distribution system, with growing conversion to pressure pipes.

(iii) *Industrial demand*

Industrial water uses were about 33 MCM, which accounted for only 4% of the total water use in 1993. Many industries install their own private wells to reduce costs and increase reliability. Some of these wells are metered and the Government charges 100 fils per cubic metre. The water price is too low to encourage the industries to initiate waste minimization programmes and utilize recycling opportunities.

(b) *Future potential water demands*

Projections of future water demands in different sectors are shown in the table below. These projections are based on municipal water consumption of 200 l/c/d, and a continuous decline in the population growth rate. The irrigation water demand projection is based on development of all possible projects. The table shows that the deficit in supply-demand is expected to increase in the future. Although analysis of several projection scenarios in different reports has shown various deficits, all scenarios agree, without exception, there is a serious gap and that a realistic solution to close it is not apparent.

WATER DEFICIT PROJECTIONS (MCM)

Year	Population	Potential municipal demand	Potential industrial demand	Potential agricultural demand	Total water demand	Available renewable resources	Expected water consumption	Water deficit
1993	3.98	292	42	900	1 234	725	983	251
1994	4.10	299	42	900	1 241	725	940	301
1995	4.24	310	50	950	1 310	800	1 000	310
2000	4.85	354	78	1 088	1 520	1 025	1 100	420
2005	5.70	416	96	1 088	1 600	1 200*	1 300	300
2010	6.50	474	119	1 088	1 681	1 280**	1 300	381

* Presuming that Jordan will utilize the agreed upon allocations of the Peace Treaty.
** If Jordan utilizes available renewable brackish water resources.

The imbalance in the supply-demand equation resulted from the demand growth in different sectors that cannot be supplied by the limited resources of renewable freshwater, and the industrial, and municipal sectors caused unprecedented strains on these limited resources. These sectoral development factors are among the factors contributed to the supply-demand imbalance in Jordan. Other factors are:

(a) High costs of new technologies to augment the freshwater resources;
(b) Rapid improvement in living standards and health conditions;
(c) Demand growth in different water-consuming sectors: agricultural; municipal; industrial; tourism; and physical and chemical requirements of the environment;
(d) Limited freshwater resources;
(e) Lack of water conservation techniques;
(f) Leakage in the water distribution and delivery systems;
(g) Incomplete wastewater management and reuse;
(h) Lack of public awareness programmes;
(i) Improper water pricing that reflects on the use efficiency of water consumption;
(j) Insufficient know-how within the institutions.

5. *Water quality issues*

In some cases, water supplies are becoming unusable. In the Dhuliel area, the salinization level increased from 300 ppm to 3,500 ppm, and the nitrate concentration increased to 70 ppm. In other cases, aquatic ecosystems are disappearing. The Azraq Oasis is a visible example of habitat loss for migratory birds of global significance. Salinity of irrigation water caused crop losses and affected the salinity of the soils. The marginal water used for irrigation caused waterlogging in some parts of the Jordan Valley, which necessitated installation of drainage systems to reduce soil salinity. Protecting existing resources from further degradation is as important as conservation and improving efficiency of water uses.

Water pollution sources:

Domestic wastewater pollution
Industrial wastewater
Municipal solid waste
Fertilizers and pesticides
Saline water intrusion/overpumping

Not only does the degradation of water quality have severe and negative effects on human health, as well as the physical and chemical parameters of the environment and the biodiversity of wild life, it also destroys expensive and scarce water resources and hence increases the gap in the imbalance of the supply-demand equation.

6. *Institutional and legal aspects of the water sector*

The main governmental organizations in the water sector are the Ministry of Water and Irrigation, the Water Authority of Jordan (WAJ) and the Jordan Valley Authority. These agencies are responsible for the planning of water resources, developing potential water resources in the Kingdom, increasing their capacity and improving their quality, protecting them from pollution, supervising them and administering their affairs and putting forth programmes and plans to meet future water needs. Other governmental agencies concerned with public health and environment and water-related issues (Ministry of Health and Ministry of Municipal, Rural and Environment Affairs, Ministry of Planning) also have supervisory roles.

(a) *Ministry of Water and Irrigation*

The Ministry was established under by-law No. 54 of 1992. It is responsible for the formulation and implementation of water and wastewater development programmes. Six Directorates were established in the Ministry. According to the by-law mandate, the Ministry's main functions are to formulate policy and strategy, plan water resources development, monitor water and wastewater, procure financial resources, conduct socio-economic studies, establish information systems, and implement human resources development and public awareness programmes. As the other ministry branches (WAJ, JVA) are empowered by laws and have strong institutions with specific job descriptions that carry out these functions and activities, the role of the Ministry has yet to be strengthened.

(b) *Water Authority of Jordan*

The WAJ is an autonomous corporate body with financial and administrative independence, and it has two principle functions: the provision of water and sewerage services; and water resources management. The WAJ is guided by a board of government and private sector representatives.

(c) *Jordan Valley Authority*

The same responsibilities are mandated to the Jordan Valley Authority in the Rift Valley. The Authority is managing the water resources and their uses in the Rift Valley, under article 2 of its by-law (19/1988).

(d) *The forthcoming General Environmental Protection Corporation*

Jordan's Environmental Act for the year 1995 is now being discussed in the Parliament to be approved this year (by September, it is hoped). This comprehensive environmental legislation aims at protecting the various elements of the environment by maintaining the natural environmental balance and achieving economical and social development.

Different articles of this Act dealt with water resources and their protection. The GEPC prepares the standards and specifications for water in cooperation with concerned institutions; monitors the water resources and their quality; controls and monitors the disposal of any solid, liquid, gaseous, radioactive or thermal pollutants in the water bodies; and sets the required guidelines for the preparation of the environmental impact assessment of the development projects.

(e) *Structural adjustment and policy support study*

A strong and coherent institutional framework is needed for the implementation of the proposed water management policies. Such a framework will consist of regulatory structures of governmental and public institutions, and all other pertinent elements. To ensure that institutional reform keeps pace with the requirements of the water sector, the Government of Jordan has initiated the above study in cooperation with the Canadian International Development Agency (CIDA). This study has presented proposals that would provide the water sector with the institutional structure to address the challenges that lie ahead.

The principles of the study are: strengthened policy development and water resources planning capabilities; separation of governance functions from service delivery functions; separation of wholesale operations (national infrastructure) from retail operations (service delivery); investment of capability to increase commercial orientation of operations; establishment of mechanisms to facilitate input to water policy from other institutions, the public and industry; and financial viability, which should be a major characteristic of the detail design.

B. Freshwater resources protection and management in Agenda 21

The Agenda focal items (programme areas) are:

1. Integrated water resources development and management.
2. Water resources assessment.
3. Protection of water resources, water quality and the aquatic ecosystem.
4. Drinking water supply and sanitation.
5. Water and sustainable urban development.
6. Water for sustainable food production and rural development.
7. Impact of climate change on water resources.

1. *Integrated water resources development and management*

The Agenda focuses on water resources as a vulnerable and finite resource. The management of this resource should integrate all the demand aspects of the resource, including quality, economic values, unity of the managing institutions and legal framework of the management. The holistic management of freshwater as a finite and vulnerable resource, and the integration of sectoral water plans and programmes within the framework of national economic and social policy, are of paramount importance for action in the 1990s and beyond. The fragmentation of responsibilities for water resources development among sectoral agencies is proving to be an even greater impediment to promoting integrated water management than had been anticipated. Effective implementation and coordination mechanisms are required. The Agenda focuses on water resources as a basic right of human beings, with the required quantity and quality needed for use and the safeguarding of the ecosystems. However, the use of water beyond basic needs should be economized.

Integrated water resources management, including the integration of land- and water-related aspects, should be carried out at the level of the catchment basin or sub-basin. Four principal objectives should be pursued, as follows:

(a) Promoting a dynamic, interactive, iterative and multisectoral approach to water resources management, including the identification and protection of potential sources of freshwater supply, that integrates technological, socio-economic, environmental and human health considerations;

(b) Planning for the sustainable and rational utilization, protection, conservation and management of water resources based on community needs and priorities within the framework of national economic development policy;

(c) Designing, implementing and evaluating projects and programmes that are both economically efficient and socially appropriate within clearly defined strategies, based on an approach of full public participation, including women, youth, indigenous peoples, and local communities, in water management policy-making and decision-making;

(d) Identifying and strengthening or developing, as required, in particular in developing countries, the appropriate institutional, legal and financial mechanisms to ensure that water policy and its implementation are a catalyst for sustainable social progress and economic growth.

In the case of transboundary water resources, there is a need for riparian States to formulate water resources strategies, prepare water resources action programmes and consider, where appropriate, the harmonization of those strategies and action programmes.

The targets set by the agenda are as follows:

(a) By the year 2000:

(i) To have designed and initiated costed and targeted national action programmes, and have put in place appropriate institutional structures and legal instruments;

(ii) To have established efficient water-use programmes to attain sustainable resource utilization patterns;

(b) By the year 2025:

To have achieved subsectoral targets of all freshwater programme areas.

2. *Water resources assessment*

The overall objective of ensuring the assessment and forecasting of the quantity and quality of water resources, in order to estimate the total quantity of water resources available and their future supply potential, to determine their current quality status, to predict possible conflicts between supply and demand and to provide a scientific database for rational water resources utilization.

Five specific objectives have been set accordingly, as follows:

(a) To make available to all countries water resources assessment technology that is appropriate to their needs, irrespective of their level of development, including methods for the impact assessment of climate change on freshwater;

(b) To have all countries, according to their financial means, allocate to water resources assessment financial resources in line with the economic and social needs for water resources data;

(c) To ensure that the assessment information is fully utilized in the development of water management policies;

(d) To have all countries establish the institutional arrangements needed to ensure the efficient collection, processing, storage, retrieval and dissemination to users of information about the quality and quantity of available water resources at the level of catchments and groundwater aquifers in an integrated manner;

(e) To have sufficient numbers of appropriately qualified and capable staff recruited and retained by water resources assessment agencies and provided with the training and retraining they will need to carry out their responsibilities successfully.

The following targets could be set:

(a) By the year 2000, to have studied in detail the feasibility of installing water resources assessment services;

(b) As a long-term target, to have fully operational services available based upon high-density hydrometric networks.

3. *Protection of water resources, water quality and aquatic ecosystem*

The complex interconnectedness of freshwater systems demands that freshwater management be holistic (taking a catchment management approach) and based on a balanced consideration of the needs of people and the environment. The Mar del Plata Action Plan has already recognized the intrinsic linkage between water resource development projects and their significant physical, chemical, biological, health and socio-economic repercussions. The overall environmental health objective was set as follows: "to evaluate the consequences which the various users of water have on the environment, to support measures aimed at controlling water-related diseases, and to protect ecosystems".

Three objectives will have to be pursued concurrently to integrate water-quality elements into water resource management:

(a) Maintenance of ecosystem integrity, according to a management principle of preserving aquatic ecosystems, including living resources, and of effectively protecting them from any form of degradation on a drainage basin basis;

(b) Public health protection, a task requiring not only the provision of safe drinking water but also the control of disease vectors in the aquatic environment;

(c) Human resources development, a key to capacity-building and a prerequisite for implementing water-quality management.

The following targets could be set:

(a) To identify the surface water and groundwater resources that could be developed for use on a sustainable basis and other major water-dependent resources and, simultaneously, to initiate programmes for the protection, conservation and rational use of these resources on a sustainable basis;

(b) To identify all potential sources of water supply and prepare outlines on water protection, conservation and rational use;

(c) To initiate effective water pollution prevention and control programmes, based on an appropriate mixture of pollution reduction-at-source strategies, environmental impact assessments and enforceable standards for major point-source discharges and high-risk non-point sources, commensurate with their socio-economic development;

(d) To participate, as far as appropriate, in international water-quality monitoring and management programmes such as the Global Water Quality Monitoring Programme (GEMS/WATER), the UNEP Environmentally Sound Management of Inland Waters (EMINWA), the FAO regional inland fishery bodies, and the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention);

(e) To reduce the prevalence of water-associated diseases, starting with the eradication of dracunculiasis (guinea worm disease) and onchocerciasis (river blindness) by the year 2000;

(f) To establish, according to capacities and needs, biological, health, physical and chemical quality criteria for all water bodies (surface water and groundwater), with a view to an ongoing improvement of water quality;

(g) To adopt an integrated approach to environmentally sustainable management of water resources, including the protection of aquatic ecosystems and living freshwater resources.

4. *Drinking-water supply and sanitation*

The New Delhi Statement (adopted at the Global Consultation on Safe Water and Sanitation for the 1990s, which was held in New Delhi from 10 to 14 September 1990) formalized the need to provide, on a sustainable basis, access to safe water in sufficient quantities and proper sanitation for all, emphasizing the "some for all rather than more for some" approach. Four guiding principles provide for the programme objectives:

(a) Protection of the environment and safeguarding of health through the integrated management of water resources and liquid and solid wastes;

(b) Institutional reforms promoting an integrated approach and including changes in procedures, attitudes and behaviour, and the full participation of women at all levels in sectoral institutions;

(c) Community management of services, backed by measures to strengthen local institutions in implementing and sustaining water and sanitation programmes;

(d) Sound financial practices, achieved through better management of existing assets, and widespread use of appropriate technologies.

Past experience has shown that specific targets should be set by each individual country. At the World Summit for Children, in September 1990, heads of State or Government called for both universal access to water supply and sanitation and the eradication of guinea worm disease by 1995. Even for the more realistic target of achieving full coverage in water supply by 2025, it is estimated that annual investments must reach double the current levels.

One realistic strategy to meet present and future needs, therefore, is to develop lower-cost but adequate services that can be implemented and sustained at the community level.

5. *Water and sustainable urban development*

The development objective of this programme is to support local and central Governments' efforts and capacities to sustain national development and productivity through environmentally sound management of water resources for urban use. To achieve this, it will be necessary to identify and implement strategies and actions to ensure the continued supply of affordable water for present and future needs and to reverse current trends of resource degradation and depletion.

The following targets could be set:

(a) By the year 2000, to have ensured that all urban residents have access to at least 40 litres per capita per day of safe water and that 75% of the urban population are provided with on-site or community facilities for sanitation;

(b) By the year 2000, to have established and applied quantitative and qualitative discharge standards for municipal and industrial effluent;

(c) By the year 2000, to have ensured that 75% of solid wastes generated in urban areas are collected and recycled or disposed of in an environmentally safe way.

6. *Water for sustainable food production and rural development*

The key strategic principles for holistic and integrated environmentally sound management of water resources in the rural context may be set forth as follows:

(a) Water should be regarded as a finite resource having an economic value with significant social and economic implications reflecting the importance of meeting basic needs;

(b) Local communities must participate in all phases of water management, ensuring the full involvement of women in view of their crucial role in the practical day-to-day supply, management and use of water;

(c) Water resource management must be developed within a comprehensive set of policies for (i) human health; (ii) food production, preservation and distribution; (iii) disaster mitigation plans; and (iv) environmental protection and conservation of the natural resource base;

(d) It is necessary to recognize and actively support the role of rural populations, with particular emphasis on women.

FAO global projections for irrigation, drainage and small-scale water programmes by the year 2000 for 130 developing countries are as follows: (a) 15.2 million ha of new irrigation development; (b) 12 million ha of improvement/modernization of existing schemes; (c) 7 million ha installed with drainage and water control facilities; and (d) 10 million ha of small-scale water programmes and conservation.

The development of new irrigation areas at the above-mentioned level may give rise to environmental concerns in so far as it implies the destruction of wetlands, water pollution, increased sedimentation and a reduction in biodiversity. Therefore, new irrigation schemes should be accompanied by an environmental impact assessment, depending upon the scale of the scheme, in case significant negative environmental impacts are expected.

When considering proposals for new irrigation schemes, consideration should also be given to a more rational exploitation, and an increase in the efficiency or productivity, of any existing schemes capable of serving the same localities. Technologies for new irrigation schemes should be thoroughly evaluated, including their potential conflicts with other land uses. The active involvement of water-users' groups is a supporting objective.

The objectives with regard to water management for livestock supply are twofold: provision of adequate amounts of drinking water and safeguarding of drinking water quality in accordance with the specific needs of different animal species. This entails maximum salinity tolerance levels and the absence of pathogenic organisms. No global targets can be set owing to large regional and intra-country variations.

7. *Impact of climate change on water resources*

The very nature of this topic calls first and foremost for more information about and greater understanding of the threat being faced. This topic may be translated into the following objectives, consistent with the United Nations Framework Convention on Climate Change:

(a) To understand and quantify the threat of the impact of climate change on freshwater resources;

(b) To facilitate the implementation of effective national countermeasures, as and when the threatening impact is seen as sufficiently confirmed to justify such action;

(c) To study the potential impact of climate change on areas prone to droughts and floods.

D. Water resources management in Jordan with respect to Agenda 21 programme areas

1. *Integrated water resources development and management*

In 1977 Jordan formulated the National Water Master Plan, which included costed and targeted national action plans and investment programmes, yet—and because of—the unprecedented demands on the resources and the fast-growing rates of the economic sectors, Jordan failed in implementing these actions. The fact that land use planning had not been integrated in the Master Plan made it difficult to implement. The Ministry of Water and Irrigation is currently updating the Master Plan, taking into consideration the environmental, social, economic and financial aspects within an integrated approach. The intention is to bridge the gap in the supply-demand equation with projects that are economically feasible, environmentally sound, and socially acceptable.

The demand-side management option is viewed as the most feasible solution to augment freshwater resources; moreover, it has environmental benefits (Win-Win solution). Jordan tries to pursue this option through reallocation of water among the different users, proper pricing mechanisms and structural adjustment programmes. In line with the side demand management, water conservation techniques in both the agricultural sector and the domestic sector were introduced. Priority will be given to modernizing and upgrading systems. Given its environmental benefits, wastewater treatment will be given high priority, and programmes will be developed to utilize treated wastewater in irrigation.

With the fast growth of population and rapid urbanization, domestic water demands are expected to rise sharply. Jordan's efforts to augment local freshwater resources are becoming very expensive, and the Government should consider the less costly demand management options. However, several options are to be investigated with regard to supply side management to develop new and alternative sources of water supply, such as sea water desalination, artificial groundwater recharge, use of marginal-quality water, wastewater reuse and water recycling.

In its structural adjustment and policy support study, the Government is currently evaluating its options, including decentralization of the services to local authorities, private enterprises and communities.

2. *Water resources assessment*

Jordan's acknowledgement of the scarcity of its water resources, and the high demands on this commodity, necessitated early assessment of water resources. Several institutions are involved in the data collection processes for different purposes. The coordination among these institutions to reduce the overlapping and optimize the efforts is prudent.

The Government will adopt the following specific policies and measures. They follow the same general order as the Five-Year Development Plan (1993-1997) and will as far as possible be implemented within the current plan period.

(a) Persisting in the assessment of water resources, the Government will:

(i) Continue the assessment and evaluation of the basic water resources, including the evaluation of the quantities and qualities of renewable and non-renewable surface water and groundwater resources;

(ii) Complete specific studies as follows: an assessment of the resources pertaining to fossil and brackish waters in the Kingdom, and the completion of ongoing (deep) groundwater surveys as a basis for developing comprehensive groundwater basin management plans;

(iii) Within the framework of proposed institutional reforms, water resources data collection and processing will be centralized;.

(b) Modernizing surface and groundwater monitoring systems, the Government will:

(i) Complete the installation (volumetric measurement facilities on all public and private wells and maintain a systematic record of all water pumped within the current Five-Year Plan period;

(ii) Create a network of observation wells and water quality monitoring.

Currently the review of the existing data-collection networks and the assessment of their adequacy is being carried out by the Ministry of Water and Irrigation. The aim is to improve networks to meet accepted guidelines for the provision of data on water quantity and quality for surface water and groundwater, as well as relevant land-use data.

The Ministry of Water and Irrigation is upgrading the facilities and procedures used to store, process and analyse hydrologic data and make such data and the forecasts derived from them available to potential users. In achieving this target the Ministry of Water and Irrigation aims at:

(a) Establishing databases on the availability of all types of hydrologic data at the national level;

(b) Identifying the need for water resources data for various planning purposes;

(c) Analysing and presenting data and information on water resources in the forms required for planning and management of the country's socio-economic development and for use in environmental protection strategies and in the design and operation of specific water-related projects.

3. *Protection of water resources, water quality and the aquatic ecosystem*

The Government's specific policies and measures with respect to protecting water resources from pollution are the following:

(a) To enact a comprehensive environmental protection law, consolidating related by-laws and regulations with a view to integrated environmental management;

(b) To create a comprehensive water quality monitoring system, consistent with the resource management and regulation;

(c) To enforce water quality standards on the effluent in respect of each industrial and commercial unit provided with a water use right.

The Directorate of Laboratories and Water Quality at the Ministry of Water and Irrigation initiated an environmental monitoring programme covering the whole country. According to the head of the Directorate, the quality of drinking water in the Kingdom is within Jordanian and WHO standards. Moreover, recent laboratory analysis showed that it is suitable for non-restricted irrigation.

The country has embarked on water rationing practices and the water is distributed according to a time schedule. This intermittent water distribution practice may have an effect on the water quality.

The Government has initiated several projects which will improve and conserve water in the Kingdom. An industrial pollution control programme covering 30 industries in the Amman-Zarqa basin was concluded in 1994. A water quality improvement and conservation project is currently ongoing. The four major components of the project—which include water resource monitoring and management, pollution prevention and cleanup, irrigation water management, and water management education—aim at conserving water and enhancing its quality for different uses. Moreover, several upgrading projects for some inefficient wastewater treatment plants are under way. Water distribution networks in some cities are also being rehabilitated.

The Jordan Environmental Act recently passed by the Parliament stressed water pollution prevention and control through several articles calling for:

(a) Application of the Polluter Pays Principle, where appropriate, to all kinds of sources, including on-site and off-site sanitation;

(b) Promotion of the construction of treatment facilities for domestic sewage and industrial effluents and the development of appropriate technologies;

(c) Establishment of standards for the discharge of effluents and for the receiving waters;

(d) Mandatory environmental impact assessment of all major water resource development projects potentially impairing water quality and aquatic ecosystems, combined with the delineation of appropriate remedial measures and a strengthened control of new industrial installations, solid waste landfills and infrastructure development projects.

NATURE RESERVES ESTABLISHED BY THE ROYAL SOCIETY FOR THE CONSERVATION OF NATURE

Name of reserve	Location	Year established	Area in dunums*	Annual rainfall (mm)
Wadi Rum	Aqaba	1989	560.00	50-100
Azraq Desert Reserve	Azraq	1987	320.00	50-100
Wadi Mujib	Madaba-Karak	1987	212.00	150
Dana	Tafila	1989	150.00	350
Shaumari	Azraq	1975	22.00	50-100
Zubia	Ajloun	1988	13.00	500
Azraq (wetland)	Azraq	1977	12.00	50-100

* One dunum = 1,000 square metres, or 0.1 hectare, or .247 acres

Since 1975, Jordan has established seven nature reserves under the management of the Royal Society for the Conservation of Nature, and seven more are planned. The establishment of grazing reserves also serves to protect ecosystems for overgrazing. Despite the establishment of nature reserves and grazing reserves, many habitats, animal and plant species are lost, degraded, or threatened because of wetland drying.

It is important to recognize the role of wildlife and plant genetic diversity in maintaining the development of new and improved varieties of crops best suited to the Jordanian environment.

The Azraq Oasis, which is listed by the Ramsar Convention as a wetland of international importance, is undergoing severe degradation owing to overpumping of the Azraq aquifer. Only two small pools remain of the original 7,400 ha of wetlands. The Dana wildlands, which encompass 150 square km in southern Jordan and are home to diverse ecosystems and habitats, are threatened by residential encroachment, grazing and uncontrolled hunting. Mining and ore processing in the vicinity also affect this valuable reserve.

4. *Drinking-water supply and sanitation*

About 97% of Jordan's population is served by drinking water supply systems, and almost 60% of the population is connected to the public sewage system. Jordan utilizes groundwater resources mainly for municipal purposes, and to some extent surface water from the Yarmouk River via the King Abdallah Canal.

Wastewater reuse as a growing source for irrigation in Jordan has received substantial attention. The Water Authority of Jordan is embarking on a very important programme to rehabilitate the operating wastewater treatment plants and construct new ones. This main objective of the programme is to protect the very limited and scarce freshwater resources and augment the water resources used for irrigation. This will alleviate the pressure on freshwater resources and allow for reallocation of higher use value.

The structural adjustment and policy support study recognized the importance of strengthening of the functioning of Governments in water resources management and, at the same time, giving full recognition to the role of local authorities. The study also calls for the encouragement of water development and management based on a participatory approach, involving users, planners and policy makers at all levels.

The Government specific policies in adopting this participatory approach and promoting public awareness of the importance of water conservation through:

(a) Undertaking systematic public education and awareness programmes, through academic institutions, multimedia approaches and other appropriate means;

(b) Involving stockholders in policy discussions at the various levels of government through public hearings, discussion meetings, committees and other participatory programmes.

5. *Water and sustainable urban development*

Over 77% of Jordan's population, or 3.2 million people, live in urban centres (communities larger than 5,000 inhabitants). The Municipality of Greater Amman alone accommodates more than 35% of Jordan's population, almost 1.5 million people. Annual growth of the urban population currently is about 4.3%, indicating further concentration of inhabitants in urban centres, when compared with the national population growth of 3.5% per year.

The negative effects of urban and industrial development are likely to increase with increasing urbanization and industrialization, unless pollution control and prevention measures are taken. Our concern here is restricted to wastewater treatment, industrial wastewater and municipal solid wastewater.

The environmental problems of sewage disposal are of concern to the Government. It is hoped that by the year 2020 efficient sewage systems with proper sewage treatment plants will be available to two thirds of the population.

To replace the use of septic tanks, the Water Authority of Jordan is currently implementing various wastewater projects for the main towns. By 1994, more than 25% of all households across Jordan were connected to wastewater systems (serving 60% of the total population). Among the new projects planned for 1995-2000, for which funds have to be allocated, are wastewater networks and plants for South Amman, Aqaba, Baqa'a and Moa'ta.

A very high percentage of Jordan's population live in the urban centres. The urban-related environmental problems cut across several water resources management issues, such as:

(a) The introduction of sanitary waste disposal facilities based on environmentally sound low-cost and upgradable technologies;

(b) Implementation of urban storm-water run-off and drainage programmes;

(c) Promotion of recycling and reuse of wastewater and solid wastes;

(d) Control of industrial pollution sources to protect water resources;

(e) Protection of watersheds with respect to depletion and degradation of their forest cover and from harmful upstream activities;

The water resources in the main urban centres (Amman, Zarqa and Irbid) are exploited and were not able to meet the growing demands, which forced the

Government to implement the costly water conveyance projects to transfer water. Reconciliation of city development planning with the availability and sustainability of water resources should be optimized to satisfy the basic water needs of the urban population.

Initiation of public awareness campaigns to encourage the public's move towards rational water utilization is a very important tool in water conservation and efficient use of expensive and scarce resources, yet proper water tariffs to limit water wastage and improve health conditions have to be set.

The Government's specific water policies to improve the efficiency of water carrying systems and reduce losses are:

(a) Progressively to integrate the management of storage and primary water delivery systems so as to optimize the management of the total resources in a flexible and efficient manner;

(b) To prepare systematic water audits and master plans for municipal systems, and upgrade and develop municipal networks to minimize unaccounted for water and to improve and extend the water delivery service in an efficient manner.

In its attempts to adopt a progressive pricing system to secure the financial viability of water delivery agencies, the Government will:

(a) Enhance the existing block tariff system in urban areas so as to cover the O&M (operation and maintenance) costs of delivering municipal water services;

(b) Regulate private water deliveries in urban areas consistent with resource management objectives and regulation of the quality of water used for drinking and domestic uses.

6. *Water for sustainable food production and rural development*

Jordan was known as an agricultural country, but in recent decades the value of the agricultural contribution to the national income and also a source of employment has considerably declined. Agricultural output is only 7%-8% of the national income and it only employs 10% of labour, most of them expatriates. Still agriculture with its limited economical contribution is drawing almost three quarters of Jordan's water. The competition among the different water users (agriculture, industry and municipal) will continue to be a major challenge to Jordan's planners and decision makers.

The wastewater reuse programmes initiated by the Government will ease the stresses on the freshwater resources to be reallocated to higher value consuming sectors. This effort should be supported to ensure the optimum environmental benefits of these projects.

The potential for utilizing brackish water resources for agricultural use should be further assessed and studied to support the appropriate use of relatively brackish water for irrigation.

The Jordan Valley Authority acknowledged the pressing need to raise efficiency in the irrigation system in the Jordan Valley, and introduced some water-saving practices at the user level. The Government's specific policies in this regard are:

(a) Encouraging cropping patterns that provide a high return on water, or which can make use of brackish water and/or treated wastewater, taking into account other constraints (soils, input costs and marketing);

(b) Promoting modern irrigation techniques that achieve water savings on-farm while optimizing crop returns and farm incomes.

7. *Impact of climate change on water resources*

Air pollution—as well as Jordan's contribution to world emissions causing the greenhouse effect and global warming—is minimal. It is estimated that 12 million tons of gaseous fumes are produced by the power plants. An average of 575 tons/annum of chlorofluorocarbons are imported, of which 200 tons are re-exported in industrial products. This would amount to about 0.05% of total world consumption. As global warming scenarios for the next 50 years have been predicting a rise in global temperatures, this would result in a decrease in rainfall in Jordan, with a disastrous impact on agriculture and water resources.

In the longer term Jordan is likely to be confronted by a severe shortage of the most basic of natural resources, water, which could be overcome to some extent through increased regional cooperation. Jordan's environmental problems and issues are dominated by the critical need to manage the scarce common resources of water and cultivable land more effectively to meet the growing needs of a population. A rise in global temperatures due to the predicted climate change would result in a decrease in rainfall, with a disastrous impact on agriculture and water resources for Jordan which would also be experiencing demographic pressures. These factors make Jordan very vulnerable to the impact of potential future climate change. As a result, there is an imperative need for Jordan to develop new policies or adapt existing policies of social and economic development that take into accout the potential impact of climate change.

At present there is a limited database on the sources of Greenhouse Gas (GHG) emissions in the Hashemite Kingdom of Jordan and the potential options to reduce or control these emissions. The current greenhouse gas emissions in Jordan are estimated to be equivalent to over 1 million tons of carbon dioxide per year, but no thorough study has been undertaken to estimate the emissions by source. Similarly, no inventory of the sinks has been prepared. In short, the country capacity to develop adequately and assess the data needs that are mandated by the Convention on Climate Change urgently needs to be built up.

A new project will be undertaken on building capacity in the Hashemite Kingdom of Jordan to respond to the challenges and opportunities created by the national response to the Framework Convention on Climate Change and will be funded under the Global Environment Facility.

This project will provide technical assistance and build capacity in Jordan to assist in climate change mitigation and adaptation through the advancement of national priorities in areas such as energy efficiency, fuel substitution, renewable energy development, and forest conservation and management. At the same time, local capacity to respond to the Framework Convention on Climate Change will be promoted through the promotion of inventory assessments, establishment of policy dialogues, evaluation of technological options, investigation of climate change impact, and analysis of adaptation opportunities identified and developed through this project. The project will actively collaborate and learn from experiences of other projects in the Maghreb, Africa and beyond.

XVI. الورقة القطرية - الجمهورية اللبنانية(*)

إعداد
بسام أديب جابر(**)

مقدمــــة

"لبنان خزّان ماء الشرق الأوسط" مقولة سرت في كافة المجتمعات العالمية وأصبحت أشبه بالمسلمات حتى أن "جويس ستار" (Joyce Star) صاحبة المؤسسة الأمريكية التي نظمت في السابق مؤتمر "قمة مياه افريقيا" وسعت الى إقامة "قمة مياه الشرق الأوسط" في اسطنبول في تشرين الثاني/نوفمبر ١٩٩٢ الذي أُلغي فيما بعد، كتبت في مقال لها حول "حروب المياه" (Water Wars) ما معناه "أما بالنسبة للبنان فلديه فائض من المياه ينبغي تقاسمه".

وفي إحدى الندوات في الخليج العربي أطلق بعضهم شعار أن في لبنان فائض من المياه يمكن أن يصدره مدعين أن المياه هي بترول لبنان ويمكن بيعها على أساس دولار واحد للمتر المكعب الواحد من المياه متناسين حاجات لبنان في الحقبة الآتية التي بدأت تشهد تنمية متزايدة بعد أن تجمَّد الوضع لا بل تقهقر في سنوات الحرب.

وسنحاول في بحثنا هذا بيان كميات المياه اللبنانية وما هي الكميات المتاحة التي يمكن الاعتماد عليها في التخطيط لاستغلالها حالياً ومستقبلياً وبيان الحاجات واستخلاص الميزانية وما إذا كان هناك ما يفيض عن الحاجات المذكورة أم لا؟ كما سنبين ما هي المشاكل التي يعاني منها وكيف تجري معالجتها.

الجزء الأول
التوازن المائي - هل هناك فائض؟

١- <u>تعريف المياه المتاحة</u>

المياه المتاحة هي تلك التي يمكن السيطرة عليها حالياً ومستقبلياً لاستغلالها في مشاريع التنمية.

٢- <u>الموارد المائية في لبنان</u>

٢-١ <u>مصادر المياه</u>

ان المصدر الأساسي للموارد المائية في لبنان هي الأمطار بالدرجة الأولى وغيرها من الهواطل بالدرجة الثانية كالثلوج والندى الخ...

(*) صدرت كما وردت من الجهة المعنية.

(**) مدير عام، دائرة التجهيز والاستثمار، وزارة الموارد المائية والكهربائية، بيروت، الجمهورية اللبنانية.

٢-٢ رصد الأمطار والثلوج

من المعروف أن الهواطل من أمطار وثلوج وغيرها تقاس بواسطة آلات بسيطة تجمع المياه المتساقطة في أوعية معروفة مساحتها اللاقطة ومرقمة بشكل يسمح بقياس كميات مياه الأمطار أو الثلوج.

وقد ركبت هذه الآلات في مواقع عدة وأُنشئت محطات كانت أولاها في الجامعة الأمريكية في بيروت في الربع الأخير من القرن التاسع عشر وتلتها محطة كسارة (البقاع) التابعة آنذاك لجامعة القديس يوسف المعروفة بالجامعة اليسوعية في أوائل هذا القرن. وبعد ذلك تكاثرت محطات رصد الأمطار حتى شكلت شبكة متكاملة تؤخذ فيها قياسات الأمطار يوميا وحتى مرتين في الأربع والعشرين ساعة في فصل الشتاء.

وصل عدد محطات رصد الأمطار في أوائل السبعينات الى ١٤٣ محطة وثلاث وأربعون محطة أي واحدة لكل ٧٣ كلم٢ وسمحت الكيول والقياسات المأخوذة فيها بوضع آخر خريطة مطرية للبنان سنة ١٩٧٠ وهي الخريطة التي نظّمها الأب بلاسار اليسوعي.

تجدر الاشارة الى أن أكثر هذه المحطات قد تعطّل أثناء الأحداث ولم يبقَ منها ما يزيد عن ١٠ في المائة قيد العمل والدوائر المختصة قد وضعت برنامجاً لإعادة تأهيلها في إطار سعيها الحثيث نحو تأمين المعطيات الأساسية التي بدونها لا يمكن البحث بأية دراسة بالمعنى الصحيح في مجال المياه.

أما المحطات المناخية فقد بلغ عددها ٦ في سنة ١٩٧٤ ولم يبقَ منها سوى ٢ في الوقت الحاضر وهما محطة الجامعة الأمريكية في بيروتٍ ومحطة مطار بيروت الدولي، وتسعى الحكومة اللبنانية حالياً لإعادة إنشائها كما ذكرنا سابقاً.

واستنادا الى الكيول والقياسات المأخوذة في مختلف المحطات المذكورة آنفاً أمكن وضع الخريطة المطرية للبنان وأحدثها تلك التي ذكرنا أن الأب بلاسار اليسوعي قد نظمها سنة ١٩٧٠ وهي الرابعة تاريخيا في هذا المضمار إذ سبقتها ثلاث خرائط نذكرها بالتسلسل:

- الخريطة الأولى التي تعود لسنة ١٩٤٣ للأب كومبيير بمقياس ٠٠٠ ٠٠٠ ١/١؛

- الخريطة الثانية وتعود لسنة ١٩٤٨ وقد نظّمها الخبير الفرنسي دوبرتريه بمقياس ٠٠٠ ٠٠٠ ١/٢ وتضم الجمهورية العربية السورية والأردن وفلسطين؛

- الخريطة الثالثة وتعود لسنةٍ ١٩٥٥ وقد نظّمها الأب راي اليسوعي بمقياس ٠٠٠ ٠٠٠ ١/٢ مع كرّاس يفسر بعض المعطيات ويستخلص بعض النتائج؛

- الخريطة الرابعة وهي الأخيرة سنة ١٩٧٠ للأب بلاسار اليسوعي، كما سبق أن ذكرنا، بمقياس ٠٠٠ ١/٢٠٠ وقد أرفق بها كتيِّب يبين المنهجية المتبعة لإستثمار المعطيات والكيول في وضع هذه الخريطة.

ولا بد من الإشارة هنا الى أن الهواطل ترتبط إرتباطاً وثيقاً بالوضع الجغرافي والطوبوغرافي كما ترتبط بالوضع المناخي وأن الهيدرولوجيا اللبنانية ككل هيدرولوجيا تتأثر تأثرا كبيرا بالحرارة والرطوبة النسبية وجيولوجية المنطقة.

فلبنان يقع الى الشرق من البحر الأبيض المتوسط وتبلغ مساحته حوالي عشرة آلاف كليومتر مربع، شكله العام مستطيل طوله ٢٥٠ كلم تقريباً وعرضه لا يزيد عن ٥٠ كلم أما مورفولوجيته فيمكن تقسيمها الى أربعة مناطق:

١- شريط سهلي ساحلي ضيق يتسع في بعض المناطق كعكّار في الشمال وسهول طرابلس والدامور وصيدا وصور.

٢- سلسلة جبال لبنان الغربية الموازية للشريط الساحلي وهي ترتفع في الشمال حتى تصل الى ما يقارب ٣٠٠٠ متر عن سطح البحر ويقل ارتفاعها تدريجيا من الشمال الى الجنوب حيث تصل الى سبعمائة أو ثمانمائة متر فوق سطح البحر.

٣- سهل البقاع الذي يفصل سلسلة جبال لبنان الغربية عن سلسلة جبال لبنان الشرقية ومتوسط ارتفاعه هو بحدود التسعمائة متراً .

٤- سلسلة لبنان الشرقية الموازية للسلسلة الغربية الآنفة الذكر وهي ترتفع في الشمال حتى تصل الى ٢٦٠٠ متر في الشمال (جبل موسى) ثم يقل ارتفاعها تدريجيا في الوسط ليعود الى الارتفاع في الجنوب (جبل الشيخ) ٢٨٠٠ متر تقريباً .

أما المناخ فهو مناخ متوسطي معتدل أقرب ما يكون الى المناخ الجاف ويمتاز بأمطار غزيرة في فصل الشتاء القصير وبطقس مشمس وجاف في باقي أيام السنة.

فالأمطار تهطل في خلال ثمانين أو تسعين يوماً في السنة بين تشرين الأول/أكتوبر ونيسان/ابريل بينما فصل الصيف طويل مع ربيع وخريف قصيرين نسبيا ، وأن وضع لبنان الى الشرق من البحر المتوسط كما ذكرنا أعلاه يضفي على مناخ لبنان خصوصيته، فالرياح الغربية الآتية من جهة البحر والمشبعة بالرطوبة تصطدم بسلسلة جبال لبنان الغربية حيث تفقد رطوبتها بشكل هواطل عند ارتفاعها فوق السفوح الغربية وتخف هذه الأمطار بعد مرورها فوق السلسلة المذكورة وانحدارها نحو البقاع ثم تعود للإرتفاع فوق السلسلة الغربية مما يجعل مناخ البقاع والسلسلة الغربية مناخاً قارياً أقرب ما يكون الى الجفاف.

والهواطل على القمم تصبح ثلوجاً تغطيها وتذوب تدريجياً مع الفصل الحار فتغذي الخزانات الجوفية لتعود فتظهر بعضها ينابيع في المناطق الدنيا أو تسيل في المجاري والوديان أنهاراً وسواقي.

أما الحرارة فتسجل أدنى مستوياتها في شهري الشتاء كانون الأول/ديسمبر وكانون الثاني/يناير بينما أعلاها يسجل حوالي شهري تموز/يوليو وآب/أغسطس من السنة ومتوسطات

الحرارة في بيروت هي بحدود ٧ درجات في الشتاء و ٢٧ درجة مئوية في الصيف بينما هي في كسارة (البقاع) ٥ر٥ درجة مئوية في الشتاء و ٢٤ درجة في الصيف.

أما التبخر فهو يتأثر بعدة عوامل كالحرارة ورطوبة الجو والتشمس وسرعة الرياح ونسبة أعلى في البقاع حيث يبلغ حوالي ١٧٦٠ ملم سنوياً منه على الساحل حيث يبلغ ١٣٤٠ ملم سنوياً في بيروت، أما الرطوبة النسبية فهي عالية على الساحل والسفوح الغربية المواجهة للبحر دون تغيرات كبرى حيث تتراوح بين ٦٤ في المائة في تشرين الثاني/نوفمبر و ٧٣ في المائة في آب/أغسطس بينما هناك تغيرات ملحوظة في نسبة الرطوبة في الداخل حيث تصل الى ٦٧ في المائة في فصل الشتاء الرطب (كانون الثاني/يناير) وتهبط الى ٤٤ في المائة في فصل الصيف الجاف. وقد أثبتت التسجيلات أن معدل الساعات المشمسة سنوياً تبلغ حوالي ٣٢٠٠ ساعة في السنة.

٢-٣ <u>كمية المياه الهاطلة أو المتساقطة</u>

من مراجعة الخريطة المطرية للبنان ومجموعات الكيول يتبين أن المياه الهاطلة أو المتساقطة متفاوتة التوزيع في المكان والزمان.

ففي المكان يكفي أن نتذكر ما أورد المهندس جعفر شرف الدين وزير الموارد المائية والكهربائية سنة ١٩٧١ في كراسه المعنون "الوضع المائي في لبنان والسياسة الواجب اتباعها في استثمار المرافق المائية".

"ان منطقة السفوح الغربية، هي أغنى منطقة بالمياه في لبنان، غير أن نسبة المياه فيها تختلف من الشمال الى الجنوب، وذلك نتيجة لتكوين السلسلة الغربية الطبيعية التي تشكل حاجزاً بالنسبة للرطوبة المتأتية من البحر الأبيض المتوسط. ان هذا الحاجز من الجبال هو أكثر ارتفاعاً في القسم الشمالي (٣٠٨٠م) منه في القسم الجنوبي من السلسلة الغربية حيث يتراوح بين ٥٥٠م و ٨٥٠م، وهذا الارتفاع لا يشكل حاجزاً كافياً لمنع الرطوبة من التسرب الى الداخل كما هو الحال في القسم الشمالي من السلسلة، مما يقلل من نسبة الأمطار على الساحل ويرفع من نسبتها في الداخل. أضف الى ذلك أن الثلوج في منطقة الجنوب نادرة جداً بسبب الارتفاعات القليلة في هذه المنطقة.

تختلف نسبة الأمطار في الجنوب مع الارتفاع عن سطح البحر، ويكون معدل هذه النسبة:

- ٦٦٠ ملم سنوياً على ارتفاع ٣٠م
- ٧٥٠ ملم سنوياً على ارتفاع ٣٨٠م
- ٧١٥ ملم سنوياً على ارتفاع ٧٦٥م

بينما يتراوح معدل الأمطار في المنطقتين الشمالية والوسطى بين ٧٠٠ ملم سنوياً على الشاطىء و ١٣٠٠ ملم اعتبارا من الارتفاع ١١٠٠م عن سطح البحر.

أما في البقاع فإن كمية الأمطار تتناقص من الجنوب الى الشمال إذ تبلغ ٨٠٠ ملم في القرعون (البقاع الجنوبي) وتصبح ٦٠٠ ملم في رياق (البقاع الأوسط) و ٤٠٠ ملم في بعلبك وتهبط الى ٢٥٠ ملم في الهرمل (البقاع الشمالي).

وهكذا يتبين أن كميات الأمطار هي بحدود ٢٥٠ملم في شمال البقاع ويرتفع معدلها الى ٢٠٠٠ ملم في أعالي جبال لبنان.

أما في الزمان فإن المناخ المتوسطي الذي يمتاز بفصل شتاء ممطر وثلاثة فصول جافة في السنة فإنه المسيطر على الأراضي اللبنانية حيث المطر يهطل لمدة ثمانين أو تسعين يوماً في السنة، كما سبق أن ذكرنا، بينما يغلب الجفاف على بقية أيام السنة.

أضف الى ذلك أن المعدل السنوي يمكن أن ينخفض في سنة جافة (٧٢-٧٣ مثلاً) الى ما يقارب ٥٥ في المائة من المعدل السنوي لسنة متوسطة المطر.

سنة ممطرة		سنة جافة	
٩٢٢ ملم	الى	٥٢٢ ملم	حسب مرصد الجامعة الأمريكية في بيروت
٦٧١ ملم	الى	٣٧٠ ملم	حسب محطة كسارة
٣٨٠ ملم	الى	٢١٦ ملم	حسب محطة بعلبك

أما متوسط المطر السنوي فهو يختلف من مرجع لآخر وهو يعود لأسباب عدة أهمها اختلاف عدد السنوات المعتمد لاحتساب هذا المتوسط ويكفي أن نذكر ما أورده المهندس سعد الدين مدلل في مقاله "الثروة المائية في لبنان" المنشور في مجلة العلم والتكنولوجيا في عددها الصادر في تموز/يوليو ١٩٨٩.

فقط وضعت الجامعة الأمريكية في بيروت متوسطات لهطول الأمطار لكل ثلاثين سنة فكان التباين في النتائج كبيرا في متوسط المطر.

- للفترة بين ١٨٩٠ و ١٩٢٠ هو ٩٢٦ ملم.
- للفترة بين ١٩١٣ و ١٩٤٢ هو ٨١٩ ملم.
- للفترة بين ١٩٣٠ و ١٩٦٠ هو ٨٦٩ ملم.

ويتبين أن المتوسط يتراوح

- بين ٨٧٩ ملم للفترة من ١٨٨٤ الى ١٩٦٣.
- بين ٨٩١ ملم للفترة من ١٨٨٤ الى ١٩٥٣.

ويكون معدل ١٩ وسطاً هو ٨٨٧ ملم

وإذا كانت كميات الأمطار بهذا التفاوت في بيروت فهي قد تكون لجميع الأنحاء اللبنانية التي لا يتوافر لها هذا العدد من الرصد المائي.

أما بالنسبة للثلوج التي تغطي أعالي الجبال كما ذكرنا فإننا لم نتوصل بعد الى وضع المعادلة بين ارتفاع مياه المطر وسماكة الثلج بالرغم من أنه بصورة عامة درجنا على اعتماد ملم واحد ارتفاع مطر لكل سم واحد سماكة ثلج ("الثروة المائية في لبنان" للمهندس سعدالدين مدلل).

وتبلغ سماكة الثلوج على ارتفاع ١٨٠٠ م فوق سطح البحر سبعة أمتار وهي ذات تأثير كبير على تغذية الطبقات الجوفية وعلى نظام الينابيع وجريان المياه في الأودية والأنهر إذ تؤخر هذا السيلان لمدة تتراوح بين شهر وثلاثة أشهر وهذا ما يجعل فيضان الأنهر ذات التغذية الثلجية يصل الى ذروته في الربيع حين تذوب تلك الثلوج أي بعد عدة أشهر من ذروة هطول المطر.

أما الكميات فهناك عدة أرقام للمعدل الوسطي للمياه الهاطلة في لبنان حيث:

- قدَّم المهندس محمد فواز مدير عام التجهيز المائي والكهربائي سنة ١٩٦٩ الرقم ٩٧٠٠ مليون متر مكعب سنويا في كتابه "سياسة لبنان المائية".

- كذلك اعتمد الرقم ذاته المهندس جعفر شرف الدين وزير الموارد المائية والكهربائية سنة ١٩٧١ في دراسته "الوضع المائي في لبنان والسياسة الواجب اتباعها في استثمار المرافق المائية".

- ذهبت بعض الدراسات الى اعتماد الرقم ٩٢٠٠ مليون متر مكعب سنوياً.

- مثلاً الدراسة المشتركة بين برنامج الأمم المتحدة الانمائي UNDP ومنظمة الأغذية والزراعة العالمية FAO لإعادة تنظيم قطاع الزراعة ووزارة الزراعة سنة ١٩٨٣.

- وقبلها سنة ١٩٨٠ تقرير برنامج الإعمار الصادر عن مجلس الإنماء والإعمار.

- أما الأب بلاسار وهو كما سبق أن ذكرنا واضع أحدث خريطة مطرية للبنان سنة ١٩٧٠ فقد أورد الرقم ٨٦٠٠ مليون متر مكعب سنوياً وهو بنظرنا الرقم الأسلم لأنه مبني على كيول حقيقية تمتد على عشرات السنين.

وفي جميع الأحوال فإن الفروقات بين مختلف الأرقام هي بحدود ١٠ في المائة وهو ليس بذي أهمية إذا نظرنا الى التفاوت في الكميات بين سنة وأخرى والى التفاوت في توزيع الأمطار كما ذكرنا سابقاً في الزمان والمكان ضمن رقعة لا تتجاوز ١٠ آلاف كيلومتر مربع إلا بقليل.

٣- <u>توزيع الأمطار</u>

ان كميات الأمطار المذكورة أعلاه تتوزع مبدئياً كما يلي:

٣-١ التبخر الفيزيائي والفيزيولوجي أو النتبخة (EVAPO-TRANSPIRATION)

النتبخة هي كلمة مركبة من النتح والتبخر الفيزيولوجي من خلال النبات والكائنات الحية إضافة الى التبخر الفيزيائي المتأثر بالرياح والحرارة ونسبة الرطوبة في الجو الخ..

ان تقدير نسبة النتبخة يختلف من مرجع الى آخر كما وأن المعادلات التي تسمح بحساب النسبة المذكورة عديدة وتستند الى عوامل عدة نورد على سبيل الذكر الموقع الجغرافي الرطوبة النسبية والتغيم (Nebulositè) الخ...

ان كيل الكميات المتبخرة من المياه هو من الصعوبة بمكان وغالباً ما اعتمدت المراجع طريقة طرح كميات المياه الجارية في الأنهر والوديان إضافة الى الكميات المتسربة الى جوف الأرض من مجموع المياه الهاطلة للتأكد من نتائج المعادلات وقد توصل الباحثون في لبنان الى نسبة تقارب الخمسين في المائة أي أن الكميات التي تتبخر قد قدرت بـ ٤٥٠٠ م.م^{٣}. وهذه النسبة تعتبر معقولة جداً إذا علمنا أن بعض البلدان المماثلة مناخياً تعتمد نسبا أعلى تتراوح بين ٥٥ في المائة و ٦٠ في المائة وتجدر الاشارة الى أن نسبة النتبخة قد ترتفع في سنة جافة الى ٧٥ في المائة.

٣-٢ المياه السطحية والجوفية

من المعروف ان كيل مياه السيلان السطحي هو الأسهل والأدق بالنسبة لغيره من كيول الكميات كتلك المتسربة الى الطبقات الجوفية من الأرض أو تلك المتبخرة بصورة أو بأخرى وحتى بالنسبة الى كيول كميات المياه المتساقطة كالمطر والثلوج وغيرها.

وتؤخذ هذه الكيول عند مصبات الأنهر والسواقي أو بعض النقاط المميزة من المجاري يضاف اليها الكمية المستغلة للشرب والري والصناعة وتلك التي يجري تخزينها خلف السدود والبحيرات الهضبية أو الاصطناعية.

والواقع أنه رصد في لبنان خمسة عشر نهرا دائما منها ثلاثة داخلية وإثنا عشر نهرا ساحليا كما وأن هناك ثلاثة أنهر مشتركة مع دول مجاورة وهي النهر الكبير الشمالي ونهر العاصي (مع الجمهورية العربية السورية) ونهر الحاصباني (من روافد نهر الأردن).

ان الأنهر الساحلية أو أنهر السفوح الغربية هي بأطوال قصيرة نسبيا وأطولها لا يزيد عن ٦٠ كلم تتجه من الشرق الى الغرب لتصب في البحر بانحدارات كبيرة نسبيا وضمن أودية سحيقة. أما التغذية فهي مطرية في المناطق التي هي أوطأ من المنسوب ٨٠٠ م فوق سطح البحر وثلجية في المناطق التي تعلو عن هذا الارتفاع ولذلك لوحظ فترتان من الفيضان: الأولى في كانون الثاني/يناير - شباط/فبراير في أوج فصل الأمطار أو الشتاء والثانية في نيسان/ابريل - أيار/مايو عند ذوبان الثلوج.

وقد تبيَّن أن المجموع الوسطي لمياه السيلان السطحي تبلغ ٤٠٢٦ مليون مترا مكعبا تقريبا، وإذا ما طرح منها ما ينساب باتجاه الجمهورية العربية السورية وفلسطين أي ما يقارب ٦٧٠ مليون مترا مكعبا فيكون الباقي ٣٣٥٦ مليون مترا مكعبا.

وإن هذه الأرقام قد أُخذت من عدة دراسات أهمها:

- دراسة النقطة الرابعة (المساعدة الأمريكية عن استقصاءات الموارد المائية في لبنان سنة ١٩٥٨)؛
- دراسة المياه الجوفية في لبنان التي قام بها برنامج الأمم المتحدة الانمائي سنة ١٩٧٠ (UNDP)؛
- تقرير عن الموارد المائية في شمال لبنان التي قامت بها منظمة الأغذية والزراعة (FAO)؛
- تقرير عن الموارد المائية في جنوب لبنان التي قامت بها منظمة الأغذية والزراعة (FAO)؛
- تقرير "الوضع المائي في لبنان والسياسة الواجب اتباعها في استثمار المرافق المائية" الذي وضعه وزير الموارد المائية والكهربائية سنة ١٩٧١ المهندس جعفر شرف الدين.

وان الأرقام المقدمة في هذه الدراسات قريبة من بعضها بالرغم من وجود فروقات إنما من الواضح أن المصادر المائية تتناقص من الشمال الى الجنوب كما وأن كميات مياه السيلان السطحي في فترة الشح تقارب ٢٧ في المائة من كامل كمية السيلان.

أما المياه الجوفية فإنها تغذى من تسرُّب مياه الأمطار ومياه ذوبان الثلوج من خلال التربة الكلسية المتشققة (الكارستية) التي تغطي ما يزيد عن ٦٥ في المائة من المساحة الاجمالية للبلاد. وان تسرب هذه المياه الى جوف الأرض يحصل بسرعة كبيرة نسبيا (من خلال الشقوق في الصخر) ومن ثم يظهر بشكل ينابيع تغذي الأنهر والمجاري السطحية في فترات الجفاف أو تضيع باتجاه البحر أو الطبقات العميقة وأحيانا تتفجر بشكل ينابيع مياه عذبة وسط مياه البحر المالحة (شكا والصرفند وعدلون والناقورة) أو قريبة جدا من شاطىء البحر (رأس العين، صور، الرشيدية وآنفا) واستنادا الى ما تقدم يتبين أن المصادر المائية في لبنان تتوزع كما يلي:

التعريـــف	الكميات مليون متر مكعب سنويا
الهواطل من أمطار ثلوج وغيرها	٨٦٠٠

التعريـــف	الكميات مليون متر مكعب سنويا
المياه التي تتبخر (نتبخة)	٤٥٠٠
مياه السيلان السطحي باتجاه الجمهورية العربية السورية عن طريق - العاصي - النهر الكبير الشمالي	 ٤١٥ ٩٥
مياه السيلان السطحي باتجاه فلسطين عن طريق الحاصباني والوزاني	١٦٠
المياه الجوفية التي تضيع في البحر أو تنساب باتجاه الحولة أو الجمهورية العربية السورية	٩٥٠
الباقي للبنان	٢٥٠٠

ومن هذه الكمية هناك فقط كمية ٨٠٠ مليون متر مكعب خلال أشهر الجفاف السبعة.

فإذا احتسبنا الكمية التي يمكن الاستفادة منها من المياه الجوفية ٥٠٠ مليون متر مكعب يضاف اليها كمية ٨٥٠ مليون متر مكعب يمكن تخزينها واستغلالها بواسطة السدود والبحيرات الهضبية الاصطناعية وهو أمر كبير الكلفة نظرا لطبيعة الأرض اللبنانية المشققة فإن كمية المياه القصوى المتاحة للبنان بكلفة معقولة خلال أشهر الجفاف لن تزيد عن ٢١٥٠ مليون متر مكعب.

علماً بأنه سبق أن ذكرنا أن هذه الكمية قد تنخفض الى ٥٥ في المائة كل عشر سنوات والى الثلث أو أقل في حالة تتالي ثلاث سنوات جافة كما حصل في السنوات الثلاث ١٩٨٨-١٩٨٩ و ١٩٨٩-١٩٩٠ و ١٩٩٠-١٩٩١.

مقابل هذه الموارد ما هي الحاجات؟

٤- الحاجات

تتوزع الحاجات الى ثلاثة أقسام

- الحاجات المنزلية؛
- الحاجات الصناعية؛
- الحاجات الزراعية أو حاجات الري.

٤-١ الحاجات المنزلية

الحاجات المنزلية تتضمن ما يلي:

- مياه الشرب والأعمال المنزلية وري بعض الجنائن حول البيوت؛
- حاجات المباني الإدارية والعامة كالمدارس والمستشفيات والسجون والفنادق وأماكن العبادة ومراكز التسلية اللهو (مسارح وسينما) أو برك السباحة وغيرها؛
- حاجات محطات غسيل السيارات وري الجنائن العامة والخاصة وسقاية الأشجار على جوانب الطرقات وشطف الطرقات ومقاومة الحريق الخ..
- الخسارة والهدر في شبكات التوزيع والتهريب والسرقات.

وهذه الحاجات تتأثر بعدد من العوامل نذكر منها:

- حجم المدن والمجمعات السكنية إذ تبين أن الحاجات تزداد مع ازدياد حجمها؛
- مستوى معيشة السكان حيث الحاجة أكبر كلما ارتفع مستوى المعيشة؛
- الطقس حيث تزداد الحاجة بنسبة ازدياد الجفاف؛
- تطور الطلب على المياه حسب ساعات النهار.

وفيما يلي نورد بعض الأرقام التي تبين الحاجات الحالية حسب المصالح في سنة ١٩٩٤ مع التسليم بهدر يتراوح بين ٤٠ و ٥٠ في المائة.

أي أن الكمية المستغلة حاليا تبلغ ٢١٦٫٥٠٠ مليون متر مكعب سنويا وأن ما يصيب الفرد معدله ١١٣ لتراً باليوم بما فيه الهدر أي أن الفرد يحصل بالواقع على ما معدله ٥٧ لتراً باليوم.

وان هذا الرقم أي ٥٧ لتر باليوم للفرد الواحد هو ضئيل جدا إذا ما قورن بالمعدلات في البلدان المتقدمة ولكنه مبرر إذا ما أخذنا بعين الاعتبار الأحداث التي مرت على لبنان حيث الصيانة كانت شبه معدومة ومشاريع التنمية غير موجودة.

واستنادا الى دراسة كامب درسراند ماك كي سنة ١٩٨٠ CAMP DRESSER & MC KE "المخطط التوجيهي للمياه المبتذلة" التي كلفها بها مجلس الانماء والإعمار فإن معدل الاستهلاك سيزداد مع ارتفاع المستوى المعيشي وقد قدرت آنذاك الحاجات الحالية والمستقبلية بما يلي:

اسم مصلحة المياه	عدد الاشتراكات	كميات المياه المتوفرة م٣/يوم	كميات المياه المخصصة لكل اشتراك م٣/يوم
<u>الشمال</u>			
البترون	٨٧٠٠	-	-
طرابلس	٤٦٠٠٠	٥٨٠٠٠	١,٢٦
نبع الفار (الكورة)			
القبيات	١٠٠٠٠	٦٥٠٠	٠,٦٥
نبع القاضي	٢٥٠٠	٣٣٥٠	١,٣٤
<u>جبل لبنان</u>			
جبيل	١٨٠٠٠	١٠٠٠٠	٠,٥٦
كسروان - الفتوح	٣٨٢٠٠	١٥٤٠٠	٠,٤٠
المتن	٣٥٠٠٠	٢٤٠٠٠	٠,٦٩
الباروك	٥٢٠٠٠	٦٠٠٠٠	١,١٥
<u>بيروت وضواحيها</u>			
بيروت	١٥٠٠٠٠	٢٠٠٠٠٠	١,٣٣
عين الدلبة	٧٠٠٠٠	٤٢٥٠٠	٠,٦١
<u>الجنوب</u>			
صيدا	١٧٠٠٠	٢٥٠٠٠	١,٤٧
نبع الطاسة	٤٢٠٠٠	٦٠٠٠٠	١,٤٣
صور (رأس العين)	١٢٢٠٠	١٩٠٠٠	١,٥٦
جبل عامل	٢٠٠٠٠	١٤٠٠٠	٠,٧٠
<u>البقاع</u>			
بعلبك - الهرمل	٢٣٠٠٠	١٨٠٠٠	٠,٧٨
شمسين	١٨٠٠٠	١٥٠٠٠	٠,٨٣
زحلة	٣٥٠٠٠	١٤٠٠٠	٠,٤٠
المجموع	٦٠١١٠٠	٥٩٠٣٥٠	

السنة	عدد السكان	الحاجة اليومية لتر للفرد	مجموع الحاجة اليومية م٣ باليوم	الحاجة السنوية مليون م٣
١٩٩٠	٥ ٢٠٠ ٠٠٠	١٦٥	٨٥٠ ٠٠٠	٣١٠
٢٠٠٠	٧ ١٠٠ ٠٠٠	٢١٥	١ ٥٠٠ ٠٠٠	٥٥٠
٢٠١٥	٩ ١٠٠ ٠٠٠	٢٦٠	٢ ٥٠٠ ٠٠٠	٩٠٠

٤-٢ الحاجات الصناعية

تعتبر حاجات الصناعات الخفيفة والحرفية من ضمن الحاجات المنزلية لوجودها ضمن المجمعات السكنية والمدن.

أما الحاجات الصناعية من المياه بالمعنى الصحيح فإن الاحصاءات الدقيقة عنها غير متوافرة ولكن يمكن تعريفها كالآتي:

(أ) المياه المستعملة لتوليد الطاقة أي لتوليد الطاقة الكهربائية وهذا الأمر لا يؤثر بالواقع على كمية المياه بل على ارتفاعها ويمكن ذكر المعامل الآتية:

- ثلاث محطات رئيسية على مشروع الليطاني التي تنتج ما مجموعه ١٩٠ ميغاوات؛

- ثلاث معامل على نهر ابراهيم تُنتج ما مجموعه ٣٢ر٥ ميغاوات؛

- معملان على نهر البارد تنتج ١٧ر٢٥ ميغاوات؛

- أربعة معامل على قاديشا تُنتج ما مجموعه ١٢ر٥ ميغاوات؛

- معامل صغيرة أو ما يسمى ميكر وسنترال لا يتعدى انتاج الواحد منها الميغاوات الواحد وتُستعمل محليا كمعامل الصفا والبردوني وشكا (مصنع الترابة).

وتعتمد المعامل المذكورة على سدود تحويل أو تخزين يومي للأنهر والمجاري.

(ب) المياه المستعملة للتبريد في بعض المعامل أو لانتاج البخار في بعضها الآخر كما في المعامل الحرارية في الجية والذوق والحريشة كذلك في المعملين اللذين بوشر ببنائهما في الزهراني والبداوي وأن معظم المياه المستعملة في هذه المعامل تعتمد على تحلية مياه البحر.

(ج) الصناعات التي تحتاج الى كميات كبيرة من المياه غير موجودة حاليا في لبنان باستثناء الصناعات الغذائية والمعلبات والمرطبات الخ..

وان معظم الصناعات المذكورة لا تعتمد في سد حاجاتها على مياه المصالح ومشاريع الدولة بل تؤمن ما يلزمها من المياه بواسطة الآبار الارتوازية بالدرجة الأولى وقلما تلجأ الى المياه السطحية.

ومن المعروف أن استعمال المياه للصناعة يخفض نوعيتها وكمياتها في آن واحد ونادرا ما يُصار الى إعادة استعمال هذه المياه المبتذلة وقد تصبح إذا لم تعالج مصدرا للتلوث.

وقد قُدرت حاليا حاجات المياه للصناعة بحوالي ٦٠ مليون مترا مكعبا بالسنة منها ما يقارب ٤٥ مليون مترا مكعبا من المياه الجوفية.

وتُقدر الحاجات لخمس وعشرين سنة مقبلة بـ ٢٤٠ مليون مترا مكعبا آخذاً بعين الاعتبار الانماء الصناعي الناتج عن البرنامج الوطني لإعادة الإعمار والإنماء.

٣-٤ حاجات الزراعة

تحدد حاجات الري بالكميات اللازمة لزراعة ما خلال دورة كاملة لنموها الطبيعي. وهذه الكميات تضم الخسارة بالنتبخة إضافة الى التبخر الفيزيائي من سطح التربة أو النبات.

أما بالوقت الحاضر فإن المياه السطحية ومياه الأنهر المحوَّلة بواسطة سدود تحويل وتلك المخزّنة خلف السدود الهضبية الاصطناعية تؤمن ما يقارب ٦٠ في المائة من الحاجات بينما الباقي أي ٤٠ في المائة منها فيعتمد على المياه الجوفية التي أصبحت سهلة المنال بعد أن تحسَّنت تقنيات الحفر وكذلك سحب المياه من الآبار.

وفي جميع الأحوال فإن الأراضي التي يمكن زراعتها تبلغ ٤٣٠ ٠٠٠ هكتار ولكن الزراعة لم تطل أكثر من ١٤٠ ٠٠٠ هكتار للزراعة البعلية و ٧٥ ٠٠٠ هكتار للزراعة المروية وتوزع المساحات المروية كما يلي:

المساحة المروية بالهكتار

المحافظة	من المياه السطحية	من المياه الجوفية	المجموع
البقاع	١٨٣٠٠	١٣٠٠٠	٣١٣٠٠
شمال لبنان	١٢٢٠٠	٤٠٠٠	١٦٢٠٠
جنوب لبنان	٩٧٠٠	١٠٠٠٠	١٩٧٠٠
جبل لبنان	٧٣٠٠	٥٠٠	٧٨٠٠
المجموع	٤٧٥٠٠	٢٧٥٠٠	٧٥٠٠٠

وتُقدَّر حاجاتها مبدئيا بـ ٧٥٠ مليون مترا مكعبا في السنة على أساس ١٠٠٠٠ متر مكعب للهكتار وسطياً.

فلو قُدِّر لنا أن نروي كافة الأراضي القابلة للزراعة لاحتجنا لري أل ٤٣٠٠٠٠ هكتار ما يزيد عن كامل المياه المتوفرة في لبنان.

لكن تقديرات منظمة الأغذية والزراعة FAO وبرنامج الأمم المتحدة الانمائي UNDP تقول بامكانية بلوغ المساحة المروية ١٧٠٠٠٠ هكتار تحتاج مبدئيا الى ١٧٠٠ مليون مترا مكعبا يمكن تخفيضها الى ١٣٠٠ مليون متر مكعب فيما لو اعتمدنا التقنيات الحديثة في الري.

٥- <u>الميزانية المائية</u>

يتبين من ما تقدَّم أن الحاجات حاليا ومستقبليا تـُقدَّر كما يلي:

نوع الحاجة	سنة ١٩٩٥ م.م٣ سنويا	سنة ٢٠١٥ م.م٣ سنويا	سنة ٢٠١٥ (شح) م.م٣
المنزلية	٤١٥	٩٠٠	٤٥٠
الصناعية	٦٠	٢٤٠	١٢٠
الزراعية	٧٥٠	١٣٠٠	١٣٠٠
المجموع	١٢٢٥	٢٤٤٠	١٨٧٠

وهكذا يتبيَّن أن سنة ٢٠١٥ ستشهد عجزاً في الميزانية المائية في لبنان كما في الجدول الآتي:

التعريف	سنة مطرية متوسطة م.م٣	في فصل الشح
الحاجات	٢٤٤٠	١٨٧٠
المتوفر	٢١٥٠	٨٠٠
العجز	٢٩٠	١٠٧٠

وهذا بالاضافة الى أن الموارد المائية تشهد تغيرات محسوسة في كمياتها من فصل لآخر خاصة في الينابيع والأنهر حيث تشاهد فروقات في الكميات من عشرة الى واحد كما وذكرنا سابقا فإن توزيعها الجغرافي غير متساوٍ.

٦- <u>الخلاصـــة</u>

يتبين مما تقدَّم أن لبنان بالرغم من صيته أنه "خزان ماء الشرق الأوسط" سيعاني حتماً من عجز مائي في العشرين سنة القادمة ويكفي أن نعود الى الأرقام السابقة لنرى أن المياه المتوفرة في فصل الشح ٨٠٠ م.م٣ بالكاد تكفي لحاجات الري البالغة ٧٥٠ م.م٣ في الفصل ذاته وسنضطر حتماً الى اللجوء الى مصادر غير تقليدية لسد العجز في سنة ٢٠١٥.

أما الشعار الذي أطلقه أحد المشاركين في مؤتمر الخليج منذ بضعة سنوات بأن المياه هي بترول لبنان وان لدينا أكثر من ٧٥٠ مليون مترا مكعبا يمكن بيعها وتصديرها فهو وإن كان

ليس بالجديد (إذ سبق للمرحوم الاستاذ موريس الجميل أن حمل هذا الشعار في الأربعينات حين كان سكان لبنان لا يتعدون المليونين). يُفترض أن هناك فائضاً من المياه لا حاجة لنا به وهذا غير حقيقي ولا واقعي إذ أن المشاريع المدروسة والجاهزة للتنفيذ ستستهلك كمية من المياه أكبر مما هو متوفر لدينا.

وكذلك ان الفكرة بحد ذاتها لا تخرج عن كونها فكرة أو شعارا تتطلب مزيدا من التعمُّق في درس جدواها خاصة إذا عرفنا أن مطلقها هو هيدروجيولوجي وان اختصاصه لا يشكل سوى جزءاً بسيطاً من مشروع جر المياه اللبنانية الى الخليج، نورد على سبيل الذكر، حصر المياه وتخزينها وجرها وضخها عند اللزوم وان هذه الانشاءات تحتاج الى تمويل وتوظيف مبالغ سيتعدى تأثيرها الدولار الواحد للمتر المكعب الواحد الذي أطلقه كسعر مبيع ولن نأتي على ذكر المشاكل الاقتصادية-السياسية التي سيثيرها مشروع كهذا.

وقد التقيت بعدد من خبراء الخليج بعد إطلاق الشعار في مؤتمر الخليج فأظهروا الكثير من التحفظات تجاهه، ناتجة عن أن تقديم المشروع يفتقر الى دراسة جدوى تبيِّن الفوائد المرجوة منه وكيفية وإمكانية تنفيذه.

وفي النهاية، ان الكلام عن المياه في ظروف كالتي نمر بها يجب أن يتم بحذر شديد إذ أن المياه حاليا أصبحت مادة استراتيجية ولا يمكن البحث بها إلا ضمن حل متكامل للمنطقة يبدأ بالسلام العادل ويُنظر بها فيما بعد.

الجزء الثاني
مشاكل المياه في لبنان وحلولها

من الواضح أنه من الضروري وصف الوضع الحالي للمياه في لبنان قبل الولوج الى الحلول.

٢-١ الوضع الحالي

٢-١-١ أوضاع مياه الشرب

في سنة ١٩٧٣ كانت وزارة الموارد المائية والكهربائية تفتخر بأن ٩٥ في المائة من مدن وقرى لبنان تنعم بمياه الشرب داخل البيوت بواسطة شبكات توزيع بالأنابيب.

وكان هذا الانجاز نتيجة سياسة الدولة المائية التي أعطت الأولوية لتأمين مياه الشرب لكافة المواطنين.

(أ) من الناحية الفنية

ان المديرية العامة للتجهيز المائي والكهربائي مسؤولة عن تصميم ودراسة وتنفيذ المشاريع المائية.

وإن الانشاءات تتضمن حصر الينابيع وحفر الآبار وتجهيزها بالمعدات الميكانيكية والكهربائية وإقامة محطات المعالجة عند اللزوم وخطوط الجر والتوزيع والخزانات.

ويعود أحدثها الى أواخر الستينات أي الى أكثر من خمس وعشرين سنة وهي الفترة التي تُعتبر فيها المشاريع مستهلكة.

ونظراً للأحداث التي عصفت بلبنان فإنها لم تجدد ولم تصن بل بالعكس تعرضت للتخريب مما جعل وضعها غير مقبول فنياً، فمنشآت الحصر غير ضابطة ومحطات الضخ والمعالجة تدنى مردود معظمها وتوقف بعضها عن العمل كليا والخزانات تشققت، وأصبحت غير كاتمة والأنابيب أصابها الاهتراء وباتت أقطارها الصغيرة نسبيا غير قادرة على تصريف الكميات اللازمة لسد الحاجات المتزايدة فضلاً عن أن موجات الهجرات وسعت رقعة العمران في بعض المناطق بشكل منقطع النظير ولم تسمح للبنية التحتية بمواكبتها خاصة وان شبكات المياه صممت على أساس تصريف لا يزيد عن ١٠٠ لتر يومياً للفرد.

أضف الى ذلك أن الطبيعة الجغرافية لأكثر المجمعات السكنية حيث الانحدارات قوية كانت سبباً في خلل في التوزيع، فمستوى الخزانات لم يعد كافيا لتغطية وتغذية كافة المنازل، كما وأن الفرق بالمنسوب بينها كان يؤدي الى اضطراب في التوزيع بمجرد أن يتلاعب سكان المنازل الدنيا بالعيارات، إذ أن الماء يتبع الطريق الأسهل عملاً بالمثل العامي "الأرض الواطية تأخذ مياهها ومياه غيرها".

أما الموارد التي كانت كافية في الستينات فإنها لم تعد كذلك في الوقت الحاضر وكان من الضروري البحث وتأمين مصادر مياه جديدة.

ولن نأتي بجديد عندما نقول أن انقطاع الكهرباء وتقنينها كانا من أسباب توقف محطات الضخ والمعالجة التي تعمل بالتيار الكهربائي، وأدى ذلك الى انقطاع المياه وتقنينها بالنسبة ذاتها إن لم نقل أكثر.

(ب) نوعية المياه

ان مياه الآبار العميقة لا تحتاج عادة الى تصفية بل يُكتفي بتعقيمها بالكلور، لكن توقف العديد من آلات التعقيم بسبب انعدام الصيانة أثناء الأحداث، جعل المياه أكثر عرضة للتلوث.

أما محطات المعالجة فإنها تشكو من انقطاع الكهرباء في معظم الأحيان ومن نقص فادح في الصيانة مما يؤدي الى التدني في أدائها.

وكانت الوزارة قد أنشأت ما يزيد عن ١٨ محطة معالجة تعمل وفق الآلية التقليدية من كلورة مسبقة وترسيب ومن ثم التصفية بالرمل وأخيرا التعقيم النهائي بالكلور كما وأنها ركبت أكثر من ١٢٠ آلة تعقيم على الآبار.

(ج) من الناحية الإدارية

بعد تنفيذ المشاريع، تسلم الى مصالح مستقلة أو لجان تعمل على استثمارها وصيانتها.

وهذه المصالح أُنشئت لتعمل بمرونة أكبر من الادارات الرسمية وهي مؤلفة من سلطتين: سلطة تقريرية ممثلة بمجلس إدارة، وسلطة تنفيذية مؤلفة من جهاز إداري وفني، يرأسه مدير أو مدير عام. وهي تخضع للوصاية الادارية الممثلة بوزارة الموارد - المديرية العامة للاستثمار، ولوصاية مالية ممثلة بوزارة المال.

ويربو عدد المصالح على ٢٣ مصلحة، كما يبلغ عدد اللجان حوالي ٢٠٠ لجنة، وهي تغطي أكثر المناطق اللبنانية.

وان هذا العدد الكبير من المصالح واللجان قد جعل حجمها أصغر من أن يتحمل تكاليف الأجهزة الفنية والادارية المناسبة لحسن أداء هذه المرافق الهامة.

وقد تنبهت الدوائر المختصة الى هذا الخلل وأصدرت سنة ١٩٧٢ قانون دمج المصالح واللجان ضمن خمس مصالح كبرى، واحدة لكل محافظة مما يؤدي الى تقوية الجهاز الفني وتخفيف الأعباء الإدارية وبالتالي الى تأمين الخدمات الفضلى ضمن تكاليف معقولة.

ومنذ سنة ١٩٧٢ تشكو هذه المصالح من صعوبات مالية ناتجة عن التضخم وعدم التوازن بين نفقاتها ومواردها، كما تشكو من صعوبات فنية وإدارية ناتجة عن النقص في جهازيها الإداري والفني، حيث أن تدني الرواتب وهجرة اليد العاملة قد أثرا على وضعها بالإجمال، ناهيك عن السرقات في المياه والوصلات غير المشروعة، وسوء حالة الشبكات قد أديا الى هدر يزيد عن ٥٠ في المائة من كمية المياه الموزعة.

٢-١-٢ أوضاع مشاريع الري

تقسم مشاريع الري في لبنان الى نوعين:

(أ) مشاريع الري التقليدية

اعتمد الري في لبنان منذ القدم حيث تفهَّم المزارع اللبناني مبادئه وطبقها تطبيقا جيدا فقام باستصلاح الأراضي، وبناء الجلول في الأراضي الجبلية، خاصة وأن الأراضي المروية تتمتع بمردود يفوق أضعاف مردود الأراضي البعلية.

وان أكثر المشاريع التقليدية صغيرة المساحة نسبياً ويقع أكثرها في المناطق الجبلية حيث تجمع الينابيع الصغيرة في خزانات (محاقن) لري الجلول وجنائن الأشجار المثمرة. أما مياه الأنهار والجداول فكانت تُحوَّل بواسطة سدود صغيرة الى الأراضي التي كانت تروى بطريقة الإغراق أو كما يسمى بالعامية "التطويف".

(ب) المشاريع الجديدة نسبياً

بوشر بتنفيذ هذه المشاريع منذ الانتداب الفرنسي وبعد الاستقلال قامت الدولة بإكمالها وتنميتها.

وهذه المشاريع تعتمد على تحويل مياه الأنهر والينابيع الى شبكة أقنية من الباطون توصل المياه الى الأراضي ونذكر منها مشاريع القاسمية وأدونيس ورأس العين والمنية وتقسم هذه المشاريع الى ثلاثة أقسام:

١- السهول الساحلية حيث تزرع بأشجار الفواكه والحمضيات والخضروات وتُروى بواسطة مياه الأنهر والمصبات التي تحول اليها بواسطة سدود تحويلية.

٢- المناطق الجبلية حيث تزرع أشجار التفاح وغيرها من الفواكه كالإجاص والكرز وهي تروى من ينابيع ضئيلة التصريف نسبياً وجداول تحول اليها كما أن بعضها يُروى بالضخ.

٣- السهل الداخلي (البقاع) حيث تزرع أشجار المشمش والتفاح والخضروات كذلك بعض الزراعات التي تستعمل في الصناعة كالشمندر السكري ودوار الشمس أو تلك التي

تستعمل للأعلاف وهذا السهل يُروى إما بالضخ وإما بالجاذبية من ينابيع محلية كراس العين بعلبك واللبوة واليمونة الخ...

(ج) المشاريع الخاصة

يعتمد العديد من المزارعين على المياه الجوفية لري أراضيهم في مناطق الساحل الجنوبية والشمالية والبقاع وتمتاز هذه المشاريع بأنها تستعمل وسائل الري الحديثة كالرش والتنقيط التي تعطي مردوداً أفضل.

(د) المشاكل والصعوبات

ليست أوضاع مشاريع الري بأحسن حال من مشاريع مياه الشرب بل أنها تشكو من الآفات ذاتها.

(١) من الناحية الفنية

تشكو هذه المشاريع من الناحية الفنية من هدر كبير في كميات المياه تعود أسبابها الى ما يلي:

- الأقنية هي إما ترابية حيث يضيع جزء كبير من المياه بالتسرب وإما من الباطون الذي تقادم عهده وأصبح مشققا يهرب الكثير من المياه ونظرا لكونها مفتوحة فإن جزءاً آخراً من مياهها يتبخر؛
- كذلك الخزانات فإنها تشكو من التشقق والتهريب كما في الأقنية؛
- سوء تصميم وتنفيذ المآخذ؛
- إن الإغراق (التطويف) لا يُعتبر أفضل الطرق للري والوسائل الحديثة للري لم تعتمد في المشاريع العامة؛
- توسع المزارعين باستصلاح الأراضي وزيادة المساحات المروية الأمر الذي يجعل المصادر غير قادرة على ري الأرض بالشكل الأمثل والكافي؛
- إقلاع المزارعين عن الري الليلي؛
- عدم اكتمال شبكات الأقنية الثانوية والثالثية؛
- عدم الصيانة بشكل عام.

(٢) من الناحية الإدارية

- تعدد المصالح واللجان وصغر حجمها بحيث لا يمكنها تحمُل أعباء جهاز موظفين كامل اللهم إلا مشروع القاسمية الذي استفاد من الحاقه بالمصلحة الوطنية لنهر الليطاني؛

- الرسوم الضئيلة حيث أن ما تجبيه المصالح واللجان لا يكفي لمواجهة أعباء أجور الموظفين؛

- العمر الوسطي للموظفين يزيد عن الخمسين سنة مما يؤثر على أدائهم في الحقل فضلاً عن أن كفاءاتهم ليست بالمستوى المطلوب.

٢-١-٣ المياه المبتذلة والصرف الصحي

لا بد من الحديث أيضا عن المياه المبتذلة والصرف الصحي حيث تنعم كبريات المدن والقرى بشبكات مجاري صحية لكن كل المصبات تفتقر الى محطات معالجة ولو بدائية مما يجعل المياه المبتذلة تتجمع في مراكز المصبات وتصبح مصدرا للتلوث خاصة للطبقات الجوفية والينابيع أحيانا ولشبكات مياه الشرب، وفي المدن الساحلية تلوث مياه البحر.

وتشكو شبكات الصرف الصحي من قدم عهدها وسوء صيانتها فضلاً عن كونها غير قادرة على استيعاب كمية المياه المبتذلة المتزايدة التي يفترض فيها تصريفها.

أما من الناحية الادارية فإن المشكل الأكبر يكمن بكثرة الجهات التي تتعاطى أمور شبكات المجارير مما يوزع المسؤولية إن لم يعدمها تماما.

٢-٢ السياسة المائية والحلول

بعد أن عرضنا بشكل سريع أوضاع المياه ومشاريعها بصورة عامة فما هي السياسة المتبعة أو التي يجب اتباعها والحلول المطبَّقة أو التي يُفترض تطبيقها.

٢-٢-١ السياسة المائية في لبنان

ترمي السياسة المائية في لبنان الى هدفين أساسيين:

الأول هو تأمين التوازن المائي في وقت أصبح للمياه العذبة قيمة كبرى. أليست هي أعز مفقود وأرخص موجود؟

والثاني هو تأمين النوعية الجيدة للمياه بمنع تلوثها وتأمين الصرف الصحي بحيث يكون صحياً بحق.

٢-٢-٢ الحلول

لا بد من اعتماد حلول على الصعيدين الفني والاداري لبلوغ أهداف السياسة المائية.

٢-٢-٢-١ على الصعيد الفني

هناك حلول على المدى القريب والمتوسط والبعيد:

(أ) على المدى القريب

- تخفيف الهدر الى حدوده الدنيا وإعادة تأهيل المشاريع والمنشآت المائية وقد نُفِّذ قسم من هذا العمل ضمن خطة إعادة التأهيل التي موَّل أعمال السنة الأولى منها البنك الدولي والسوق الأوروبية المشتركة؛

- مراقبة التوزيع بشكل يمنع الهدر؛

- إجراء الصيانة اللازمة وتأمين التشغيل المناسب وتأمين الجهاز البشري الكفوء وتدريب الجهاز الموجود حاليا وقد بوشر ذلك باجراء عدة دورات تدريبية فنية حول صيانة محطات المعالجة وآلات التعقيم ومحطات الضخ وصيانة الخطوط والقطع التابعة لها؛

- القيام بحملات إعلامية بواسطة أجهزة الإعلام السمعية البصرية لحث المواطنين على المحافظة على المياه والاقتصاد باستعمالها.

فيما يعود للنوعية فقد جرى تجديد آلات التعقيم المعطلة وإصلاح ما يمكن إصلاحه منها وتأمين مواد تعقيم للمشاريع.

(ب) على المدى المتوسط

- المباشرة بوضع مخطط توجيهي للمياه؛

- اعتماد طرق حديثة في الري كالرش أو التنقيط للحصول على مساحات مروية أكبر وعلى انتاجية أفضل؛

- إعادة تأهيل مخططات كيل الأنهار وقياس المطر والمحطات المناخية التي تؤمن المعطيات الأساسية التي من دونها لا يمكن القيام بأية دراسة مستقبلية أو أي تطوير؛

- اعتماد طرق لمعالجة المياه المبتذلة وإعادة استعمالها مجددا للري أو لغيره؛

- استكمال خطة إعادة التأهيل للسنتين الثانية والثالثة والتي بوشر بها في العديد من المناطق بتمويل من الصناديق العربية والبروتوكول الفرنسي وغيره.

(ج) على المدى الطويل

اعتمادا على المخطط التوجيهي للمياه والمعطيات التي تكون قد توافرت بواسطة المسح الكامل للمياه يمكن وضع سياسة مائية للبنان تعتمد:

- محاولة السيطرة ما أمكن على المياه السطحية وذلك بانشاء السدود والبحيرات الجبلية ومنع سيلانها هدرا الى البحر؛

- تطوير النطاق المائي الجوفي لتوفير الدعم للمياه السطحية حيث يكون ذلك ممكنا وتغذيته اصطناعيا بواسطة المياه السطحية في فصل الشتاء؛

- تنفيذ المشاريع الكبرى التي تؤمن مصادر إضافية من المياه لمشاريع سد بشري وجر مياه الأولي لبيروت وتستغني عن الضخ حتى ولو كان ذلك لفترات الشتاء (كمشروع جعيتا العليا ونبع الجويزات)؛

- المحافظة على نوعية المياه السطحية والجوفية بنوع خاص أو بعبارة أخرى المحافظة على البيئة من خلال التصريف الفني لمياه السيلان السطحي والمياه المبتذلة ومعالجتها.

- الحرص على منع تلوّث المياه المخزونة خلف السدود باتخاذ اجراءات وقائية ومعالجة هذا التلوث في حال حدوثه.

٢-٢-٢-٢ على الصعيد الإداري

أما على الصعيد الإداري فتتلخص السياسة المائية اللبنانية بما يلي:

(أ) انشاء مجلس أعلى أو هيئة عليا للمياه تهتم بموضوع تنفيذ السياسة المائية للبنان، وذلك بتنفيذ التخطيط التوجيهي ووضع الأسس اللازمة لتوزيع الموارد بشكل عادل ومتوازن والتصميم العام للمشاريع المائية وترتكز على جمع المعلومات الأساسية بالدرجة الأولى لتحليلها تمهيداً للاستفادة منها بشكل علمي ومنطقي؛

(ب) تنفيذ قانون المصالح وإلغاء اللجان المحلية حيث يمكن ذلك. فالإدارة منذ أوائل السبعينات كانت قد وعت مشكلة تعدد المصالح وعددها ٢٣ واللجان التي يفوق عددها ٢٠٠ وما يجره ذلك من تشتت للجهود واستصدرت آنذاك قانون دمج المصالح وجَعل عددها خمسة أي واحدة في كل محافظة ولكن الأحداث التي مرت لم تكن لتسمح بتطبيقه فجرى تجميد القانون المذكور وأعيد إحياؤه بموجب قرارات من مجلس الوزراء صدرت في الآونة الأخيرة وقضت بتنفيذ الدمج في ثلاث مصالح في الجنوب والبقاع وبيروت؛

كذلك أُلغيت اللجان في الشمال وأنشئت مصالح على صعيد القضاء نذكر منها عكار والضنية والكورة والبترون وكذلك في زغرتا وبشري وهذه المصالح هي خطوة أولى في سبيل إنشاء مصلحة مياه الشمال على غرار ما ذكرناه آنفا.

(ج) جمع كافة وجهات استثمار المياه في المناطق ضمن المصلحة المولجة بها أي الشرب والري والمياه المبتذلة ليأتي التنسيق تاماً ومتكاملاً؛

(د) تحديث قوانين المياه المعمول بها حاليا لمواكبة التطور في استعمالها إذ أن أكثر هذه القوانين يعود لأيام الانتداب وبعضها للعهد العثماني.

وأخيرا وقبل إنهاء هذا الحديث لا بد من فكرة تتعلق بالسياسة المائية والاقتصادية وكثر الكلام عنها في الآونة الأخيرة ألا وهي الخصخصة أو التخصيص وهو ما كان معتمدا في الامتيازات. والإدارة وإن كانت لا تمانع في المستقبل من اعتمادها كما في الكثير من الدول المتقدمة فإنها تفترض قبل ذلك الوصول الى:

- تأمين المنافسة بين الشركات الخاصة التي ستوكل اليها المهمة؛
- تأمين المراقبة الفعالة من قِبَل الإدارة عليها؛
- تقوية المصالح المائية بالوقت الحاضر ليكون المفاوض مع الشركات من قِبَل الإدارة في موقع أفضل ومتابعة الدعم ريثما نصل الى الاستقرار الاقتصادي إذ أن الماء هي أساس الحياة وليست فقط سلعة لا تعطى إلا لمن يدفع ثمنها.

هذا باختصار شديد، ملخص لوضع المياه في لبنان، وللسياسة المائية المتبعة، أو المفروض اتباعها ضمن تطبيق روزنامة ٢١ شاكرين إصغاءكم آملين أن نكون قد وفقنا بعرضها مشددين على أن مواردنا المائية بالكاد تكفي حاجاتنا في العشرين سنة القادمة وسنضطر فيما بعد الى البحث عن مصادر مياه جديدة وغير التقليدية منها.

مدير عام الاستثمار

المهندس
بسام جابر

XVII. THE FORMATION OF THE PALESTINIAN NATIONAL WATER AUTHORITY

by

*Hisham Zarour**

Introduction

After so many years of lacking control over all aspects of life, the Palestinian people are re-establishing national sovereignty and reinstating control over national land and resources. The international community recognized the Palestinian right to control and manage national water resources in the Multilateral Talks on Water in the Middle East which were held in Muscat, Oman in April 1994. The Palestinian Authority announced in the Oman Talks its intention to establish the Palestinian National Water Authority (NWA).

On 26 April 1995, the Palestinian Authority announced officially the establishment of the NWA. Upon its establishment, the NWA recognized the need for a legal framework to organize the nation's water sector and manage its waters. In due course, a draft law entitled "National Water Council and National Water Authority Act" was produced and submitted to the President. The Act is now being reviewed by the President and it is anticipated that it will be signed and implemented in the very near future.

The intention of this paper is to give a brief overview of the past situation and recent developments related to water resources management in Palestine and present, in brief, the main features of the proposed water act. The intention of the Palestinian Authority is to comply with Agenda 21 and the guidelines set by the World Bank in planning water resources management in Palestine.

A. Pre-Palestinian Authority water management

Until the beginning of May 1994, all water resources in the Gaza Strip and West Bank were controlled by the Civil Administration, the administrative arm of the Israeli occupation. The Civil Administration managed water in the West Bank and the Gaza Strip through the West Bank Water Department and Gaza Department of Agriculture. Although both departments were staffed primarily by Palestinians, the West Bank Water Department and the Gaza Department of Agriculture were run by Israeli military officers, who carefully watched to ensure that military regulations were being applied in their respective areas.

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Under the Israeli occupation, the water management systems applied in the occupied territories of the Gaza Strip and the West Bank were like mirror image reflections of the system applied in Israeli: water is managed by agriculture institutions and essentially for the interest of Israel and Israelis, whether living in Israel or in settlements on the occupied lands. The discriminatory water management policy applied in the occupied territories resulted basically in:

(a) Unjust allocation of rights as well as unjust allocation of social and economic benefits of water use and services;

(b) Economically inefficient and environmentally unsustainable utilization of the limited resources of available water;

(c) Political complexities that will continue to overshadow the Israeli-Palestinian negotiations;

(d) Inapt infrastructure and legal framework;

(e) Weakening of Palestinian institutional and professional capacity in the field of water management.

B. WATER MANAGEMENT UNDER THE PALESTINIAN AUTHORITY

As of 4 May 1994, the Civil Administration lost control over most of the Gaza Strip and the Jericho area as a result of the implementation of the self-rule arrangements agreed upon between the Palestine Liberation Organization and the State of Israel in Cairo. As of that date, the Palestinian Authority took charge of civil affairs, including the responsibility for water resources management, in the self-rule areas.

Under the new arrangements, the Water Division of the Department of Agriculture in Gaza became a division within the Agriculture Ministry of the Palestinian Authority. Later on, the name was changed into the Directorate General of Water, Hydrology and Geology. In the Jericho area, the Palestinian Authority, supported by the Water Resources Action Programme (WRAP) and a number of non-governmental organizations (NGOs), established the Jericho Water Office in June 1994 in order to undertake the essential task of hydrological monitoring in the area. On 28 February 1995, the Palestinian Authority established the Hydrology Bureau (HB) as a unit within the Water Planning Directorate of the Ministry of Planning and International cooperation (MPIC). The HB has the very precise mandate of: (a) undertaking hydrological monitoring; (b) development and maintenance of hydrological archives, databases and information systems; and (c) designing, carrying out and supervising hydrological studies (including assessment of water resources).

All of the above-mentioned intermediate institutional and organizational arrangements were essential at the time when they were made by the Palestinian Authority. However, the target of the Palestinian Authority has been to capitalize on existing resources and "building blocks" and, ultimately, the development of a comprehensive legal and institutional framework to manage water in Palestine in a manner that guarantees social equity, economic efficiency and environmental sustainability. Accordingly, the Palestinian Authority established the NWA to achieve this goal.

Fortunately, the NWA did not have to start from scratch. Expertise and initiatives to enhance water management capacity in Palestine exist in governmental units, universities, NGOs, and national programmes. One very important component that the NWA has available to it is the Water Resources Action Programme. WRAP is a joint initiative of the Palestinian leadership and the international community and was launched in the beginning of 1993. WRAP is financially and technically supported by the United Nations Development Programme (UNDP), the Canadian International Development Agency (CIDA) and the British Overseas Development Administration (ODA).

The basic objective of WRAP is to develop Palestinian water management capacity. An interdisciplinary team of national professionals, the WRAP Task Force, constitutes the technical executive arm of the programme. As the programme was designed to support the establishment of the NWA, work on the programme has been executed in such a manner as to this end. The first activity of WRAP was to identify priority issues related to water resources management that needed prompt action, and then mobilize resources to address these issues. WRAP has undertaken a number of activities ranging from supporting institutional development to undertaking technical hydrological investigations and launching a public awareness campaign. During the first month of operations, WRAP supported a workshop on the appropriate institutional framework for water within the Palestinian Authority. In addition, the work organized by WRAP on the legislative dimensions related to water management proved to be very helpful to the NWA in preparing the draft act on the "National Water Council and National Water Authority", which (as noted above) was presented to the attention of the President by the NWA upon its establishment.

Recently, the work of WRAP was taken over by the NWA, and all the programme's resources are now at the disposal of the NWA. The NWA is now focusing on the development of a comprehensive analytical framework for planning water resources management and development in Palestine. In addition, the NWA is working with the Norwegian Government on a project which aims at enhancing Palestinian water management capacity and at the activation of the NWA. A number of other activities involving other parties are also on the NWA agenda.

C. MAIN FEATURES OF THE PALESTINIAN WATER ACT

Maximum involvement of stakeholders; observing social equity and environmental sustainability while maximizing economic benefits; modern, high-tech, and capitalizing on all available and existing resources; largely interdisciplinary, but highly specialized; and de-fragmented, but decentralized: this is how water management in Palestine is envisaged by the Palestinian leadership and the NWA. This is easily sensed when reading through the National Water Council and National Water Authority Act;

According to the proposed law, the highest water authority is in the hands of the National Water Council (NWC). The NWC is headed by the President and includes ministers of agriculture, planning and international cooperation, justice, local government and industry and a representative of national universities. In addition, membership in the Council is open to any party whenever deemed necessary by the Council. The proposed act defines water in Palestine as: all the water in the country; whether surface or subsurface, and including wastewater and brackish water. As for management, the proposed act defines it as: the control of water resources development by means of policy guidelines, studies and dissemination of information, development of comprehensive water use plans, and licensing.

While deciding on strategic options, including general policy, pricing, involvement in regional cooperation, water resources protection and pollution control regulations, investment priorities are the responsibility of the NWC. The NWA represents the executive arm of the NWC. The NWA has been conceived as a public institution attached to the presidency. The head of the NWA would be nominated directly by the President.

The proposed National Water Council and National Water Authority Act set the objectives of the NWA as the following:

(a) To ensure the most rational management of the water resources available in Palestine, in order to achieve a balance between available water, in terms of both quantity and quality, and the needs of the Palestinian people at present, as well as in the future;

(b) To promote introduction of those laws and regulations that are necessary to prevent abuse and pollution of water resources;

(c) To ensure the endorsement of the NWC for all water projects, and to oversee the implementation of those projects through national and local government departments or individual contractors;

(d) To achieve the highest level of cooperation between local administrative bodies for the purpose of enhancing their water management capacity, and rational assessment of future needs;

(e) To achieve the highest level of cooperation between the NWA and all parties that have common interests.

D. CONCLUSION

The Palestinian Authority is now in charge of water management in the self-ruled area of the Gaza Strip and Jericho and is now involved in extensive negotiations regarding the control of water resources in the rest of the West Bank. The Palestinian Authority entrusted the responsibility of water management to the NWA. The NWA prepared draft by-laws to organize the water sector and manage water resources in Palestine. The basic concern of the NWA at this stage is to capitalize on existing resources and expertise and consolidate efforts targeting the socially equitable, environmentally sustainable and economically efficient management of national water resources. The NWC and the NWA are policy makers rather than implementing agencies. Coordination of plans and activities between the NWA and different parties as well as among different interested parties is seen as an essential role of the NWA. The NWA is trying to develop a comprehensive approach in which centralization is avoided and fragmentation is absent. Guidelines set by the World Bank and Agenda 21 are adopted by the Palestinian Authority as the strategic basis for planning water resources management in Palestine. Many countries and organizations are supporting Palestinian endeavours to set up a capable water resources management system. To all of them, we are highly appreciative and grateful.

REFERENCES

Al-Shareef, N., 1995. Oral communications. National Water Authority. Palestinian National Authority.

Caponera, D., 1995. Establishing a National Water Council and a National Water Authority. Unpublished consultant's mission report. WRAP.

Palestinian National Authority, 1995. National Water Council and National Water Authority Act (draft, in Arabic).

Qashu, H.K., 1994. Palestine Water Code (Water Resources Management Act of 1994). Unpublished draft. The Center for Applied Environmental Technology. USA.

Technical and Advisory Committees, 1994. An Institutional Framework for Water within the Palestinian National Authority: Recommendations of a Workshop held at Birzeit University, 21-24 April 1994. Technical and Advisory Committees, 1994. Jerusalem.

Water Resources Action Programme Taskforce, 1994. Palestinian Water Resources: A rapid interdisciplinary sector review and issues paper. Water Resources Action Programme—Palestine (WRAP), Gaza Strip and West Bank.

XVIII. الورقة القطرية - دولة قطـــــر

مقدمـــــة

من العلامات الواضحة والهامة في الميزان المائي في قطر هي أن صافي استهلاك المياه الجوفية أعلى بكثير من التغذية والتي مصدرها الوحيد الأمطار (الجدول ١). ويبلغ متوسط التغذية خلال الفترة ما بين ١٩٧١ و ١٩٩٣ حوالي ٥٠ر٤ مليون متر مكعب في السنة، ويبلغ معدل العجز حوالي ٣٨ر٣٤ مليون متر مكعب سنويا وبعجز تراكمي يقدر حاليا بحوالي ١٠٠٠ مليون متر مكعب. وهذا يعني أن الاستهلاك من الحوض الجوفي يسحب من كمية المياه المخزونة. وعليه فإن المشكلة الأساسية التي تواجه التوسع الزراعي هي استنزاف الحوض الجوفي وانحسار الاحتياطي فيه. وتأخذ هذه المشكلة شكلا خطيرا في القطاع الشمالي حيث تتركز غالبية المزارع ويبلغ الاستهلاك الزراعي أكثر من ثلاثة أضعاف التغذية من مياه الأمطار.

ومن ناحية أخرى فإن سحب مياه الحوض الجوفي للاستهلاك الزراعي أدى الى انخفاض منسوب المياه العذبة في القطاع الشمالي بمعدل يتراوح بين ٥٠ سم الى ١٠٠ سم كل عام. وقد تسبب ذلك في تداخل المياه المالحة عرضيا من البحر والمياه الشبه مالحة رأسيا من الطبقات السفلى على عدسة المياه العذبة. وقد أظهرت الدراسة في المنطقة الشمالية بأن تداخل مياه الخليج الى الطبقة الحاملة للمياه يتزايد عاما بعد عام. وكانت النتيجة الطبيعية لذلك زيادة ملوحة المياه بمعدل يتراوح ما بين ٥-٧ في المائة في السنة وقد تسبب تدني نوعية المياه الى تدهور التربة والذي أدى الى هجرة الأراضي الزراعية وخصوصا الأراضي القريبة من السواحل.

هذا وإذا اعتبرنا مخزون المياه الجوفية العذبة للقطاع الشمالي المقدَّر حاليا بحوالي ١٥٠ مليون متر مكعب، وبافتراض استمرار العجز السنوي على نفس المعدل الحالي، فإنه بعد ٣٩ سنة سوف يستنزف المخزون، هذا من الناحية النظرية. أما عمليا ومع نسبة الانخفاض في منسوب المياه الجوفية والزيادة المستمرة في درجة الملوحة، فإن الاستفادة الفعالة من المياه العذبة لن تتعدى ٢٠ عاما.

الجدول ١- الميزان المائي للموارد المائية الجوفية في دولة قطر للفترة ما بين ١٩٧١ - ١٩٩٣

السنة	(١) التغذية للحوض الجوفي م.م٣	(٢) العائد من الري م.م٣	(٣) الفاقد عن طريق التسرب م.م٣	(٤) صافي الكمية المغذية م.م٣	(٥) اجمالي الاستهلاك السنوي م.م٣	(٦) صافي الاستهلاك م.م٣	(٧) العجز أو الزيادة السنوية م.م٣
١٩٧٢/١٩٧١	٣٠ر٣٦	١٠ر٦٤	١٨ر٠	٢٣ر٠	٤٢ر٥٨	٣١ر٩٢	-١٩ر٥٨
١٩٧٣/١٩٧٢	١٢ر٢٨	١١ر٩٦	١٨ر٠	٦ر٢٤	٤٧ر٨٤	٣٥ر٨٨	-٤١ر٦٠

الجدول ١- (تابع)

السنة	(١) التغذية للحوض الجوفي م.م٣	(٢) العائد من الري م.م٣	(٣) الفاقد عن طريق التسرب م.م٣	(٤) صافي الكمية المغذية م.م٣	(٥) اجمالي الاستهلاك السنوي م.م٣	(٦) صافي الاستهلاك م.م٣	(٧) العجز أو الزيادة السنوية م.م٣
١٩٧٤/١٩٧٣	٢٢ر٤٢	١٢ر٨٢	١٨ر٠	٢٨ر٤	٥١ر٢٦	٣٨ر٤٦	٢٢ر٠٢-
١٩٧٥/١٩٧٤	٢٨ر٤٤	١٣ر٧٤	١٨ر٠	٢٤ر١٨	٥٤ر٩٦	٤١ر٢٢	٢٠ر٧٨-
١٩٧٦/١٩٧٥	٧٧ر٤١	١٤ر٨٧	١٨ر٠	٧٤ر٢٨	٥٦ر٤٦	٤٤ر٦١	١٤ر٢٨+
١٩٧٧/١٩٧٦	٦٠ر٩٧	١٥ر٨٣	١٨ر٠	٥٨ر٨٠	٦٣ر٣٢	٤٧ر٤٩	٤ر٥٢-
١٩٧٨/١٩٧٧	١٨ر١٠	١٦ر٦٩	١٨ر٠	١٦ر٧٩	٦٦ر٧٥	٥٠ر٠٧	٤٩ر٩٦-
١٩٧٩/١٩٧٨	٢٥ر٨٥	١٧ر٤٥	١٨ر٠	٢٥ر٣٠	٦٩ر٧٨	٥٢ر٣٥	٣٤ر٤٨-
١٩٨٠/١٩٧٩	٤٠ر٦٩	١٧ر٦١	١٨ر٠	٤٠ر٢٠	٧٠ر٤٥	٥٢ر٨٣	٢٠ر٤٨-
١٩٨١/١٩٨٠	٢٠ر٥٨	١٩ر٢٦	١٨ر٠	٢٢ر٩٤	٧٧ر٤٢	٥٨ر٠٨	٥٤ر٤٨-
١٩٨٢/١٩٨١	٦٥ر٤٨	٢١ر٢٥	١٨ر٠	٦٨ر٧٣	٨٥ر٠	٦٣ر٧٥	١٦ر٢٧-
١٩٨٣/١٩٨٢	١٠٧ر٦٤	٢٢ر٧٨	١٨ر٠	٢١١ر٤٢	٩١ر١٢	٦٨ر٦١	٢١ر٢٠ +
١٩٨٤/١٩٨٣	١٩ر٠٢	٢٢ر٥٤	١٨ر٠	٢٤ر٥٦	٩٤ر١٥	٧٠ر٦١	٦٩ر٥٩-
١٩٨٥/١٩٨٤	١٠ر٠٢	٢٤ر٢٢	١٨ر٠	١٦ر٢٥	٩٦ر٩٠	٧٢ر٤٦	٨٠ر٦٥-
١٩٨٦/١٩٨٥	٥٧ر٨٢	٢٤ر٩١	١٨ر٠	٦٤ر٧٤	٩٩ر٦٥	٧٤ر٧٤	٣٤ر٩١-
١٩٨٧/١٩٨٦	٥٩ر٤٩	٢٠ر٧٣	١٨ر٠	٧٢ر١١	١٢٢ر٨٧	٩٢ر١٥	٥٠ر٦٦-
١٩٨٨/١٩٨٧	١٥٨ر٥٤	٢٢ر٥٠	١٨ر٠	٣١٧ر٠٤	١٣٠ر٠	٩٧ر٥٠	٤٣ر٠٤ +
١٩٨٩/١٩٨٨	١٦ر٠٢	٢٢ر٧٥	١٨ر٠	٣١ر٧٧	١٣٥ر٠	١٠١ر٢٥	١٠٢ر٢٢-
١٩٩٠/١٩٨٩	٩٠ر٥٢	٣٥ر٠	١٨ر٠	٧١٠ر٥٢	١٤٠ر٠	١٠٥ر٠	٢٢ر٤٧-
١٩٩١/١٩٩٠	٢٢ر٤٥	٢٦ر٢٥	١٨ر٠	٤٠ر٧٠	١٤٥ر٠	١٠٨ر٧٥	١٠٤ر٣٠-
١٩٩٢/١٩٩١	٢٩ر٢١	٤٠ر٠	١٨ر٠	٦١ر٢١	١٦٠ر٠	١٢٠	٩٨ر٧٩-
١٩٩٣/١٩٩٢	٩٢ر٨٦	٤٣ر٣	١٨ر٠	١١٨ر٨	١٧٢ر١	١٢٩ر٠٧	٥٣ر٢١-

المصدر: قسم البحوث المائية - إدارة البحوث الزراعية والمائية.

1. The status of water resources potentialities:

- Distilled sea water for domestic purpose	=	92.812 million m^3 (1994 statistics)
- Groundwater extraction for drinking	=	2.458 million m^3 (1994 statistics)
- Groundwater extraction for irrigation	=	185.380 million m^3 (1993/1994) statistics for agricultural season)

Prediction of availability and needs for various purposes up to the year 2025.

Not available.

2. Plans and programmes for updating information on water resources potentialities:

- Installation of water meters in all wells for proper assessment of groundwater extraction;
- Using GIS in water resources operation and management;
- Storage and retrieval of water resources data in computers;
- Using softwares for water resources design, graphical representation of data and interpolation and extrapolation of data;

3. Main features of the national strategy and policy for development, manager and use of water resources up to the year 2025:

- Water Master Plan in application at present:

    * Using treated sewage effluent for forage production in Rakiyah Project;
    * Natural recharge of groundwater reservoir;
    * Using modern irrigation systems in all Government agricultural projects and big private projects;
    * Irrigation with saline water as in the case of Al-Mashabiyah Project for planting 50,000 date palm trees;

- Justification for eventual revision and modification to overcome current environmental impacts:

- * Minimize deterioration of water quality;
  * Stop desertification due to lack of irrigation water;
  * Avoid salinity of soils and abandonment of farms;

- Priorities for water resources allocation and usages:

  * Domestic use;
  * Agricultural use;
  * Industrial and commercial;

- Plans and programmes for implementing major water resources development projects:

  * Increasing water resources for agriculture by <u>either</u> importation of freshwater <u>or</u> desalination of sea water;
  * Artificial recharge in northern Qatar;
  * Improvement of irrigation systems in Qatari farms;
  * Continuation of research works in water resources.

4. The objectives, activities and means of implementation (included in chapter 18) that have been incorporated into the national water master plans:

- Freshwater needs for domestic, industrial and commercial purposes have been satisfied;

- Feasibility studies for importation of freshwater;

- Programme of development of deep aquifer;

- Programme of natural recharge of groundwater;

- Design of artificial recharge project;

- Implementation of groundwater laws;

- Study of "Protection of groundwater in Umm Al-Affai landfill site";

- Preliminary design of the project: "Improvement of the Irrigation Systems in the Qatari Farms";

- "Farms and wells committee for rational utilization, protection, conservation and management of groundwater";

- Annual farms wells survey;

- Implementation of projects:

    * Er-Rakiyah Project for forage production using T.S.E. (41,000 m^3/day);
    * Al-Mashabiyah Project for plantation of 50,000 date palm trees using saline water;

- Intensive extension and training programmes;

- Effective bilateral and multilateral cooperation with regional and international organizations dealing with water resources.

5. Training sessions, seminars, lectures, exhibitions and field days concerning general awareness in water use were held in Doha with cooperation of national, regional and international organizations.

6. Expected environmental impacts of water resources development, means and overcoming these effects:

- Pollution of groundwater in landfill sites, to be overcome by lining the landfill floor;

- Deterioration of groundwater quality, to be overcome by natural and artificial recharge of freshwater;

- Salinity of arable soils, to be overcome by adequate leaching of salts and integrated water and land resources management.

7. Recommendation for strengthening cooperation between the ESCWA member states in the light of the basis for action for the various programmes.

It is recommended that ESCWA make preparations for strengthening cooperation between the member States by holding seminars, workshops, training courses and transfer of technology in the field of water resources development and management.

It is recommended that ESCWA offer technical assistance to the member States in implementing studies concerning development and management of water resources up to the year 2025.

XIX. الورقة القطرية - الجمهورية العربية السورية(*)

إعداد
عبد العزيز المصري(**)

ألف- مدخـــل

يـُعتبر الماء من أهم وأغلى مرافق الحياة وسبب ديمومتها، وهو ثروة طبيعية يستحيل ايجاد بدل عنه.. له صلة بكل مناحي الحياة الاقتصادية بفروعها وتعقيداتها المختلفة.

ان كل الاجتماعات والمؤتمرات والندوات التي تـُعقد في العالم بهذا الصدد وإن اختلفت عناوينها فهي تدور حول نقطة واحدة هي (أهمية المياه "والحفاظ عليها نظيفة" لاستمرار الحياة) لا غرابة في الأمر فقد قال تعالى:

(وجعلنا من الماء كل شيء حي)(١).

وبهذا السياق نثني على كل الجهود التي تبذلها اللجنة الاقتصادية والاجتماعية لغربي آسيا (ESCWA) للتركيز على مفهوم الإدارة المتكاملة لموارد المياه في دول الإسكوا والتي ربما يستغرق الربط بين هذا المفهوم والأمور الأخرى ذات الصلة مثل البيئة، التنمية المستدامة.. وقتا طويلا .

باء- مقدمـــة

يأتي اجتماعنا هذا ضمن الجهود التي تبذل في التحضير للدخول بالعالم الى القرن الحادي والعشرين بورشات عمل مكثفة تتطلب المزيد من الجهد والتعاون بين دول الإسكوا لتنفيذ ما جاء في مقررات قمة الأرض التي عـُقدت في ريو دي جانيرو عام ١٩٩٢.

ونؤكد على المقولة:

(إذا كان القرن التاسع عشر قرن الفحم الحجري، والقرن العشرين هو قرن النفط، فإن القرن الحادي والعشرين هو قرن الماء).

وطالما أن هناك أرضا واحدة تصلح للحياة هي كوكب الأرض وطالما أن هناك كمية محدودة من المياه المتجددة لهذا الكوكب، فننشد أن يكون الماء "عنصر سلام" بين شعوب هذا الكوكب لمواجهة متطلبات الحياة فالانفجار السكاني وتنامي الحاجة مع تقدم العلم والتكنولوجيا الى المزيد من الصناعة والزراعة.. كلها مع "محدودية وسوء توزيع" كمية المياه الموجودة تجعل الأمر الوحيد الذي يضيق الهوة بين العنصر المحدود "الماء" والعنصر المتزايد (الحاجة الى المياه) هو التعاون لتنمية وتطوير المحافظة على الماء.

(*) صدرت كما وردت من الجهة المعنية.
(**) خبير المياه الدولية، وزارة الري، دمشق، الجمهورية العربية السورية.
(١) سورة الأنبياء، الآية ٣٠.

ومع تأكيدنا على أهمية البنود التي وضعت لتكون أساس ورقة العمل الوطنية ونجد بأنه من الضروري أن نذكر بشيء من التفصيل عن المصادر المائية في الجمهورية العربية السورية ومفهوم الإدارة المتكاملة لها، ثم لمحة عن خصائص وضع الخطط العامة للمياه الوطنية ليتسنى لنا إسقاط ذلك على جدول أعمال القرن الحادي والعشرين وبشكل خاص الفصل رقم (١٨) منه.

وننهي ورقتنا هذه بتحديد العقبات الرئيسية لإدخال تلك الأهداف ضمن الخطط الرئيسية للمياه الوطنية وخطط التنمية الاقتصادية وإمكانية مواجهة تلك العوائق.

جيم- المصادر المائية في الجمهورية العربية السورية[٢]

١- لمحة عامة عن القطر

تبلغ مساحة القطر العربي السوري ١٨٠ر١٨٥ ألف كم٢ وعدد سكانه ٣٧٧ر١٤ مليون نسمة يقع الجزء الأكبر من أراضيه في نطاق المناطق الجافة وشبه الجافة، لذلك فإن معدلات الهطولات المطرية السنوية يتفاوت بشكل كبير فهو يتجاوز ألـ ١٠٠٠ ملم في المرتفعات الجبلية والساحل ويتناقص ليقل عن ١٠٠ ملم في البادية الجنوبية ويقدر الوسطي السنوي منها حوالي ٤٥ مليار م٣ تقاس بواسطة ٤٩٢ محطة مطرية موزعة في أنحاء القطر.

وكما أن الهطول المطري متفاوت فإن التبخر يجاريه ولكن بشكل عكسي. فقيمة التبخر في الساحل تقل عن ٦٠٠ ملم وفي البادية تصل الى ٢٢٠٠ ملم. ونظرا للطبيعة الجيومورفولوجية والتكتونية للساحل السوري. ونظرا لتركز معظم الهاطل المطري فيه فإن الاستفادة من معدلات الأمطار تبقى محدودة لأنها تنتهي خلال وقت قصير الى البحر.

٢- المصادر المائية

يُقدَّر المتوسط السنوي لحجم المصادر المائية السطحية والجوفية في الجمهورية العربية السورية بحوالي ٩ر٩ مليار (دون تصريف نهري الفرات ودجلة) وتُقدَّر السطحية بـ ٦ر٩ مليار[٣] م٣ والجوفية ٣ مليار م٣ سنويا وتتوزع هذه المصادر على سبعة أحواض مائية رئيسية.

١- المياه السطحية: وتنقسم الى:

<u>أنهار دائمة الجريان</u> وهي بدورها تنقسم الى فئتين:

(أ) أنهار دولية مشتركة مع الدول المجاورة ولها أهمية خاصة (كما سنبين لاحقا) في خطط التنمية الاقتصادية والاجتماعية ومنها أنهار: الفرات، دجلة، العاصي، عفرين، اليرموك، قويق، جغجغ، الكبير الجنوبي، الساحور.

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(٢) المرجع رقم ١.

(٣) المرجع رقم ٢.

(ب) أنهار داخلية: وهي التي تقع بكاملها من النبع الى المصب داخل حدود القطر العربي السوري ومنها، أنهار الخابور، البليخ، السن، بردى، الأعرج، الكبير الشمالي، بانياس... والجدول ١ يوضح أهم الأنهار وتصاريفها السنوية:

الجدول ١

اسم النهر	متوسط الجريان السنوي (مليون م٣)	الغزارة الوسطية (م٣/ثا)
الأنهار المشتركة		
الفرات	٣١٤٠٠	٩٩٥
دجلـــة	١٨٥٠٠(*)	٥٨٦
العاصي	٨١٣	٢٥ر٨
عفرين	٢٣٠	٧ر٢
اليرموك	٤٤٠	-
جغجغ	١٢٦	٤
الكبير الجنوبي	٢٥١	٨
الساجور	١٣٥	٤ر٢
قويق	٩٥	-
مجموعة الأنهار الداخلية		
الخابور	١٦٠٠	٥٠ر٧
بردى	٣١٥	-
الأعوج	١٠٠	-
الكبير الشمالي	٢١٠	٦ر٦
السن	٣١٥	٩ر٩
البليخ	١٤٠	-

(*) في نقطة الحدود السورية-التركية، إلا أن متوسط جريانه السنوي بالكامل وبما يرفده في العراق من أنهار هامة، كالزاب، والعظيم .. يصل الى (٥٠) مليار م٣ سنوياً.

٢- الأنهار غير دائمة الجريان وتنتشر بشكل رئيسي في المناطق الساحلية حيث تجري فيها لمدة لا تتجاوز الأربعة أشهر بشكل مستمر، أما باقي الجريان فيكون متقطعا وفي بعضها مستمر بشكل محدود ومنها الصنوبر، الأبرش، مرقية، السوريت، الحصين، الحديد، الروس، الفقمة، السبع بيار، الوعر، المياه، الشام، التنف.

٢- المياه الجوفية

تمتد الصخور الحاملة للمياه الجوفية في الجمهورية العربية السورية من العصر الجوراسي وحتى الحديث حيث يقدر متوسط الوارد المائي الجوفي السنوي مع الينابيع بحدود ٣ مليار م٣ وبناء على أعمال الاستكشافات الكبيرة التي تمت في القطر لا سيما ربع القرن الماضي والتي اعتمدت على أعمال المسح الجيولوجية والجيوفيزيائية والهيدروجيولوجية وحفر الآبار تبين أن هناك أربع وحدات هيدروجيولوجية وهي:

(أ) اللحقيات الرباعية والحصى والانهدريت الميوسيني، وتنفجر منها ينابيع أهمها، قلايا، حاروش، دير العصافير، الهول، الخاتونية وتل التبان.

(ب) الطبقات البركانية العائدة للنيوجين والرباعي والحديث تتفجر بعض الينابيع منها: مزيريب، زيزون، الساخنة، الصيادة، الثريا، أم الدنانير.

(ج) طبقات الحجر الكلسي الباليوجيني تتفجر منها ينابيع أهمها: رأس العين بتصريف (٤٠ م٣/ثا) الذي يعتبر ثاني أكبر نبع كارستي في العالم[٤] وعين العروس ومنين.

(د) طبقات الحجر الكلسي الدولوميتي العائدة للكريتاسي الأوسط والجوراسي وتعتبر من أهم مجموعات المياه الجوفية في الجمهورية العربية السورية وأهم ينابيعها: عين الفيجة، عين التنور[٥]، عين الساخنة، تل العيون، بانياس، بردى، البارد، السن.

دال- الناعـــور

إدارة المصادر المائية في الجمهورية العربية السورية[٦]

تقوم وزارة الري في الجمهورية العربية السورية بإدارة المصادر المائية وفق نظام متكامل كما ورد في قانون إحداثها حيث تتولى المهام التالية:

١- دراسة الموارد المائية في القطر ومتابعة قياسها وتنميتها وحمايتها ومنع تلوثها وتحديد أوجه الاستفادة منها.
٢- دراسة وتصميم مشاريع الري والصرف وما يتبعها من انشاءات الري والصرف والسدود.
٣- تشغيل شبكات الري والصرف ومحطات الضخ وصيانة منشآتها وشبكاتها الرئيسية.
٤- استزراع الأراضي المستصلحة واستثمارها خلال فترة استزراعها.
٥- اقتراح الخطط والسياسة الاقتصادية الزراعية والاجتماعية.
٦- اعداد وتأهيل مساعدي المهندسين والفنيين في مجال اختصاصها.

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(٤) يوجد النبع الأول في أواسط الصين ويقدر تصريفه بـ (٧٠) م٣/ثا.
(٥) تتفجر عين التنور من طبقات النيوجين إلا أن لها تغذية اضافية من الكريتاسي.
(٦) المرجع ٣.

والادارة المتكاملة للموارد المائية في الجمهورية العربية السورية يرسمها ما يلي:

(أ) الهيكل التنظيمي لوزارة الري والذي يتألف إضافة الى السيد الوزير ومعاونوه ومكاتبهم من مديريات مركزية متخصصة ومؤسسات عامة كبرى ومديريات عامة للأحواض المائية.

(ب) اعتماد مبدأ الادارة المتكاملة للحوض الواحد، وليس تبعا للتقسيمات الادارية وبالتالي فإن كثيرا من الأحواض تقع أجزاء منها في أكثر من محافظة، وبالتالي فإن هذا الأسلوب يسهل عملية التخطيط المتكامل لحصر الموارد المائية واستثمارها وحمايتها من التلوث.

(ج) التشريعات المائية الحديثة:

ركزت وزارة الري منذ إحداثها على إصدار تشريعات مائية حديثة (أتت نتيجة تطور طبيعي للتشريعات المائية القديمة الموجودة) متكاملة تعتبر أداة لتنفيذ السياسات المائية والتي تهدف الى تحقيق إدارة مثلى للموارد المائية لكافة الأنشطة المتعلقة بتنمية وتطوير واستعمال الموارد المائية والحفاظ عليها وترشيد استهلاكها وحمايتها من التلوث إضافة الى ما ذكر، فإن هناك تجربة رائدة في الجمهورية العربية السورية في إقامة السدود، فقد بلغ عدد السدود المنفذة (كبيرة ومتوسطة وصغيرة) حتى الآن ١٣٩ سدا والجدول ٢ يوضح مواصفات بعض تلك السدود.

وهي في نطاق السياسة المائية المحكمة للاستفادة من كل قطرة ماء في الجمهورية العربية السورية إضافة الى انشاء أقنية الري بشبكاتها المختلفة وبصورة متكاملة لتحقيق الادارة المتكاملة للمياه بما يكفل أكبر انتفاع ممكن منها.

هاء- الاحتياجات المائية في الجمهورية العربية السورية[٧]

الجدول ٣ يوضح تطور استعمالات المياه مع الزمن في الجمهورية العربية السورية وتقدير الاحتياجات المائية حتى عام ٢٠٢٥ ومن الجدول السابق نبين ما يلي:

(أ) ان استعمال المياه للري تتطور من ٤٥١ مليون م٣ عام ١٩٧٠ الى ١٣٦١٨ مليون م٣ هذا العام ١٩٩٥.

(ب) ان استعمالات المياه للأغراض المنزلية بما فيها مياه الشرب بلغت ٢٩٧ مليون م٣ عام ١٩٧٠ تتطور الى ٧٧٣ مليون م٣ عام ١٩٩٥، وستتزايد لتصل الى ٣١٤٥ مليون م٣ عام ٢٠٢٥.

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(٧) المرجع ٧.

(ج) وبالنسبة للصناعة فإن التطور يساير ما ذكر أعلاه فهي عام ١٩٧٠ (٤٦ مليون م٣) وفي عام ١٩٩٥ تبلغ ١٧٥ مليون م٣ وتقديرات عام ٢٠٢٥ تشير الى رقم ١٢٩٧ مليون م٣. وفي هذا البند نستنتج أنه ومنذ السبعينات قد تضاعف مساحة الأراضي المروية من ٥٠٠ ألف هكتار الى أكثر من ١٢٥٠ ألف هكتار عام ١٩٩٥.

واو- العجز في إمدادات المياه

بالمقارنة بين المصادر المائية في الجمهورية العربية السورية ٩ر٩ مليار م٣ عدا الفرات ودجلة والاحتياجات المائية لعام ١٩٩٥ التي تبلغ ١٣٦١٨ مليون م٣ ولعام ٢٠٠٠ تبلغ ١٦٥٤٣ مليون م٣، نرى بوضوح أن الموارد المائية الداخلية في حدود الاستعمال وهناك عجز في المصادر المائية لا يمكن تغطيته إلا عن طريق الحصة العادلة والمعقولة من مياه نهر الفرات ودجلة ومن هنا تأتي علاقة التخطيط للتنمية الاقتصادية والاجتماعية في الجمهورية العربية السورية بتلك الحصة إذ لا سبيل آخر لذلك، وبهذا أكد السيد وزير الري في الجمهورية العربية السورية "المهندس عبدالرحمن مدني" من خلال كلمته التي ألقاها بمناسبة انعقاد الاجتماع الوزاري الثلاثي الأول (تركيا، الجمهورية العربية السورية، العراق) عام ١٩٨٨ في أنقرة ما يلي: (ومع القناعة التامة بالأهمية البالغة التي تتمتع بها مياه نهر الفرات بالنسبة للبلدان الثلاثة المشتركة نشير الى الأهمية الاستثنائية لمياه هذا النهر بالنسبة للقطر العربي السوري، نظرا لأن هذه المياه تشكل الكتلة الأساسية من الموارد المائية في قطرنا وهو وحده المسؤول عن مقولة (الأمن الغذائي الوطني لدينا)[٨].

زاي- لمحة عن وضع وحالة الخطط الرئيسية للمياه الوطنية لا سيما التي لها علاقة بخطط تنمية الاقتصاد الوطني على مستوى القطر

أدركت الجمهورية العربية السورية أهمية المياه في كافة مجالات الحياة (الاقتصادية والاجتماعية) واعتبرتها أساسا للتنمية لذلك ومن هنا عملت منذ الستينات على إقامة المشاريع المائية وخططت لإقامة مشاريع مائية مستقبلية ضمن الخطط الخمسية المتلاحقة التي بدأتها عام ١٩٦١ والتي تعكس جزء[٩] من التصورات بعيدة المدى والتي تتعلق بأهداف التنمية واستراتيجيتها.

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(٨) المرجع رقم ٦.

(٩) المرجع رقم ٧.

Table D/Tableau D -٢ الجدول

No	Name of dam	Name of basin	Length m	Height m	Area of lake ha	Capacity hm^3	Purposes of dam	Year of completion
1	Tabqa	Euphrates	4 500	60	64 000	14 100	Irrigation 640000 ha Electricity	1978
2	Rastan	Orontes	382	67	2 100	228	Irrigation - Electricity	1960
3	16 November	Coastal	854	52	1 100	215	Irrigation 14430 ha	1985
4	Qattina	Orontes	1 120	7	6 000	200	Irrigation 6000 ha	1969*
5	7 April	Tigris Khabur	6 370	26	3 100	200	Irrigation 48000 ha	1990
6	Baath	Euphrates	2 650	14	2 715	93-24	Electricity	1989
7	8 Mars	Tigris	2 860	30	1 020	90	Storage	1990
8	Mehardeh	Orontes	228	41	450	67	Irrigation - Electricity	1960
9	Assafan	Tigris Khabur	512	35	407.5	50	Irrigation 2000 ha	1983
10	Koudana	Yarmuk	2 990	29	318	30	Irrigation 4000 ha	1992
11	Qastoun	Orontes	1 850	20	35	27	Irrigation 4400 ha	1992
12	Babal Hadid	Tigris Khabur	610	22	3 200	23	Irrigation 2250 ha	1972
13	Almuayzlieh	Steppe	955	18	40	21	Irrigation - Cattle Watering	1992
14	Sahor Aljoulan	Yarmuk	3 259	29	260	20	Irrigation 18000 ha	1992
15	Aljarrahi	Tigris Khabur	675	30	205	19.5	Irrigation 1900 ha	1980
16	Jabal al-Arab	Yarmuk	700	20	260	19.5	Drinking water	1978
17	Balloran	Coastal	330	34	112.5	15.5	Irrigation 1200 ha	1978
18	Deraa al-Sharki	Yarmouk	208	35	136.5	15	Irrigation 1200 ha	1970
19	Taldou	Orontes	1 169	23	165	15	Irrigation 2200 ha	1975
20	Shikh Miskin	Yarmouk	1 640	17	322	15	Irrigation 1100 ha	1982
21	Alhwaiz	Coastal	302	35	95	12	Irrigation 400 ha	1986
22	Saladin	Coastal	600	41	90	10	Irrigation 1110 ha	1986

(*) In 1976 the height of the dam has been increased by 2 m.

المرجع رقم (٥).

الجدول ٣- تطور استعمالات المياه مع الزمن في الجمهورية العربية السورية

السنوات	عدد السكان (بالمليون)	إجمالي المساحات المروية (ألف هكتار)	استعمالات المياه (مليون م٣/السنة)			الاجمالي
			الــري	الشرب	الصناعة	
١٩٧٠	٦٢٥٧	٤٥١	٤٥١٠	٢٩٧	٤٦	٤٨٥٣
١٩٧٥	٧٣٨٠	٥١٦	٥١٦٠	٣٥٠	٥٤	٥٥٦٤
١٩٨٠	٨٧٠٤	٥٣٩	٥٣٩٠	٣٩٨	٦١	٥٨٤٩
١٩٨٥	١٠٢٦٧	٦٥٢	٦٥٢٠	٤٨٧	٧٥	٧٠٨٢
١٩٨٦	١٠٦١٢	٦٥٢	٦٥٢٠	٥٦٩	١٢٧	٧٢١٦
١٩٨٧	١٠٩٦٩	٦٥٤	٦٥٤٠	٥٨٨	١٣٢	٧٢٦٠
١٩٨٨	١١٣٣٨	٦٥٠	٦٥٠٠	٦٠٨	١٣٧	٧٢٤٥
١٩٨٩	١١٧١٩	٦٧٠	٦٧٠٠	٦٢٩	١٤١	٧٤٧٠
١٩٩٠	١٢١١٦	٦٩٣	٦٩٣٠	٦٥٠	١٤٦	٧٧٢٦
١٩٩١	١٢٥٢٩	٧٨٨	٧٨٨٠	٦٧٢	١٥١	٨٧٠٣
١٩٩٢	١٢٩٥٨	٩٠٦	٩٠٦٠	٦٩٥	١٥٦	٩٩١١
١٩٩٣	١٣٣٩٣	١٠١٣	١٠١٣٠	٧١٩	١٦١	١١٠١٠
١٩٩٤	١٣٨٤٤	١١٥٩	١١٥٩٠	٧٤٣	١٦٧	١٢٥٠٠
١٩٩٥	١٤٣٤٢	١٢٦٧	١٢٦٧٠	٧٧٣	١٧٥	١٣٦١٨
٢٠٠٠	١٧٥٠٠	١٤٨٢	١٤٨٢٠	١٢٧٦	٤٤٧	١٦٥٤٣
٢٠٢٥	٣٨٦٧٩	-	-	٣١٤٥	١٢٩٧	-

الجدول ٤- نسبة تطور استعمالات المياه مع سنة الأساس ١٩٩٥

١٩٧٠	١٩٧٥	١٩٨٠	١٩٨٥	١٩٩٠	١٩٩٥
٣٥ر٦	٤١	٤٣	٥٢	٪٥٧	٪١٠٠

نستعرض هنا باختصار الأسس التي تـُبنى عليها تلك الخطط:

من أهداف الخطة الخمسية:

(أ) <u>أهداف عامة</u>: وضع استراتيجية للعمل على:

- إدخال مساحات جديدة في الاستثمار لتحقيق الأمن الغذائي؛

- حماية المصادر المائية من التلوث؛
- زيادة مصادر توليد الطاقة؛
- درء الفيضان الناجم عن السيول؛
- تنمية الثروة السمكية والحيوانية؛
- تحقيق استقرار السكان وتحسين وضعهم الاجتماعي والمعاشي؛
- تشغيل اليد العاملة؛
- إعادة استعمال المياه العادمة الناتجة عن الصرف بأنواعه.

(ب) أهداف محددة: تهدف الخطة بشكل مخطط لاستيعاب الموارد المائية بشكل كامل وتخزينها وحمايتها واستثمارها بالشكل الأمثل، وبالتالي زيادة رقعة المساحات المروية وكذلك استثمار المياه الجوفية بحدود المتجدد منها وبعقلانية، كما تهدف الخطة الى حسن أداء المنشآت من خلال الصيانة الدورية لها وزيادة في الحرص على نجاح وفعالية المشاريع وحسن استثمارها فقد تم مؤخرا إحداث مركز البحوث المائية في وزارة الري، لإعداد الدراسات والبحوث والنماذج الرياضية وأعمال التحريات وذلك لتقديم الحلول الفنية والاقتصادية أي أن وضع الخطط المائية مرتبط بجملة أمور هدفها الرئيسي تحقيق الأمن الغذائي لتأمين حياة كريمة للمواطن.

وكان من ثمار هذا النسيج المترابط بين التخطيط للحفاظ على الموارد المائية وتطويرها وخطط التنمية الاقتصادية، زيادة حجم الاستثمارات الاقتصادية الى عشرات الأضعاف خلال فترة لا تتجاوز العشر سنوات ضمن نظام التعددية الاقتصادية الذي تنتهجه الجمهورية العربية السورية الآن.

٨- إسقاط الواقع الفعلي للخطط الرئيسية للمياه على الأهداف الواردة في جدول أعمال القرن ٢١ الفصل ١٨ والفصل ٨.

(الى أي مدى تم إدخال الأهداف الواردة في الفصل ١٨ وفي الفصول الأخرى المتعلقة بمسائل المياه العذبة في جدول أعمال القرن ٢١ ضمن الخطط الرئيسية للمياه الوطنية وخطط التنمية الاقتصادية).

ان جميع الأبحاث الواردة في جدول أعمال القرن ٢١ المتعلقة بالمياه لاسيما الفصل رقم ١٨ أتت في إطارها الشامل والدقيق وضمن منهج يمكن معه التعرف بسهولة على ما سيتم على الصعيد الوطني بعد إسقاط النصوص على الواقع الفعلي كما أنها اتسمت بنظرة بعيدة تحفظ حق الأجيال القادمة بحياة كريمة بعيدة قدر الإمكان عن التلوث ومسبباته، ولا ضير إذا قلت أنه يصعب في عجالة كهذه أن تأتي لتنفيذ كل ما ورد بها بندا بندا وهنا أرى أن تكثيف اللقاءات كهذه، لإعطاء مزيد من الفرص أمام الجهود الفنية الوطنية لتوضيح رأيها ومن هنا نميز بين أمرين:

(أ) النصوص الواردة في جدول أعمال القرن ٢١ التي تحتاج الى تعديل جذري؛
(ب) النصوص الواردة في جدول أعمال القرن ٢١ التي تحتاج الى مناقشة؛

(أ) النصوص الواردة في جدول أعمال القرن ٢١ التي تحتاج الى تعديل جذري

(١) هناك تعبير أُستخدم بشكل متكرر في الفقرات التالية من الفصل الثامن عشر وهو "المياه العابرة للحدود".

الفقرة ١٨-٤ السطر الأول منها
الفقرة ١٨-٢٠ السطر الأول منها
الفقرة ١٨-٢٣ السطر الرابع منها
الفقرة ١٨-٢٧ (رابعا)
الفقرة ١٨-٥٠ (ح-١)

ان هذا التعبير ليس له وجود في مبادىء القانون الدولي وليس له وجود في ٣٠٠ اتفاقية دولية عُقدت في العالم وصُدقت وسُجلت في الأمم المتحدة، وقد جاء هنا للدلالة عن معنى ما. نؤكد هنا على ضرورة استبداله بعبارة (المياه الدولية المشتركة)، ولعل ما يؤكد على صدق حدسنا وريبنا من المعنى الذي أتى به هو الفقرة رقم ١٨-٢٣ التي نصت علي ما يلي:

(وتتطلب قضايا المياه العذبة والعابرة للحدود العالمية...) حيث فصلت العبارة بصراحة ما بين المياه العابرة للحدود (حسب المفهوم أعلاه). والمياه العالمية (الدولية) وهذه مخالفة لأبسط التعاريف للمجرى المائي الدولي الواردة في مبادىء القانون الدولي وقواعد هلسنكي وتوصيات سالزبورغ وغيرها.. وللبيان على ذلك نشير الي ما ورد في المادة (٢) الفقرة (ب) من مشروع قانون استخدام المجاري المائية الدولية في الأغراض غير الملاحية الذي أُعتمد في قراءته الثانية من قبَل لجنة القانون الدولي ورفعته الى الجمعية العامة لدراسته والنظر فيه في أيلول/سبتمبر ١٩٩٦ باعتباره (اتفاقية إطار شامل) وهي:

(المجرى المائي الدولي هو شبكة المياه السطحية والمياه الجوفية التي تشكل بحكم علاقتها الطبيعية ببعضها البعض كلا واحدا وتتدفق عادة صوب نقطة وصول مشتركة)[١٠].
وكمثال آخر على أهمية استبدال تعبير المياه العابرة للحدود بتعبير المياه الدولية المشتركة ما ورد في الفقرة (١٨-٢٧)أ (الإطار المؤسسي) ليصبح كما يلي:

(التعاون على تقدير الموارد المائية الدولية المشتركة، رهناً بإبرام اتفاق مسبق مع كل دولة من الدول المتشاطئة المعنية بالأمر).

كما ورد في كتاب الأمانة التنفيذية للإسكوا المؤرخ في ٧ حزيران/يونيو ١٩٩٥ والمذكرة المرفقة به عبارة (منطقة الإسكوا).

نقترح استبدال هذا التعبير (بالدول الأعضاء في الإسكوا) أينما ورد.

(٢) المجالات الرئيسية التي وردت في البرنامج (الفصل ١٨) وإسقاطها على الواقع الفعلي

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(١٠) المرجع ٨.

المقدمة:

- ألف: التنمية والإدارة المتكاملتان لموارد المياه؛
- باء: تقييم الموارد المائية؛
- جيم: حماية موارد المياه ونوعية المياه والنظم الايكولوجية المائية؛
- دال: توفير مياه الشرب والمرافق الصحية؛
- هاء: المياه والتنمية الحضرية المستدامة؛
- واو: الماء من أجل الانتاج الغذائي والتنمية الريفية المستدامة؛
- زاي: آثار تغير المناخ على موارد المياه.

المقدمة:

نؤكد على ما جاء في المقدمة (الفصل ١٨) حول النقاط التالية:

(أ) ان الادارة المتكاملة لموارد المياه على نحو فعال هي أمر هام لجميع القطاعات الاجتماعية والاقتصادية التي تعتمد على المياه؛

(ب) الماء مورد محدود لا بد منه لبقاء الحياة على الأرض؛

(ج) تتسم المياه الدولية المشتركة واستخدامها بأهمية كبيرة بالنسبة للدول المشاطئة المعنية وأهمية التعاون بين تلك الدول عبر اتفاقات تأخذ في الاعتبار مصالح جميع الدول المشاطئة المعنية؛

(د) أهمية بناء القدرة كشرط مسبق للإدارة المتكاملة لموارد المياه وفي هذه المقدمة وضمن الأهداف العامة التأكيد من أن تتوفر لسكان هذا الكوكب جميعا إمدادات المياه الجيدة النوعية:

وقد قامت الجهات المعنية بالجمهورية العربية السورية بتنفيذ مشاريع، والتخطيط لتنفيذ مشاريع لإمدادات مياه الشرب للسكان لما بعد عام ٢٠٢٠ ضمن عمليات البحث والاستكشافات لمصادر بديلة أو رديفة سواء عن طريق الاستفادة من كامل طاقة بعض الينابيع أو عن طريق ايجاد مصادر جوفية أو عن طريق التغذية الصناعية لطبقات المياه الجوفية وقد تصدر هذا الجانب أولى اهتمامات وزارة الري.

ألف- التنمية والادارة المتكاملتان لموارد المياه

نؤكد على تلازم التنمية والادارة المتكاملتان لموارد المياه بغية تحقيق أكبر انتفاع ممكن ووضع هذا الأمر ضمن إطار السياسة الاقتصادية والاجتماعية الوطنية ولتحقيق ذلك قامت الجهات المعنية بالأنشطة التالية:

- أُحدثت الهياكل التنظيمية لوزارة الري؛

- أحدثت وزارة الدولة لشؤون البيئة؛

- قامت بتحديث التشريعات المائية باعتبارها أداة لتنفيذ السياسات المائية وفي طريقها لاستصدار صكوك أخرى هامة ذات الصلة وبالتالي فإنها ستدخل القرن ٢١ وهي مستعدة تنظيميا وقانونيا لمواجهة إدارة المصادر المائية.

تعمل لاستحداث قواعد بيانات تفاعلية عبر دوائر الكومبيوتر المختصة بالرغم من أنها في بداياتها الآن وتسعى لتطويرها.

- باعتبار أن أهم عنصر في إدارة الفيضانات والجفاف هو التحكم بالفيضانات لاستخدامها أوقات الجفاف هو بناء السدود وقد قطعت الجمهورية العربية السورية، شوطا طويلا في هذا المجال؛

- قامت بتجهيز موقع المزرعة بدمشق لإعادة شحن المياه الجوفية بالطرق الصناعية؛

- قامت على صعيد إعادة استخدام المياه العادمة بالاشراف على الانتهاء من انشاء محطة المعالجة للمياه العادمة لمدينة دمشق بالقرب من (موقع عدرا) وهي تسعى لتطبيق نفس الأسلوب لمدينة حلب وهكذا ضمن الامكانيات المادية للسعي لنقل ذلك الى جميع مدن القطر.

- وفي مجال بناء القدرات تتوفر لدى الجمهورية العربية السورية تجربة جيدة في مجال إشراك مجالس التنمية القطاعية المنظمات الشعبية والنقابات المهنية "لجان المجتمعات المحلية" (اتحاد الفلاحين، مجالس الإدارة المحلية بالمدن، المكاتب التنفيذية...).

باء- تقييم موارد المياه

قامت الجمهورية العربية السورية بالتعاون مع بعض المؤسسات العالمية بدراسة الأحواض المائية فيها لتقييم مواردها المائية، وربطت مجاري الأودية والأنهار بشبكات رصد (محطات قياس) كما حفرت مجموعة آبار لمراقبة المياه الجوفية، وقد سهّل ذلك تطبيق النظام المتكامل لمجرى النهر الواحد عبر مديريات الري العامة، كما بدأت بعد إحداث مركز الكومبيوتر بالتخطيط لأرشفة بعض المواد ولكنها في بداية الطريق وتعمل الى تطوير وتوسيع شبكة الكومبيوتر لتصل الى المديريات المركزية.

أما على صعيد وسائل التنفيذ:

ان جميع الموارد المائية في الجمهورية العربية السورية تُدار بالخبرات الوطنية والجهات المختصة تعمل لـــ:

- توسيع شبكة الكومبيوتر ضمانا لانقاذ البيانات؛
- الى استنباط نماذج هيدرولوجية عالية بهدف دعم تحليل تأثير تغير المناخ وتقييم الموارد المائية؛
- المزيد من الدورات الدراسية والاطلاعية لتنمية الكوادر البشرية.

جيم- حماية الموارد والمياه ونوعية المياه والنظم الايكولوجية

دور وزارة البيئة:

١- في مجال مكافحة التلوث الصناعي تم التنسيق والتعاون بين البيئة والـــ (UNDP) لتمويل دراسة محطة معالجة لمياه الدباغات في منطقة الزبلطاني بدمشق حيث يبلغ عددها ٢١٥ دباغة والآن نحن في صدد البحث عن تمويل لتنفيذ هذه الدراسة.

٢- وقد وضعت وزارة البيئة بالتعاون مع الجهات الحكومية الأخرى مواصفة للمياه الصناعية المسموح بالقائها الى مجرور الشبكة العامة. ونحن نأمل باستكمال هذه المواصفة لتشمل كافة المياه الصناعية وذلك بالتعاون مع الخبرات الدولية.

٣- وقد أصدرت وزارة البيئة المواصفة السورية لمياه الشرب وذلك بالاعتماد على دليل جودة مياه الشرب لمنظمة الصحة العالمية.

٤- تقوم حاليا بتحديد حرم المصادر المائية لحمايتها على نطاق القطر.

كما قامت وزارة الري عبر مديرية مكافحة تلوث المياه العامة برصد نوعية المياه والوقوف على أسباب تردي تلك النوعية.

نؤكد على أهمية تطبيق مبدأ (الملوث يدفع) على جميع أنواع المصادر، كما نؤكد على الطلب الى أصحـــاب المصانع الكبيرة تأسيس محطة معالجـــة نوعية لمنع المزيد من الملوثات.

دال- توفير مياه الشرب والمرافق الصحية

كما ذكرنا في التعليق على مقدمة هذا الفصل فإن هناك مخططات طموحة واسعة للتغيير بشبكات ماء الشرب والصرف الصحي، وقد بدأت الخطوات العملية فعلاً منذ سنوات قليلة خلت لتحويل شبكات الصرف الصحي لمحافظة دمشق لتصل الى محطة المعالجة في (عدرا).

هاء- المياه والتنمية الحضرية المستدامة

تم إدخال مفهوم تقييم الآثار البيئية لكافة المشاريع ويجري تطبيقه حاليا عبر وزارة البيئة وذلك بهدف الوصول الى تنمية حضرية مستدامة.

تقوم حاليا وزارة الدولة لشؤون البيئة بتطبيق التخطيط المتكامل البيئي ووضع خطط إدارة الموارد الطبيعية واستعمالات الأراضي، كما قامت بدراسة المناطق العشوائية الناجمة عن التحضر السريع لوضع الحلول والاجراءات المطلوب تنفيذها في هذه المناطق وخاصة إدارة الموارد وحماية المياه.

ونؤكد على ما جاء في هذه الفقرة ونسعى لتطبيق النشاطات الواردة وبشكل خاص حماية دول المجرى الأسفل من الأنشطة الضارة التي تقوم بها دول المجرى الأعلى.

واو- الماء من أجل الانتاج الغذائي والتنمية الريفية المستدامة

لا شك عندما يرتبط الأمر بالانتاج الغذائي فإنه يصبح أكثر دقة وحرصا على توفير الغذاء والوصول به الى الاكتفاء الذاتي بالاعتماد على القدرات والامكانيات الوطنية، ولهذا فإن معظم مشاريع الري الزراعية تقع في المناطق الريفية، لذلك تأتي العناية بهذه الأخيرة كنتيجة طبيعية ضمن السياق القاضي بتطوير مشاريع الري، كما أن هناك مجالس ريفية (فلاحية، تعاونيات...) تعنى بهذه الأمور إضافة الى أن تطبيق أسلوب الادارة المتكاملة للحوض المائي يغطي باهتمام هذه الثغرة بالريف.

زاي- آثار تغير المناخ على موارد المياه

بالتأكيد هناك نوعا من الافتقار الى اليقين فيما يتعلق بالتنبؤ بتغيرات المناخ لما شهده العالم من صدق هذه المقولة في الآونة الأخيرة، وكثيراً ما يخطط للقيام بنشاطات مرتبطة بالمياه (زراعة...). على أساس أن هناك احتمال سنة مائية رطبة إلا أن النتائج أو الواقع الفعلي قد تأتي بالعكس.

تم إجراء دراسة أثر التغيرات المناخية المتوقعة على المنطقة الساحلية وقد أُخذ بالاعتبار افتراضات الأمم المتحدة حيث اعتبرت أنه من المتوقع ارتفاع درجة الحرارة ما بين ٥ر١ - ٣ د.م وارتفاع منسوب البحر من ٦٠ - ١٠٠ سم وقد أظهرت هذه الدراسة بأن هناك بعض المناطق من الساحل السوري سيتم غمرها وان ارتفاع ١ م من سطح البحر سيؤدي الى تداخل مياه البحر مع المياه الجوفية الأمر الذي سيؤدي الى تملُّح هذه المياه وفقدان قيمتها في الري.

(ج) <u>الفصل رقم ٨ إدماج البيئة والتنمية في صنع القرار</u>

انه بحث متكامل إلا أنه يتطلب تعديل الفقرة (ب) من المادة (٨-٢٣) حول "القضايا العالمية والعابرة للحدود" واستبدالها "بالقضايا الدولية المشتركة".

٩- تحديد العوائق الرئيسية لإدخال تلك الأهداف ضمن الخطط الرئيسية للمياه الوطنية وخطط التنمية الاقتصادية وإمكانية مواجهة تلك العوائق.

(أ) ان وسائل التنفيذ التي وردت في جدول أعمال القرن ٢١ التي تمكن من تحقيق الأهداف التي وضعت بشكل مفصل تتعلق بنقاط أربع:

- التمويل وتقدير التكلفة؛
- الوسائل العلمية والتكنولوجية؛
- تنمية الموارد البشرية؛
- بناء القدرات.

ان النقاط المشار اليها أعلاه يتم تطبيقها بما يتواكب مع التطورات التنموية القائمة سواء بالدعم بأجهزة حديثة أو تنمية الموارد البشرية عن طريق الدورات والمنح وذلك وفق سياسة مدروسة بدقة.

١٠- خاتمـــــة

نرى أن ما ورد في جدول أعمال القرن ٢١ من توصيات، بأنها عامة وشاملة أتت بالتفصيل على كل ما هو ضروري للاستفادة منها عند وضع الخطط وهذا ما تقوم به الجمهورية العربية السورية، لأن مبادىء وأسس وضع الخطط لديها ينسجم مع ما هو وارد في تلك التوصيات.

نؤكد ختاما على إجراء تعديلات جذرية في النصوص التي وضحناها سابقا وخاصة تعبير المياه العابرة للحدود.

المراجع باللغتين العربية والانكليزية(*)

١- السياسة المائية في الجمهورية العربية السورية وأبعادها الاستراتيجية مؤتمر الموارد المائية للدول العربية وأهميتها الاستراتيجية، "المهندس عبدالعزيز المصري" "الجيولوجي نضال تقي الدين".

٢- مذكرات حول الأنهار في الجمهورية العربية السورية، إعداد وزارة الري عام ١٩٨٣ وعام ١٩٩٥.

٣- An overview of water resources in Syria and its management (Regional Conference on Water Resources Management [WRM] 95).
Isfahan - Irak (August 28. 30. 1995), by Eng. Abdul Aziz Al-Masri and Eng. Mohammed Al-Hasbani.

٤- استعمالات المياه في الجمهورية العربية السورية، إعداد الدكتور منير أشلق لاجتماع مؤتمر المنظمة العربية للتنمية الزراعية، القاهرة، ٢٩-٣١ تموز/يوليو ١٩٩٥.

٥- .Water from Dams in Syria CIGB, Cold 1993

٦- تقرير عن الاجتماع الوزاري الثلاثي (الجمهورية العربية السورية، العراق، تركيا) أنقرة، ١٩٨٨.

٧- دراسة اقتصادية عن مشاريع الري والمياه بالجمهورية العربية السورية إعداد المهندس جمال دحروج.

٨- مشروع قانون استخدام المجاري المائية الدولية في الأغراض غير الملاحية (منشورات الأمم المتحدة).

إضافة الى المراجع التالية:

٩- التخطيط الشامل لاستثمار مياه حوض العاصي، إعداد المهندس عبدالعزيز المصري، قدم الى ندوة حمص، ١٩٨٨.

١٠- وثائق قمة الأرض في ريو دي جانيرو.
١١- الخطط الخمسية السورية لاسيما السادسة والسابعة.
١٢- أرشيف المياه الدولية المشتركة بوزارة الري.
١٣- اجتماعات اللجنة الاستشارية القانونية الأفرو آسيوية، الدورة ٣٤، (الدوحة، قطر).

(*) لم يتم التحقق من المراجع.

XX. NATIONAL REPORT: WATER RESOURCES IN THE UNITED ARAB EMIRATES

by

*Mohammed Saeed Abdullah**

The United Arab Emirates is situated in the south-eastern corner of the Arabian Peninsula. Like other countries in the region, it has a hot, dry climate and very erratic and meager rainfall. The average annual rainfall is about 100 mm and varies from 50 mm in the south-western desert to 160 mm in the northern and eastern mountainous regions (chart 1). In the absence of perennial surface water resources, the country depends on groundwater for all its agricultural water as well as domestic in the rural areas. In big cities such as Abu Dhabi and Dubai, the municipal supply needs are mainly met through desalinated water.

A. PRESENT WATER RESOURCES POTENTIALITIES

The water resources of the United Arab Emirates can be grouped into two categories: conventional and non-conventional.

1. *Conventional water resources*

(a) *Groundwater*

(i) *Quaternary aquifer*

In the absence of perennial surface water resources, the country depends on groundwater for all its agricultural and rural water supplies. The most important aquifer underlies the gravel plains. This aquifer belongs to the Quaternary age and hence is known as the Quaternary Aquifer. It is unconfined and is generally good in quality.

It is distributed all over the gravel plain from north of Ras Al Khaimah to Al Ain and along the east coast. This is the main source of the groundwater currently being abstracted. The deposits of the gravel plains have undergone important digenetic transformations which led to the formation of new weathering minerals and resulted in alteration of permeability.

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The aquifer consists of a mixture of sands, gravels and silty clay with local facies variation and lenses of impervious material. As a result of overpumping, this aquifer could dry up and its water quality could deteriorate; already, in some areas, the wells have dried up and been abandoned;

(ii) *Carbonate aquifer*

In addition to the Quaternary Aquifer the other potential aquifer is that of the carbonate rocks in the Northern mountains—Rus Al Jibal—and in the outcrops near Al Ain region. The preliminary investigations have indicated the presence of substantial amounts of water in the Karst topography. The presence of hot water springs at Khatt near Ras Al Khaimah, where the water issues directly from the limestone, having above normal groundwater temperature of about 39°C against the normal range of 28°-32°C suggests that a considerable amount of water percolates quite deep through the limestone structures. A detailed study is required to assess the full potential of the aquifer before any development programme is carried out. The other deep aquifers such as Dammam and Umm er Radhuma in the southern desert (near Liwa) were found to be highly saline.

(b) *Surface run-off*

The mean annual run-off from the wadies during the rainy season is about 120 million cubic metres. The water runs in the wadis for a period ranging from a few hours to weeks and even longer, depending upon the nature and the duration of the rainstorms. This water either drains to the sea or in the desert plains.

(c) *Falajes and springs*

The Arabic term *falaj* is defined as open channels, cut and cover aqueducts and tunnels of water, usually driven in a hillside or sloping ground where the water is found at higher head sufficient to allow gravity drainage of water to the flat low-lying areas under cultivation. Although the dependence on *falajes* for agricultural water supplies has reduced greatly with the advent of deep bore-holes pumps, there still exist about 48 *falajes* all over the country, with an annual average discharge of about 20 million cubic metres.

2. *Non-conventional water resources*

(a) *Desalinated water*

Desalinated water is the main source of the municipal and industrial supplies. The total annual production of desalinated water in 1994 was about 475 million cubic metres, with Abu Dhabi and Dubai having the largest share in the production. At present the use of desalinated water in irrigation is virtually nil because of the high cost.

(b) *Sewage effluent (recycled water)*

This is an important—but not the sole—source of irrigation water for the landscaping and beautification of the country's big cities. The total production of treated water in 1994 was about 80 million cubic metres. The major plants are in Abu Dhabi, Dubai and Sharjah. There is great potential for development in this sector, and its uses may not be limited to landscaping only as is the case currently; they could be extended further and supplement agricultural water supplies and could also be used for artificial recharge of groundwater.

3. *Priorities for water resources allocation and usage*

The top priority in water resources allocation and usage is of course municipal water supplies. Owing to quality constraints, groundwater is contributing to only a small percentage of total requirements, and by and large the municipal and industrial supply needs are met through desalinated water, as noted above. Agricultural water supply needs come next after municipal supplies and are met through groundwater. The third main sector is the landscaping and beautification of the cities. Treated water is mainly used in the big cities for irrigating lawns, roadside trees, plants and parks.

Owing to the high cost of desalination, desalinated water is not currently used in agricultural irrigation, but because of the limited fresh groundwater reserves, the future use of desalinated water for agricultural supplies cannot be ruled out. With the development of technology and the utilization of a natural source of energy—the sun—and a virtually unlimited source of raw water from the Arabian Gulf, desalination may become cheaper and the output from the desalination plants could become a major source of freshwater in the United Arab Emirates and other regions in the Gulf.

Recycled water at present is mainly used for landscaping in the cities. The present output is about 80 million cubic metres annually, which is very little compared with the total water consumption in the urban areas. There is great potential for development in this sector, and local authorities have plans to increase the production of the treated water, which could be used in the agriculture and possibly for artificial recharge if there is excess output.

With the increase of the country's cultivated area from 10,867 ha in 1977 to 65,557 ha in 1993, water consumption also increased greatly. Total groundwater consumption for agriculture afforestation is about 1 billion cubic metres annually. The Government policy of providing subsidies, extension services and other incentives to the farmers has resulted in rapid growth in the agriculture sector, but at the same time the water reserves have been affected adversely. Recognizing the effects of the water shortage on development, the concerned authorities have taken the necessary steps and adopted preventive measures to optimize the return from the investment in agriculture and prevent a decline in agricultural yield from the current levels.

B. NATIONAL STRATEGY FOR DEVELOPMENT AND MANAGEMENT OF WATER RESOURCES

Water resources in the United Arab Emirates are managed by Federal and State authorities at the national and local levels. At the national level, the Ministry of Agriculture and Fisheries, the Ministry of Electricity and Water, and the General Water Resources Authority are responsible for management of water resources, while at the local level the water departments of the respective Emirates manage the water resources. The Ministry of Agriculture and Fisheries develops and manages the agricultural water supplies and the Ministry of Electricity and Water is responsible for the drinking water supplies.

The main features of the national strategy and policy for development and management of water resources are conservation and augmentation of the water resources. Since groundwater is the main source of the water supply for agriculture, which consumes about 80% of the total amount of groundwater abstracted, it has been overpumped heavily during the past two decades.

To meet the demands of the municipal sector, the output of the desalination plants has been increased. New plants have been installed and more are planned. Similarly, the production of sewage water treatment plants has been increased and there are plans for further expansion.

To meet the shortages of agricultural water supplies, the Ministry of Agriculture and Fisheries has taken various steps, including:

(a) Application of modern irrigation systems;

(b) Construction of dams to harness the wadi run-off for recharge;

(c) Providing extension services to farmers and for research work;

(d) Carrying out investigations and surveys for the exploration of groundwater resources;

(e) Emphasizing water conservation through direct contacts and media campaigns;

(f) Environmentally controlled agricultural production;

AVERAGE ANNUAL RAINFALL IN THE UNITED ARAB EMIRATES, 1965-1994

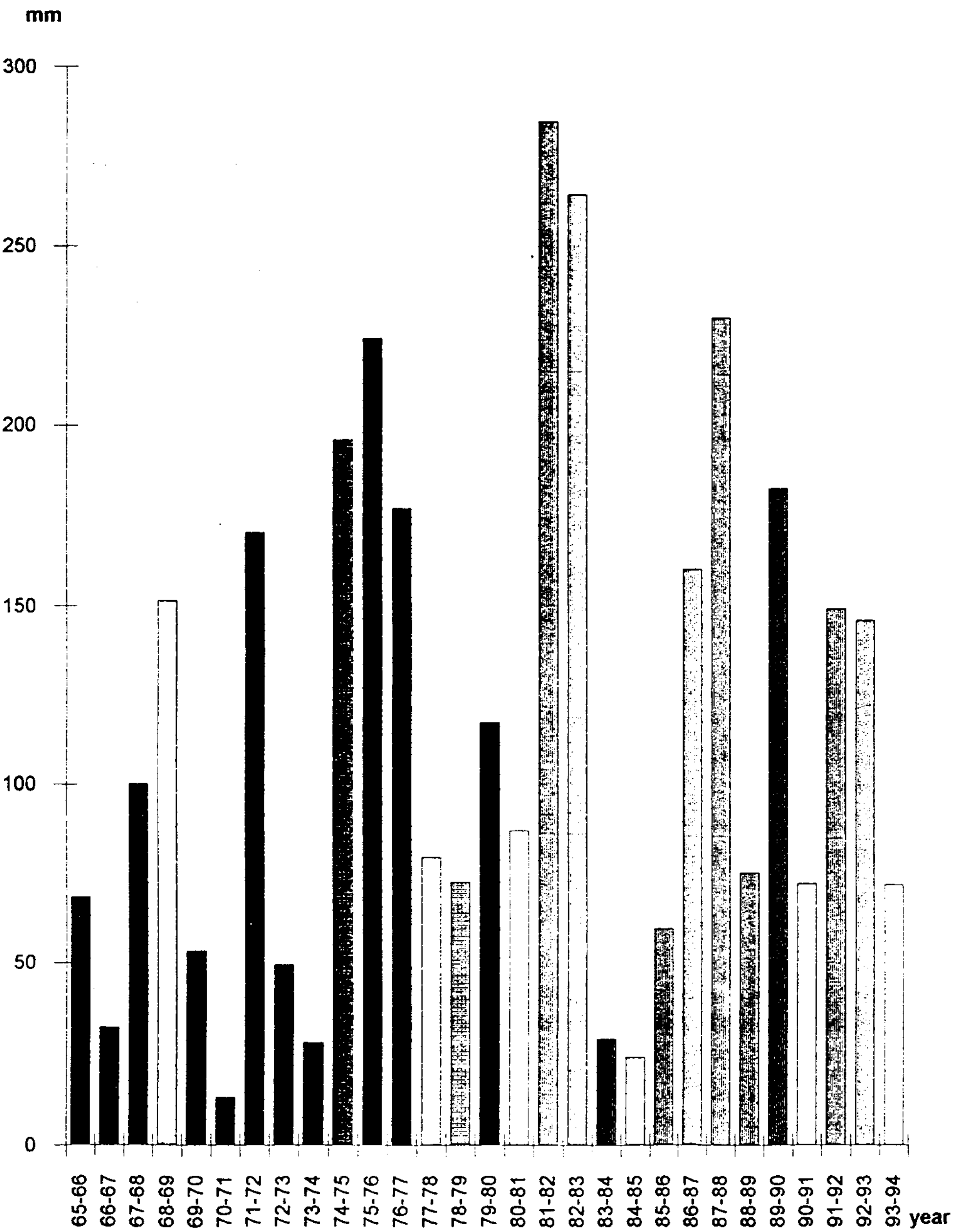

CHART 1

(g) Research on growth of salt-tolerant crops;

(h) Using management as a tool for conservation of water, and establishing computerized database and computer modelling.

1. *Modern irrigation techniques*

The most effective of the above measures is the application of a modern irrigation system. Extensive research was carried out during the period 1976-1981 to select the most suitable types of irrigation systems for the water and soil conditions of the United Arab Emirates. A pilot farm was established in 1983 to familiarize farmers with modern irrigation systems. Subsequently, a project on modern irrigation was carried out under which the irrigation network was provided to the farmers on a 50% subsidy basis. By adopting a modern irrigation system, water savings of up to 60% could be achieved compared with the traditional irrigation methods. By adopting a modern irrigation system, not only is water saved but productivity increases.

Modern irrigation, which was almost non-existent in the country before 1980, has proved very effective. Out of a total cultivated area of 65,557 ha, approximately 40,455 ha are under the modern irrigation system (chart 2).

2. *Construction of dams for groundwater recharge*

The second most important of the above measures is the construction of dams to harness floodwater during the rainy season. Dams have been constructed and more are being planned.

There are about 35 small and large dams throughout the United Arab Emirates, with a total reservoir capacity of about 70 million cubic metres. Chart 2 shows the capacity and the year of construction of some of the major dams, and chart 4 shows the flood volumes at different dams during the period 1982-1994. These dams have proved very effective in recharging groundwater, and the results of the monitoring wells at the dam sites clearly indicate that these dams are functioning effectively and contributing to groundwater recharge.

3. *Extension services to farmers*

The Ministry of Agriculture and Fisheries provides technical advice to farmers through 50 Extension Service Units, and monitors the growth of crops on farms. Irrigation engineers of the Extension Units, as well as visiting experts, play an important role in the development of irrigation systems and water conservation measures by helping the farmers in designing and installing modern irrigation systems on their farms and provide advice on the types of crops suitable to be grown in the light of experiment results. The extension officers regularly visit the farms and carry out farm surveys, collect and analyse soil and water samples, advise on irrigation scheduling and crop water requirements, and train the farmers on operation and maintenance of the irrigation networks.

RESERVOIR CAPACITY AND THE YEAR OF CONSTRUCTION OF SOME DAMS IN THE UNITED ARAB EMIRATES
(Million cubic metres)
السعة التخزينية لبعض السدود فى الدولة و تاريخ انشائها

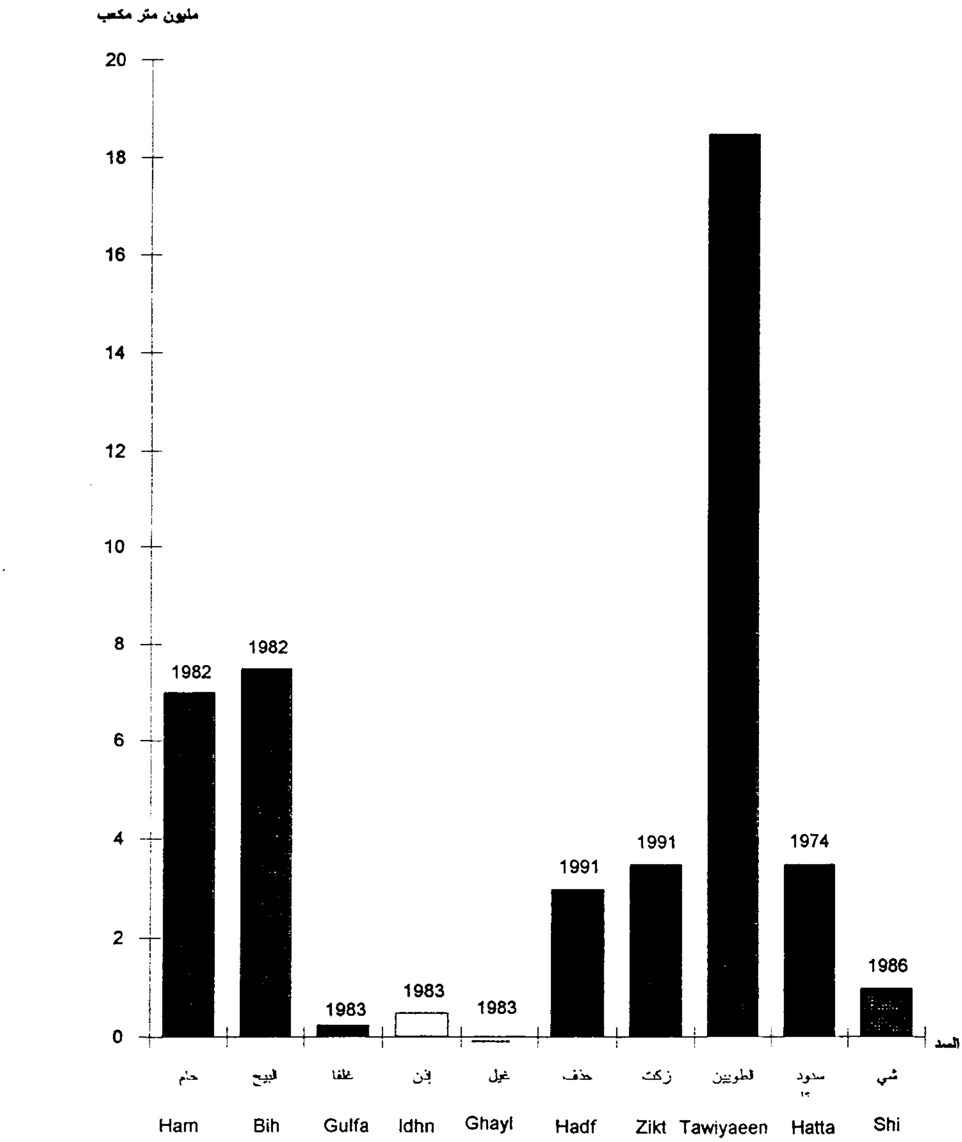

CHART 2

IRRIGATION SYSTEMS USED IN 1994

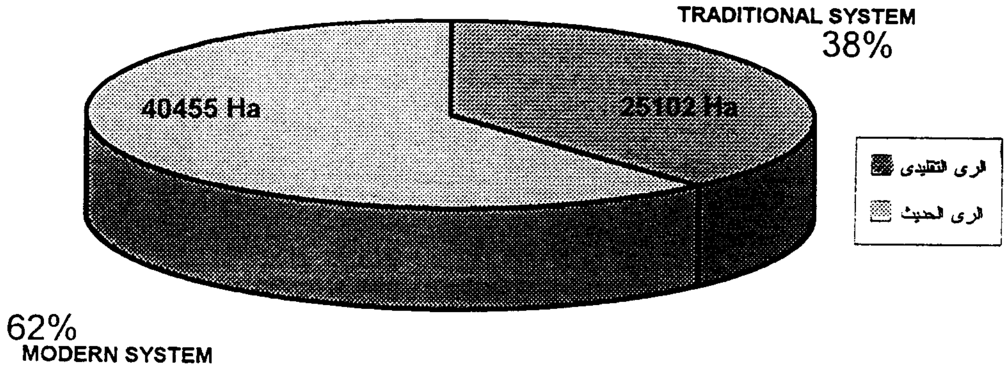

CHART 3

COLLECTED FLOOD VOLUMES OF SOME DAMS (MCM) 1982-1994

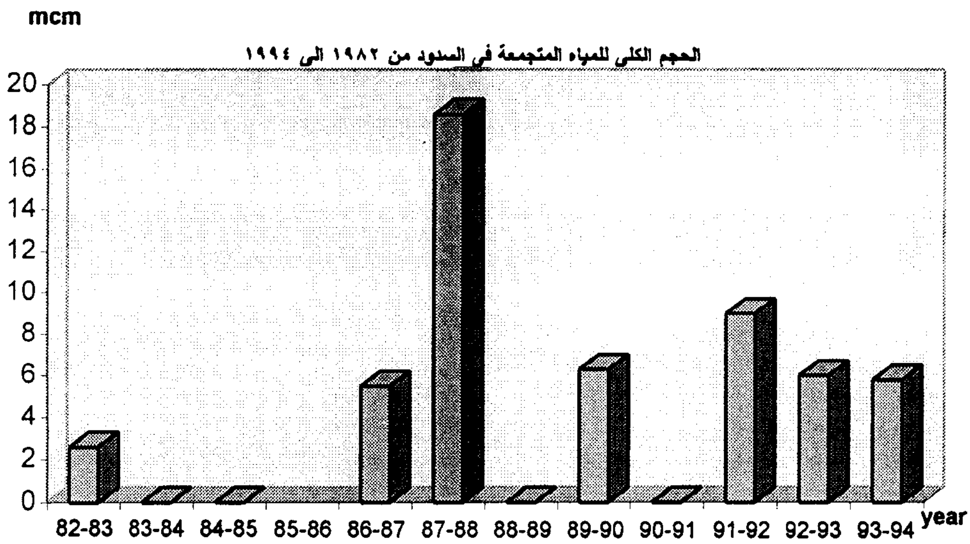

CHART 4

4. *Exploration of groundwater resources*

The main aquifer for groundwater abstraction in the United Arab Emirates, the Quaternary Aquifer, is fast being depleted because of overpumping. The search for new aquifers has remained a top priority, and all the concerned authorities have carried out groundwater studies on exploration of deep aquifers.

One such study was carried out by the Ministry of Agriculture and Fisheries in 1987, under which exploration boreholes of up to 1,000 metres in depth were drilled to explore the deep aquifers. The study covered the area from Shaam in the north to Liwa in the south-west. The study indicated the presence of good reserves in the karst topography in the limestone. A detailed study must be carried out to determine the full potential of the aquifer before any development programme is implemented in the karst region. Studies are under way in various regions for the exploration of new aquifers.

5. *Media campaigns for emphasis on water conservation*

Regular campaigns in print and the electronic media are carried out by the concerned authorities to create public awareness of water conservation and to put emphasis on the preservation of this precious resource.

Pamphlets and other literature on water conservation measures are distributed to farmers and general consumers, and on special occasions, such as World Water Day, functions are held, including exhibitions and lectures on the importance of water conservation.

6. *Environmentally controlled agriculture production*

Owing to the harsh climatic conditions in the United Arab Emirates, some vegetables are largely grown in environmentally controlled greenhouses. In 1986, there were 1,678 greenhouses in the country covering an area of about 56 ha. The number of greenhouses increased to 3,960 in 1993, covering an area of 156 ha. Farmers can grow crops in greenhouses at times when it is difficult to grow these crops in open fields. Although the production of crops under controlled environments is comparatively expensive and requires high technical levels of operation and maintenance, it is still feasible economically because of the high yield, better quality products, and savings in irrigation water, fertilizers and pesticides.

7. *Research on growth of salt-tolerant crops*

The quality of water used in agriculture is deteriorating constantly. This limits the growth of certain types of crops. Research is being carried out on a variety of local and foreign crops which can be grown using salty water. Some success has been reported, but a breakthrough has yet to be achieved.

8. *Establishment of a computerized data bank and updating information on water resources*

Better management of water resources is an important tool for conservation. For effective management, access to up-to-date data is a prerequisite. The Ministry operates a network of observation stations to collect various hydrological, meteorological and groundwater parameters and agricultural statistics. All such data available in files are being transferred to computer programs. This will provide a clear scenario and better understanding of the water situation in the country, and help in managing the water resources more effectively.

C. MAJOR WATER DEVELOPMENT PLANS

The major plans for development of water resources consist of the following:

1. *Construction of dams for harnessing the floodwater*

All the major wadis have been studied and dams have been constructed for harnessing the floodwaters to recharge underlying aquifers. The rainfall in the United Arab Emirates is meager and erratic in nature, but during the rainy season flash floods of high intensity are frequent and produce heavy run-off in the wadies. In the absence of dams or other hydraulic structures, this good quality water will drain either to the sea or into areas where it will not be beneficial.

Three dams are in the design stage at present, and construction is expected to start as soon as the designs are finalized. Under another contract, about 20 wadies will be studied with a view to developing water resources in the catchments. Based on the results of the hydrological studies, dams and other structures will be constructed at suitable sites.

A network of observation wells at major dam sites is maintained to observe the groundwater levels. The results of the observation wells are positive and indicate that the dams are functioning and serve the purpose for which they were built—recharge of the groundwater.

2. *Groundwater exploration projects*

Since groundwater is the main source of agricultural water—and the cheapest too—the authorities at the national and local levels are highly interested in developing the groundwater resources. In this regard, technical assistance has also been obtained from international agencies for implementation of the projects. Groundwater exploration projects for new freshwater aquifers are currently being implemented in various parts of the country.

D. TECHNOLOGY UTILIZATION

In spite of all the efforts to conserve and develop natural freshwater resources, it is imperative to develop non-conventional water resources and to use modern irrigation technologies to meet the water demands of an arid country like the United Arab Emirates. The fact is that there are not enough fresh groundwater resources, or that not enough have been explored yet, and the annual recharge of groundwater is only one tenth of its abstraction. In this regard, the following are the main fields of development and utilization to meet the water demands:

(a) Desalination;
(b) Sewage treatment;
(c) Modern irrigation systems.

E. HUMAN RESOURCES DEVELOPMENT

The Government is placing particular emphasis on the education and training of water management and technical staff at all levels. The professionals are trained abroad and locally, and on-the-job training is given during the implementation of the projects. Technical staff and professionals also participate in seminars and conferences to gain from the experiences of the advanced countries and to keep abreast of the latest technologies in the field. Research work and experimental projects are carried out in collaboration with the United Arab Emirates University and international agencies.

The training programme for technical staff and water managers has played an important role in capacity-building, and the training programme has been expanded and more opportunities created for in-country training as well as training abroad.

F. RECOMMENDATIONS

For strengthening cooperation between the ESCWA member countries the following recommendations are submitted:

1. Meetings should be held for the exchange of technical know-how and updating on the status of major water projects. Meetings of the water managers of the member States should be held at least once a year. This will enable the ESCWA member States to discuss management and technical matters and gain from the experience of the others.

2. Exchange visits should be conducted for technical staff of member States to see the projects in other member countries to promote technology transfer, gain first-hand knowledge and study conditions of project execution.

3. Regular visits should be made by the ESCWA experts for evaluation of planned and ongoing projects.

4. Pilot projects may be executed by ESCWA in the member countries.

XXI. THE WATER SECTOR IN YEMEN: STATUS AND OUTLOOK

by

Abdul Kareem Al-Fussail and Mohamed Al-Eryani***

Introduction

This paper outlines the major activities and developments in the water sector in Yemen over the past three years. In particular, it addresses the extent to which the various objectives of the seven freshwater programme areas of chapter 18 (Agenda 21) were achieved. The objective is to update the reader on the activities pertaining to each area and the status of the water sector in Yemen in general.

A. ACTIVITIES IN THE PROGRAMME AREAS

The seven programme areas which were proposed for the freshwater sector in chapter 18 of Agenda 21 are listed below:

1. Integrated water resources development and management.
2. Water resources assessment.
3. Protection of water resources.
4. Drinking water supply and sanitation.
5. Water and sustainable urban development.
6. Water for sustainable food production and rural development.
7. Impact of climate change on water resources.

1. *Integrated water resources development and management*

Since the early 1980s, it has been widely acknowledged that water resources planning and management tasks should be separated from water development and use activities, so that the former are undertaken nationally while the latter are undertaken by sectoral entities in accordance with nationally approved plans. Consequently, a High Water Council, supported by a Technical Secretariat which was to act as the national planning and management agency, was established. However, several factors prevented this entity from functioning as planned.

Because of this, water planning at the national level has not been practised up till now. Instead, the drinking, irrigation and industrial water projects are implemented by various public and private entities, each to serve its own sectoral objectives. In

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other words, water development projects are driven or motivated by sectoral demands and the responsibility for resource management is fragmented among numerous user sectors and entities instead of being consolidated into a single national management entity which integrates development activities with socio-economic development. In this situation, the various users are essentially focusing on resource utilization and ignoring resource management, a situation which resulted in overexploitation of finite resources.

It was not until April 1995 that the idea of an independent water management entity became politically feasible when the principal line ministry (Ministry of Agriculture and Water Resources) became convinced that water planning and management must be separated from development and use. It was agreed that a National Water Resources Authority (NWRA) would be established by merging the Technical Secretariat of the High Water Council with the other three water management and planning entities at the Ministries of Oil and Mineral Resources; Agriculture; and Electricity and Water.

Consequently, a team of professionals representing the four entities began drafting the NWRA mandate, organizational chart and other basic documents. In September 1995, the Cabinet approved the establishment of the NWRA, which was expected to be functional by early 1996. Valuable support to strengthen NWRA capacity to manage the country's water resources will be provided through a multilateral project jointly funded by the Yemeni Government, the Netherlands Government and UNDP.

According to its mandate, the goal of NWRA is to "conserve the water resources of the country, prescribe strategies, policies and plans to ensure proper management and sustainable development of these resources, within the context of socio-economic development plans." Its mandate describes it as "the sole governmental agency responsible for the formulation of water resources policies and development strategies and the study, planning and management of water resources at the national level." The mandate terminates all water resources activities currently undertaken by the Ministries of Agriculture; Oil and Mineral Resources; and Electricity and Water and other agencies which are similar to those of the Authority or impinging on its functions and powers.

To conclude, the establishment of NWRA is the main development pertaining to water resources development and management. The issuance of a Water Law is the next step.

2. *Water resources assessment*

Five objectives were targeted under this programme area; namely, access to appropriate assessment technology, availability of financial resources, full utilization of information, adequate institutional arrangements, and capacity-building.

In view of the lack of adequate institutional arrangements for water resources management at the national level, most activities in this programme area were largely at the sectoral level and only a few studies were at the national level. It is hoped that the establishment of NWRA will provide the institutional framework which will enable these objectives to be achieved.

In addition to the numerous local and regional assessment studies, at least four national studies were completed during the past three years. These are:

(a) The "Water Master Plan", a 10-volume publication of the Technical Secretariat of the High Water Council issued in June 1992 (in cooperation with UNDP);

(b) The "National Water Policies", a publication of the Ministry of Agriculture and Water Resources issued in September 1992 (in cooperation with FAO);

(c) The summary of available information on the water resources of Yemen, a one-volume publication of the Ministry of Oil and Mineral Resources issued in March 1995 (in cooperation with the Netherlands);

(d) The Hydrogeologic Map of Yemen, an eight-sheet map published by the Ministry of Oil and Mineral Resources issued in July 1995 (in cooperation with a Russian consulting team).

Of the regional studies; the study of Mukalla Sandstone in Wadi Masila (Hadramawt) is worth pointing out. The groundwater potential of this aquifer was discovered during the oil exploration activities. Initial findings suggest that the volume of water in this aquifer may well exceed 2,000 billion m^3.

3. *Protection of water resources*

The overall objective in this programme area is to protect the water resources against quantity and quality degradations. Various measures and activities to achieve this objective were outlined in Agenda 21. However, because of the tendency of sectoral entities to focus on development and use and to ignore management, the water degradation problem was largely ignored.

As a result, quantity and quality degradation of groundwater resources has been ongoing for years in more than one basin in Yemen. The problem of depleted groundwater aquifers is already felt in Rada, Sana'a, Sa'adah and other basins.

Similarly, serious groundwater-quality degradation problems have already had a significant impact in the Sana'a Basin (where the pollution is due to untreated sewage) and in the Tihama Plain (where it is due to salt water intrusion). However, although these problems have existed since the late 1980s, they were overlooked owing to the inadequate institutional arrangements for water management.

One emerging problem is associated with oil production in Hadramawt Governorate, where more than 200,000 barrels of brine water are produced daily. Presently, the water is disposed of by injection into underground strata at various depths. There are genuine concerns regarding the potential pollution hazards of this practice, particularly on the recently discovered reserves of groundwater in Masila.

4. *Drinking-water supply and sanitation*

The overall situation with respect to the population's access to a safe water supply for drinking purposes remained, more or less, unchanged. That is, about 30%-40% of the country's 16 million people receive piped water. Because the sewerage system is underdeveloped (only 35% of the urban population are served, and the sewage is not adequately treated), the water systems and supplies are frequently polluted. These two problems (the small percentage of the population with access to piped water and the high pollution risk) are probably the leading causes behind the high mortality rate among children under five (154 deaths per 1,000 births). Waterborne diseases are believed to cause some 70% of these deaths.

5. *Water and sustainable urban development*

Four targets were set in Agenda 21, namely: to supply all of the urban population with at least 40 litres of water/capita/day; to supply sanitary service (on-site or community) for at least 75% of the urban population; to establish and apply discharge standards; and to collect and safely dispose of 75% of all the solid waste generated in urban areas.

Recent estimates for service coverage in urban areas put the water supply target at 50% achievement rate and sanitation at 35%. The average per capita water rate (for the served population) is probably more than the target of 40 lpcd.

6. *Water for sustainable food production and rural development*

Three targets were identified in this programme area, namely to achieve: economic value of water, community participation in management, and comprehensiveness of management policies. Again, because the institutional framework for water resources management has been inadequate, very little was achieved in this programme area. These objectives, however, are emphasized in the mandate of NWRA.

The table below summarizes the main indicators in the fields of water supply and sanitation in urban and rural areas.

7. *Impact of climate change on water resources*

Following the Climatic Changes Conference held in Berlin, Germany, the Netherlands Government committed funds to sponsor research into climatic changes in 10 countries, of which Yemen is one. In June 1995, the Environmental Protection Council (EPC) invited research proposals to address the various impacts of climatic changes; including the impact on water resources. Numerous proposals were presented, and a workshop was held to discuss and prioritized the ones to be funded. The final decisions are expected by early 1996.

TABLE 1. PERFORMANCE INDICATORS FOR THE WATER SUPPLY AND SANITATION

(Compiled from several sources)

	Problem areas	Impacts
1	**Inadequate Urban Water Supply Service:** Mainly due to accelerated growth of demand as a result of rapid urban growth, depletion of aquifers and failure to forecast the demand and to undertake appropriate expansion. Poor planning and poor cost recovery (under-pricing) are among the main causes behind this failure. The problem is further complicated by growing water competition with agriculture in urban basins leading to accelerated depletion of aquifers (e.g. Sana'a basin) and unclear water rights (preventing development of alternative supplies (e.g. Taiz and Shibam-Sana'a problems).	**Direct impacts:** (i) Low percentage coverage: only 50% of the estimated 3.76 million urban population (1994 data). The percentage of coverage is diminishing due to urban growth while the network connections are fixed; (ii) Low per capita rate of domestic water supply: about 50 lpcd according to 1992 data. Also diminishing. **Indirect impact:** Undermines public hygiene, the quality of urban environment/life and increases the cost of water, especially on the poor. It is estimated that about 70% of infant mortality is due to waterborne diseases. Thus, of the 154 deaths per 1,000 live births which occur before reaching 5 years old, some 107 deaths are probably due to waterborne diseases.
2	**Inadequate rural water supply service:** Problem is created/further aggravated by: demand growth due to national population growth; inherently high capital cost of new systems due to scattered/remote locations of settlements; unwillingness of the benefactors to bear the full cost of water production; inability of the Government to continue building, and in many cases maintaining, free systems.	**Direct impact:** (i) Low percentage coverage: only an estimated 40% of the 12 million rural population (1994 data); (ii) Low per capita rate of domestic water supply: about 25 lpcd (1994 data). **Indirect impact:** Undermines public hygiene and the quality of life (impact on infant mortality like the urban case), leads to relatively higher domestic water cost (e.g., during droughts), encourages migration to cities.

TABLE 1. *(continued)*

	Problem areas	Impacts
3	**Inadequate urban sewerage services:** Owing to rapid growth of urban centres, relative increase of per capita water consumption rate over the past three decades, failure of traditional (cess-pit) systems in cities or sections of cities to handle new rates and failure to forecast and implement required expansions as a result of poor institutional set-up and poor cost recovery.	**Direct impact:** (i) Low percentage coverage (only 35% of the estimated 3.76 million urban population (1994 data); (ii) Pollution (groundwater, beaches of coastal cities, and the quality of urban life in general). **Indirect impact:** (i) Public health hazards due to waterborne disease; (ii) Economic losses (lost productivity due to water-borne disease; lost tourism revenue in coastal areas owing to sewage discharge to the sea).
4	**Inadequate rural sewerage services:** Owing to rapid population growth (nationally), relatively higher rates of water consumption over the past three decades, failure of traditional (open) systems to handle the new rates and failure to introduce/promote appropriate alternatives.	**Direct impact:** Several types of systems are used. Data on the types and percentages of rural population served by each type will become available when the results of the 1994 census are released. **Indirect impact:** Poor hygiene, low quality of rural environment/life.

B. Relevant activities in other sectors

The most significant activity of relevance to the water sector was the Workshop on Preparation of the National Action Plan for Environment and Development, which was organized by the EPC in cooperation with the World Bank from 16 to 19 September 1995. In that Workshop, more than 100 participants, who came from all regions and institutions of the country, ranked two water and sanitation-related problem areas at the top of the environmental problems. These are: (i) inadequate water supply and sanitation services; and (ii) water scarcity.

As a follow-up on the findings of this Workshop, policy options and implementation programmes are currently being prepared and are to be included in the forthcoming Five-Year Plan (1996-2000).

C. Conclusions

Except for the establishment of the National Water Resources Authority and the expected positive role which the National Action Plan for Environment and

Development can play in enhancing the water sector, it is obvious that not much was achieved in this sector during the last three years.

Nevertheless, the significance of these two developments should not be under-estimated. Most of the water sector's problems are due to fragmentation of management responsibilities, a problem which would be resolved by the Authority. However, the enthusiasm regarding the National Action Plan stems mainly from the expectation that it will be well received by funding agencies.

PART THREE

INTERNATIONAL PAPERS

XXII. PLANNING IN AN ARID ENVIRONMENT

by

Rémy L. de Jong

Introduction

Water differs from other natural resources in that it has not received economic recognition or been assigned a monetary value, in spite of the fact that it is essential for the survival of the living environment. This has contributed to the rather arbitrary manner in which water has been allocated among a wide variety of users. In this respect, it differs sharply from other resources which are being developed, exploited, used and allocated according to the respective contributions their exploitation makes to the local economy, or to the well-being of the people claiming ownership of those resources.

This peculiar and anomalous treatment of water is acceptable where the commodity is in ample supply, because its role in the economic process is not critical. When the supply is ample any errors in the allocation can be easily overcome by switching from one source to another. Moreover, in the absence of a shortage, the cost factor is insignificant.

In arid regions the situation is radically different. The decision makers in any specific economy not only do not have the hydrological option of switching from one source to another owing to the aridity, they are also limited by political and territorial constraints because many of the existing water resources are of an international and shared nature, outside the jurisdiction of any one planner.

It is well recognized that the increase in population is one of the factors that has increased pressure on the development of water resources, but it is not always understood that those increasing populations are of a different type. They communicate and move about much more than before; they share ideas, facilities and land, as well as industrial and agricultural products. The concept of autarky, national economic self-sufficiency and independence, has lost its viability and is being replaced by widespread dependence on international trade whereby the best (and cheapest) producers attain the highest market shares. In theory, this leads to economic efficiency, except in local pockets of economic activities where, for specific reasons, subsidies and protective measures have been adopted by the decision makers. This trend has recently been recognized and emphasized by the conclusion of various regional or global free trade agreements, all of which share the common desire to encourage a free exchange of goods and services.

The fact remains that in many regions and communities the availability of water is not assured. Free trade in many commodities represents a partial solution to the local water shortage because significant quantities of water were used at their origin for production or cultivation. Nevertheless, there is still a need for direct allocation of the basic commodity "water" for consumption, for sanitation, and for public health.

A. THE PROBLEM

The basic problem for water managers and water planners continues to be to balance the available water resources against the reasonably foreseeable demands. This basic problem is assuming particular significance in the ESCWA region because of the following constraints and circumstances.

The most obvious constraint is climatological. Almost all ESCWA member countries share an arid climate, which eliminates most opportunities for "supply management". Mobilizing new natural water resources, or minimizing existing natural losses, are not realistic strategies because those resources and losses hardly exist.

Another constraint is financial. Much of the region depends, directly or through trade and manpower links, on the exploitation of petroleum resources. The market for the latter has lately been rather flat and so has the related regional income. Consequently many local governments have begun to adopt policies that call for moves towards self-sustaining public utilities. This means that utility managers need to consider very carefully whether the production techniques they use are not only technically sound but also economically justified. The expected utility income needs to be able to cover the operation and maintenance of the facilities, without automatic guarantees and subsidies from the Government. This circumstance makes many options for "supply management" unattractive.

The ESCWA region does not presently experience major political conflicts. Nevertheless, recent history has seen serious disagreements and any decision maker should incorporate the probability of their recurrence in his planning. This circumstance throws a dim light over many water importation schemes, most of which rely for their successful implementation on a large measure of cooperation with other nations.

An ironic constraint is the fact that many facilities in the region have just recently been constructed and are still in good working order. Although this makes life easier on today's utility manager, it also decreases the scope for cutting losses from leaks, because many of those losses may be very small and well within acceptable operating conditions.

Before considering the issue of economic productivity it is useful to briefly review the traditional tools available to implement water sector management.

B. The traditional tools

Traditionally the two approaches to water management have been either to enhance the resources (supply management) or to decrease the demands (demand management). In slightly more detail, these approaches encompass several well-researched and applied technologies.

1. *Supply management*

(a) The reduction in the statistical variability of streamflow by means of constructing storage reservoirs;

(b) The reduction of natural losses to sea or desert by means of a timely diversion or storage of surface run-off;

(c) The increase in freshwater supply by means of converting poor quality water (wastewater and sea water) into high-quality water;

(d) The increase of precipitation by means of cloud seeding or other induced climate changes;

(e) The reduction of evaporation losses to the atmosphere from both natural and artificial reservoirs or swamps;

(f) The reduction of subsurface seepage into water bodies of poor quality, such as seas;

(g) The importation of water from unconventional sources, for instance by means of the transportation of icebergs from the arctic regions;

(h) Interbasin transfers from areas of surplus to areas of deficit, for instance by means of the pumpage/diversion of water through pipelines or canals, or by marine transport in flexible containers or tanker ships.

2. *Demand management*

(a) The volumetric reduction in the water consumption by various end-users in the domestic, agricultural, commercial, services, and industrial sectors;

(b) The improved matching of water quality with the water requirements of the various end-users;

(c) The reduction of water losses from water supply reservoirs and systems used by water utilities or other major water users.

The relevance of these tools to the ESCWA region was discussed in an earlier section. The next section will raise the issue of reaching a compromise, not based primarily on increasing supply or decreasing demand, but on reallocating existing water resources.

C. THE SHIFT TO ECONOMIC PRODUCTIVITY

It is universally accepted that water is the most basic resource to sustain the life of people, animals and plants. In spite of the fact that the lives of people are not expressible in terms of commercial value, it is also universally accepted that they deserve first priority in terms of water use and this point is not further addressed here. However, a few aspects deserve some scrutiny.

It is of interest to note that even for people the level of the minimum requirement varies from place to place, and from society to society. All human beings appear to have a certain biological minimum amount to sustain essential body functions, although this may vary with climate.

In addition, humans expect to have access to a certain daily amount of water for hygienic purposes, which may generally be referred to as the "public health" requirement. The magnitude of this requirement varies considerably, depending to a large extent on the economic well-being of the person concerned.

Within the family unit, or the household, there are further demands that derive from food preparation and from the use of a range of household equipment in support of the needs referred to in the preceding paragraphs. Those household requirements vary even more considerably, largely in correlation with individual living standards and with the ability of society to provide the necessary infrastructure.

It is obvious that there is no standard for domestic per capita water "need", but this does not contradict that, within a given set of conditions, the domestic demand deserves first priority.

The problem then becomes to design an allocation scenario for the water that is left in an effort to satisfy all remaining feasible demands and claims. In order to ensure that all affected parties are fairly treated such a scenario needs to be based on verifiable, quantifiable, and defensible criteria. Several countries in the ESCWA region are being guided in their development by national development plans, frequently on the basis of a five-year cycle. Most of those plans, and in fact most governmental pronouncements of a planning nature, contain statements like "the Government intends to pursue economic development" of the country in question, or other words to that effect. Since water is one of the ingredients of almost any economic activity, there is a clear logic in basing water allocation scenarios on economic grounds. In other words, water should be allowed to flow in the direction (i.e. towards a subsector) where it will make the biggest contribution to the economy. This is often expressed as the pursuit of maximum "water productivity".

An important question concerns the definition and quantification of the water productivity and several options exist. One of those defines water productivity as:

$$WP = GM/WU$$

where: WP is the Water Productivity, GM (Gross Margin) is the monetary output of a certain economic activity (expressed in a convenient currency), and WU (Water Use) is the production factor, in this case water (expressed in a convenient unit such as m^3).

In order to calculate WP it is necessary to have access to estimates or statistics for Gross Margin, either for the relevant subsector or for specific enterprises or establishments, depending on the level of detail that is aimed for in the water allocation. This parameter is very commonly used for measuring the economic performance of sectors and subsectors of the economy, and it can also be fairly rapidly calculated for individual enterprises from standard accounting records.

Moreover, reasonably accurate records or estimates are required of the actual Water Use on the same time base as the data on Gross Margin. Although the physical flow of water is measured and metered on many occasions, the definition of this parameter may in reality present considerable practical problems. The main reason for this is that many enterprises obtain their water from municipal water systems and the operators of those systems, the municipal water utilities, have no reason to differentiate between domestic, commercial, and industrial customers. However, in order to estimate for instance the water use of the local hotels, one of the main components of the tourism industry, it is necessary to have data for all hotels. It may require considerable research of water meter records to obtain such data.

Even if all data problems can be overcome, the approach of basing water allocations on strictly economic grounds has several weaknesses. The concept of basing the merit of water use on the relevant economic contribution of a sector ignores the fact that societies are composed of living human beings, most of whom expect to participate in the activities of that society. In other words, the creation of employment, regardless of the economic benefits, may be an objective in its own right. Although economic development may be a desirable goal, other factors may enter the picture. For instance, geographical distribution of the population, or strategic occupancy of certain lands, may in certain cases assume as much significance as economic optimization.

In order to accommodate such arguments, it would be necessary to develop an evaluation procedure that could override the economic arguments and replace them with others, taking into account that society is not a purely economic creation.

D. CONCLUSIONS

It appears that, particularly in the ESCWA region, the traditional methods for balancing supply and demand are beginning to reach the limits of their applicability. Therefore, serious thought has to be given to redistributing the available water resources according to clear and quantifiable criteria. The extent to which water contributes to economic development offers such an approach, provided that the necessary data are available and can be processed to support the definition of a certain strategy. In addition, a method needs to be found to satisfy other, conflicting objectives, which may in specific cases take precedence over the purely economic arguments.

XXIII. WATER RESOURCES INFORMATION SYSTEM: WHYCOS, A BASIC TOOL FOR INTEGRATED WATER MANAGEMENT

by

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A. BACKGROUND

While the pace of development is accelerating in many parts of the world, there is also growing and widespread pressure for increased protection of the environment. To reconcile these differing thrusts and to satisfy a number of other aspirations, the United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro, Brazil, in June 1992. UNCED produced a blueprint for the future of this planet, namely Agenda 21, which addresses the problems of today to prepare for the coming challenges.

One matter which became clear was that a common and adequate knowledge base is lacking in many areas where judgement of priorities and far-reaching decisions are needed. Among the most important of these is the area of freshwater, since few other resources affect so many areas of the economy and of human and environmental health.

The ESCWA region belongs mainly to the arid and semi-arid zones. Some of the countries of the region are at present facing water shortages hampering their socio-economic development and according to recent United Nations projections many of the countries of the region will experience chronic scarcities of freshwater in the near future.

B. NEED FOR WATER RESOURCES INFORMATION SYSTEMS

Both the freshwater chapter (chapter 18) of Agenda 21 and the report of the International Conference on Water and the Environment (ICWE 1992), on which it was based, recognize that knowledge of the hydrological cycle, in terms of both quantity and quality, is the essential basis for effective integrated water management.

These same sentiments are reflected in a number of other similar documents (IUCN 1991, Dooge et al. 1992, World Bank 1994). These reports indicate the need for monitoring systems, including data archives, for water resources assessment and for pollution protection and control. They identify the importance of communicating information on water to decision makers and to the general public. They insist on the necessity to develop cooperation and coordination at the regional and interregional levels through appropriate information systems for the integrated management of shared water resources.

However, chapter 18 and the ICWE report also recognize that the monitoring systems and the Hydrological Services that operate them are in decline in many parts of the world (WMO/UNESCO 1991), largely because of budgetary constraints but also because decision makers and the general public are normally not aware of the economic value of very high quality and timely available data and of the dependence of water development on modern information systems in the field of water resources.

These problems continue despite the international programmes promoted by WMO, UNESCO and other agencies, regional organizations and bodies. They also continue despite parallel regional and national initiatives, in many cases, initiatives stimulated by technical assistance programmes funded by donors.

Records of river flows from around the world are collected at the Global Runoff Data Centre (GRDC) in Koblenz, Germany. A similar collection of water quality records is carried out by the WHO Collaborating Centre on Surface and Ground Water Quality at Burlington, Ontario, Canada. The first of these centres comes under the aegis of WMO, with UNESCO cooperation, the second has UNEP, UNESCO, WHO and WMO involvement. However, neither of these centres has adequate coverage of the globe, in terms of the countries concerned, nor in terms of the duration of the data sets and the data are of variable quality. For these reasons, it is extremely difficult to employ these data, even with additional international or national data sets, to assess comprehensively the world's water resources over the long term. To undertake this task for a particular decade, a year or a month is an impossibility. An entirely fresh approach is needed.

C. THE WHYCOS INITIATIVE

As a contribution to address this situation, WMO, with the support of the World Bank and other agencies, has developed and promoted the concept of a World Hydrological Cycle Observing System (WHYCOS), which will be implemented to act as a tool for the improvement of collection, dissemination and use of high quality, standardized and consistent hydrological and related information at the national, river basin, regional and international levels for development purposes.

WHYCOS would establish a basic network of benchmark, or reference stations throughout the participating countries. These stations would generally be selected sub-sets of the existing station network agreed with the national agencies. These stations would almost always be existing stations with long records. All stations contributing to the WHYCOS network would be upgraded to common minimum standards, such that users of the database could be assured that the data met assured standards.

Stations would transmit data in real time using modern Data Collection Platforms (DCPs) with data being transmitted from field stations to national, regional, and possibly international, centres via satellites, generally those geostationary satellites intended primarily for meteorological observations. Existing segments in the WMO Global Telecommunication System (GTS) of the World Weather Watch (WWW) will also be used, where these are available.

Raw data would be available to users in real time, but the national hydrological agencies responsible for each contributing station would subsequently validate and quality control the data, according to agreed WHYCOS criteria, which would then be stored on the database with flags to indicate that the data have been checked.

All these stations would measure routinely a common core set of variables comprising for example: river level/flow, rainfall, the climatic variables required for estimation of potential evaporation using the Penman equation, selected basic physio-chemical parameters of water (see table). Users would be involved in the selection of this standardized core set of variables and of any additional ones, taking into account the technological limitations.

WHYCOS

TABLE. DATA TO BE ACQUIRED AND TRANSMITTED

Environmental variable	Frequency of measurement per day
1. Water level	1 to 6 (depending on size of river)
2. Water pH	1
3. Water conductivity	1
4. Water temperature	1
5. Dissolved oxygen	1
6. Turbidity	1
7. Air temperature	8 (synoptic hours)
8. Rainfall	24, plus daily total
9. Relative humidity	8
10. Windspeed	8
11. Net radiation	8

TABLE. *(continued)*

Housekeeping variable	Frequency of measurement per day
1. Battery voltage	Once per day
2. Solar panel voltage	Once per day
3. Memory status	Once per day
4. Temperature inside instrument housing	Once per day

The WHYCOS database would be a distributed one, with operational centres at national and regional centres. The data belong to the participating countries and must be managed at this level. Once a year, or more frequently according to the needs, historical data from selected stations should be passed to GRDC for archiving and to other international centres. In addition to the key role of managing the global database, which is seen as essential to address the goals of a large-scale phenomenon, the GRDC could assist in the definition of operational guidance and to support the national and regional operational centres, notably through training within its field of competence.

As stated above, the data would be stored on a series of distributed, but linked databases. These would be at the national and regional levels, but these databases should be linked using some sort of flexible, easy-to-use communication network, such as the World Wide Web on Internet. Such network communications would also extend to other related data sets such as those maintained under the Global Climate Observing System (GCOS), the Global Terrestrial Observing System (GTOS), the Global Environment Monitoring System (GEMS) and the Global Ocean Observing System (GOOS) programmes, and to the databases maintained by the GRDC at Koblenz and by the Global Precipitation and Climate Centre (GPCC) in Offenbach, and the FRIENDS' databases.

It is proposed that basic data held on the WHYCOS databases should be available free of charge to users. However, any derived products, such as maps of specific run-off, hydrographs, results of analyses and so on, would be charged for in order to generate an income stream for national hydrometric agencies. Such a system would help to create a sustainable data collection and dissemination service.

Capacity-building would be part of WHYCOS activities. Therefore the needs for qualified experts would be assessed and relevant initiatives to improve and/or to sustain the situation would be developed, not just in the field of training which is only one of the ways to build national capacities.

WHYCOS has already been endorsed by the Commission for Hydrology (CHy) during its ninth session held in January 1993. The Executive Council (EC) of WMO during its forty-sixth session, held in June 1994, expressed the view that WHYCOS was potentially of great importance to water resources assessment on the global, regional and national scales and that WHYCOS should be given more prominence in the long-term plan of WMO. More recently, the eleventh session (Paris, 30 January - 4 February 1995) of the Intergovernmental Council of the International Hydrological Programme of UNESCO adopted a resolution with WMO, for the planning and implementation of WHYCOS.

The Twelfth Congress of WMO (30 May - 21 June 1995) in resolution 20 (Cg-XII) notably encourages members "to facilitate the establishment of WHYCOS through the implementation of national, subregional and regional components of the system."

Furthermore, WHYCOS is one of the responses of WMO to the United Nations Commission on Sustainable Development (CSD), which during its second session (May 1994) urged "UNEP, FAO, UNIDO, WHO, WMO and UNESCO, in collaboration with UNDP, the World Bank and other relevant bodies, to strengthen their efforts towards a comprehensive assessment of freshwater resources, with the aim of identifying the availability of such resources, making projections of future needs and identifying problems to be considered by the 1997 Special Session of the General Assembly".

D. MED-HYCOS: A REGIONAL COMPONENT OF WHYCOS

The implementation phase of the Mediterranean Hydrological Cycle Observing System (MED-HYCOS) started when, upon the invitation of the District and City of Montpelier (France), representatives of 20 countries in the Mediterranean Basin as well as representatives of FAO and UNEP and of non-governmental organizations attended a scientific and technical meeting jointly organized by the World Meteorological Organization and the World Bank (Montpelier, 17 to 19 May 1995).

The meeting agreed that MED-HYCOS would be a regional system composed of three fully integrated subsystems respectively for data acquisition; data storage, retrieval and processing; and data and information exchange and dissemination. The objectives of the system have been prioritized by the meeting as follows:

(a) To modernize hydrometeorological monitoring region-wide and promote exchange between Hydrological Services;

(b) To achieve a better understanding of regional hydrometeorological phenomena and environmental trends;

(c) To encourage free exchange of quantitative and qualitative hydrological data as well as environmental data.

The meeting also agreed that such a system would help to improve water resources assessment and management in the countries of the Mediterranean Basin, besides strengthening the collaboration and cooperation between hydrologists and between the national services in charge of hydrology and water resources throughout the Basin. Participants also emphasized that MED-HYCOS should contribute to the knowledge of hydrological processes, in particular their interaction with the climate and environment, and should play a role in the monitoring and the abatement of pollution in the Mediterranean Sea. Therefore, they agreed to a request of representatives from the Black Sea countries to extend the system to the Black Sea Basin, which is heavily polluted and has a hydrological connection with the Mediterranean Sea.

Data acquisition would be made through a network of 150 standardized DCPs, installed at key stations equipped with automatic sensors for the measurement of some 16 variables related to water quantity and quality and climate, transmitted in real time through the METEOSAT Data Collection System (DCS).

After a detailed review of a concept paper, prepared by WMO on the basis of a questionnaire which was circulated to all countries and to various international, regional and non-governmental organizations during the second half of 1994, the participants adopted the draft detailed implementation plan and work plan proposed by WMO, as the Executing Agency for the project.

The participants decided that a Pilot Regional Centre (PRC) should be created to implement the different activities related to the project, notably the preparation of the technical specifications for the equipment, the development of data management and processing software for the raw data, the development of a regional database and the organization of training courses. These tasks will be undertaken under the supervision of a Regional Cooperative Group (RCG) comprised of the representatives of the participating countries, regional organizations concerned, funding agencies and donors, as well as the World Bank and WMO. An initial coordinating team with representatives from Bulgaria, France, Italy, Malta, Romania, Spain and Tunisia and representatives of WMO and regional non-governmental organizations has been created to support the PRC.

The meeting accepted the offer made by the French Scientific Research Institute for Development in Cooperation (ORSTOM) to host the PRC, which will serve as a focal point of a dynamic network grouping the MED-HYCOS project partners.

Thanks to the World Bank, which has made available to WMO US$ 500,000 as the first part of a total grant of US$ 1,700,000, the installation of the first 20 DCPs is expected to be completed by the end of this year or in the beginning of next year. Spain, Italy and Malta have already expressed their willingness to support the project, and additional funds will be sought from international sponsors, such as the European Union. At the same time as the first DCPs are going to be installed and people trained in the use of the new equipment, an Internet-type communication network will be completed to link all the participating bodies to each other and to the PRC. The first products of the system are expected to be available by the second half of 1996.

E. CONCLUSIONS

Sustainable development and meaningful environmental protection are both dependent on effective water resources management, which in turn is dependent on data, particularly reliable hydrological data. Currently such data are not readily available globally, regionally and even nationally for a number of nations.

WHYCOS is intended as a key element in the strategy of the international community for combating the approaching water crisis through capacity-building and access to an information highway. WHYCOS provides the key element of an effective strategy for combating the water crisis through a two-pronged fully integrated approach: a global conceptual basis providing a framework and general guidance which would be developed interactively and concurrently with the implementation of national, subregional, regional and basin-wide operational components (HYCOSs), such as the above-mentioned MED-HYCOS or SADC-HYCOS, currently under development by WMO with the 11 countries of the Southern Africa Development Community (SADC), with the support of the European Union.

As stated by the WHYCOS Concept Panel meeting convened by WMO (6-8 February 1995, Geneva), WHYCOS should be flexible and adaptable enough to take into account the different current situations and their possible evolution. Therefore, it might be considered as one of the possible tools for improved integrated water management in the ESCWA region.

REFERENCES

Dooge, J.C.I., G.T. Goodman, J.E.M. La Rivière, J. Marton-Lefèvre, T.O. O'Riordan, and F. Praderia (eds), 1992. *An Agenda of Science for Environment and Development into the 21st Century,* C.U.P. 331p.

ICWE, 1992. *The Dublin Statement and Report of the Conference*, International Conference on Water and the Environment, 56p.

IUCN, 1991. *Caring for the Earth.* A Strategy for Sustainable Living. IUCN/UNEP/WWP. 228p.

Rodda, John C., Serge A. Pieyns, Naginder S. Sehmi (WMO), and Geoffrey Matthews (World Bank), 1993. *Towards a World Hydrological Cycle Observing System. Hydrological Sciences Journal,* October 1993. p 373 to 378.

WMO/UNESCO, 1991. *Report on Water Resources Assessment.* Progress in the Implementation of the Mar del Plata Action Plan and A Strategy for the 1990s.

The World Bank, 1994. *A Guide to the Formulation of Water Resources Strategy.* World Bank Technical Paper Number 263, 102p.

The World Bank, WMO, 1995. *Final Report of the MED-HYCOS Scientific and Technical Meeting* (Montpelier, 17-19 May 1995). 16p.

XXIV. ISOTOPE METHODOLOGIES IN WATER RESOURCES AND EXAMPLES OF APPLICATIONS IN THE ESCWA REGION

by

*Yuecel Yurtsever**

Introduction

Methodologies based on the use of isotopes in a wide spectrum of hydrological problems encountered in water resources assessment, development and management activities are already an established scientific discipline recognized as "Isotope Hydrology", and proven methods are presently employed as an integral part of water resources investigations, particularly in groundwater systems. Together with the techniques based on the employment of radioactive isotopes for water tracing purposes and the use of sealed radioactive sources for *in-situ* measurements related to water movement, they comprise the overall field of "Nuclear Techniques in Hydrology".

During the last three decades, the International Atomic Energy Agency (IAEA) has been directly involved in efforts directed towards research and development of nuclear techniques in water sciences, their actual field applications, and acted as an international scale focal point for dissemination of information and promoting their wider scale use, within the framework of its activities related to peaceful nuclear applications.

A. ROLE OF ISOTOPE APPLICATIONS IN WATER RESOURCES

Potential role and contributions of isotope methods in water resources sector can be grouped into the following general categories:

(a) Determination of physical parameters related to flow, its dynamics and structure of the hydrological system;

(b) Delineation of processes involved in transport and circulation of water (process tracing);

(c) Study of origin (genesis) of water;

(d) Determination of mixing ratios of component flow (component tracing);

(e) Study of "time-scale" of events.

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The use of naturally occurring isotopes, often referred to as "Environmental Isotope Methodologies", has the distinct advantage of facilitating study of water movement in much larger temporal and spatial scales than possible with intentionally injected tracers, which are often used for site-specific local-scale engineering and geo-technical problems. The production and temporal/spatial variations of environmental isotopes in the hydrological cycle cannot be controlled by the investigator, and they are the result of different natural processes. However, hydrological inferences can be made on all of the above cited type of applications, through observations to be made of their concentration distributions in a given hydrological system. Therefore, environmental isotope methodologies are commonly employed in regional scale studies in water resources, and particularly in groundwater systems. This paper, therefore, is restricted to environmental isotope applications in groundwater systems.

Environmental isotopes of potential use in hydrology are listed in tables 1 and 2. The most commonly employed natural isotopes of oxygen and hydrogen have the advantage of being ideal tracers for water. The unique decay property of environmental radioactive isotopes (table 2) makes it possible to infer characteristic time parameters of water transport through a time scale of thousands of years.

TABLE 1. STABLE ISOTOPES IN WATER RESOURCES INVESTIGATIONS

Isotope	Potential application areas
Oxygen-18 (^{18}O) and Deuterium (^{2}H)	- Genesis of water - Source of replenishment to groundwater and process tracing - Component tracing—mixing proportion of different components of flows; hydraulic interconnections - Paleohydrological indicators - Geothermal activity
Carbon-13 (^{13}C)	- Origin of carbon compounds - Correction for C-14 age-dating
Sulphur-34 (^{34}S)	- Natural tracer for sulphates in water - Identification of source of pollution
Nitrogen-15 (^{15}N)	- Origin of nitrates - Identification of sources of pollution

TABLE 2. ENVIRONMENTAL RADIOACTIVE ISOTOPES IN WATER RESOURCES INVESTIGATIONS

Isotope	Half-life (years)	Source (origin)	Limitations at the present
^{85}Kr	10.8	Nuclear reactors	Sampling, counting
^{3}H	12.43	Cosmic rays Thermonuclear Nuclear reactors	
^{32}Si	100	Cosmic rays Thermonuclear Crustal (?)	Initial activity Sample size Counting time
^{39}Ar	269	Cosmic rays Crustal	Sample size Counting time
^{14}C	5 730	Cosmic rays Thermonuclear Crustal	Complex geochemistry Isotope exchange processes
^{81}Kr	210 000	Cosmic rays	Analytical
^{234}U	250 000	Decay china	Initial activity Interactions
^{36}CI	306 000	Cosmic rays Nuclear tests Crustal (?)	Initial activity (?) Sources and *in situ* production (?) Need for AMS

Specific types of information that can be obtained from applications of natural isotopes in groundwater resources assessment, development and management are:

(a) System boundaries;

(b) Hydraulic discontinuities and stratification;

(c) Hydraulic interconnections;

(d) Origin (genesis) of water;

(e) Process and rate of replenishment of groundwater;

(f) Source and process of salinization;

(g) Mixing proportions of component flows originating from different sources;

(h) Travel times involved in groundwater flow, and distribution of travel times, covering a time scale of up to 40,000 years (age-dating of groundwater);

(i) Dynamics of geothermal waters;

(j) Parameters related to mass transport characteristics, most relevant to pollutant transport mechanisms and required for water pollution management.

A substantial amount of background data and experience has been acquired in the applications of environmental isotopes in hydrological sciences so as to understand the cause/effect relationships of their occurrence and distribution, and to develop sound evaluation methodologies [1,2]. Characteristic features of the isotope-input into the hydrological cycle have mainly been derived from systematic data collected from monitoring undertaken by the IAEA on the isotope content of precipitation from a global scale network of precipitation stations. The location of stations included in this network that have a reasonably long record is shown in figure 1.

The most commonly used stable isotopes of 0-18 and H-2 (Deuterium) show temporal and spatial variations due to isotopic fractionation occurring during phase changes, i.e. evaporation and condensation, which is mainly a temperature dependent phenomenon. The isotopic change thus induced is a conservative property of the water during its transport, and it is a fingerprint of the history of the processes involved in its formation and circulation. Characteristic relationships of these table isotopes for different hydrological processes are shown in figure 2, which provides the basis for the above applications. An example of isotopic content of precipitation in the ESCWA region is given in figure 3, where the long-term mean monthly isotopic content of rain in three selected stations is shown on a 0-18 versus H-2 plot.

Among the environmental radioactive isotopes, H-3 (Tritium), with a half-life of 12.43 years; and C-14, with a half-life of 5,730 years, are the most frequently employed isotopic species for study of water movement in "Time" domain, and also providing dating method for determination of the age of groundwater. The long-term variations of tritium concentration of precipitation as a basis for defining the tritium input into the hydrological systems are shown in figure 4, for selected long-term stations in the IAEA network together with a few stations in the ESCWA region.

Figure 1. Precipitation stations in the IAEA/WMO global monitoring network for environmental isotopes

Figure 2. Characteristic Oxygen-18 vs. Deuterium relationships: (a) related to different processes; (b) related to hydrological applications

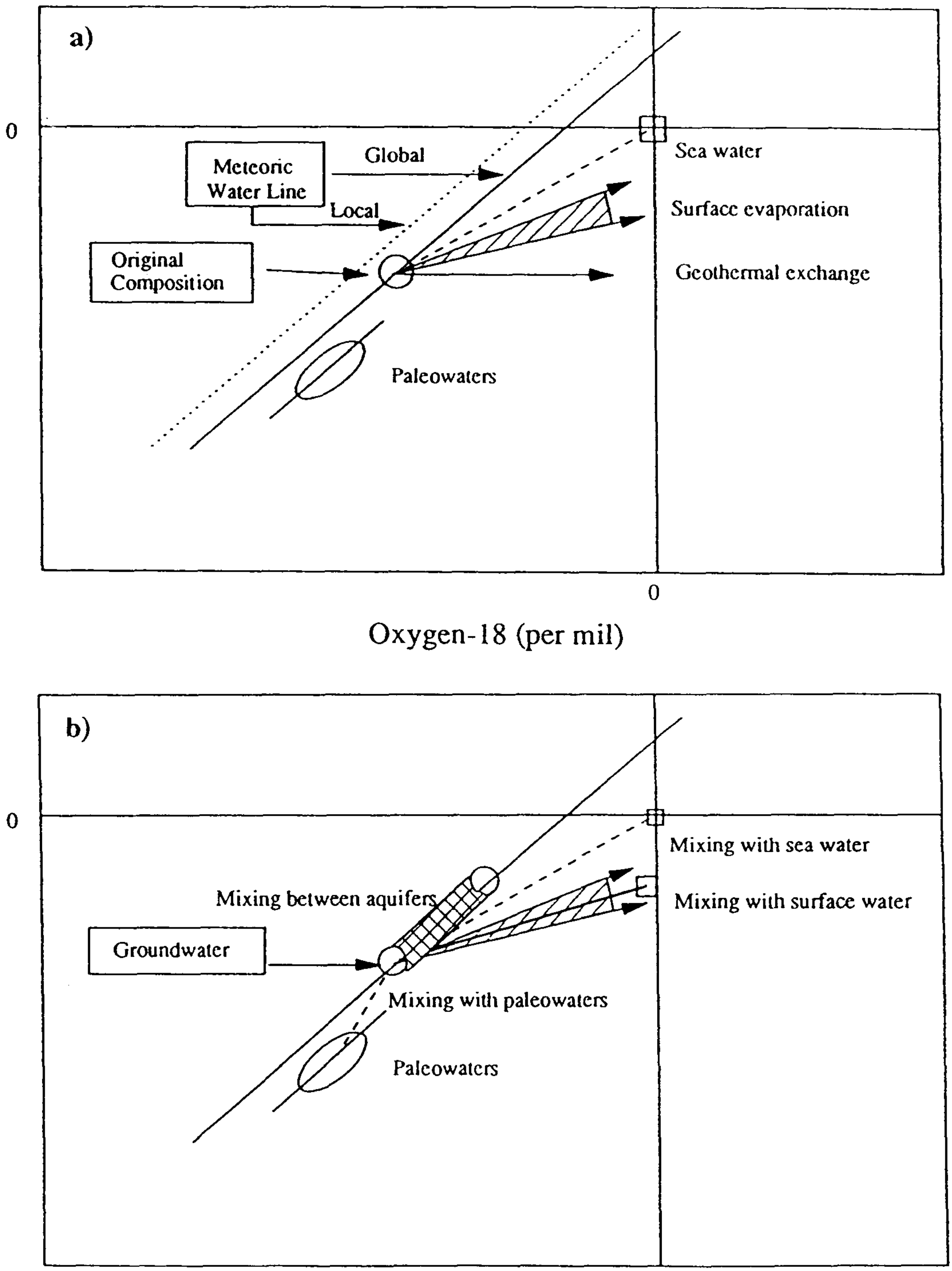


Figure 3. Stable isotope concentration of selected stations in the ESCWA region

(Monthly means)

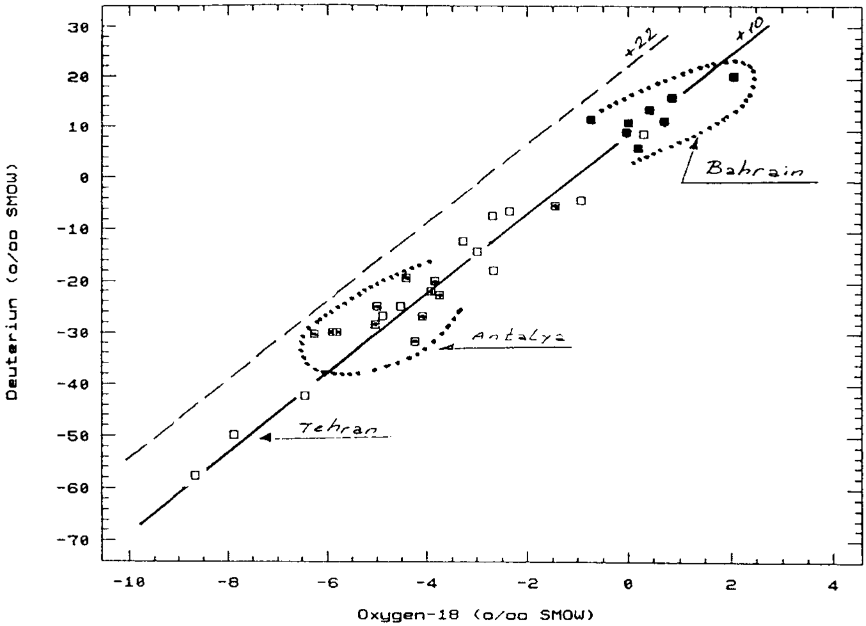
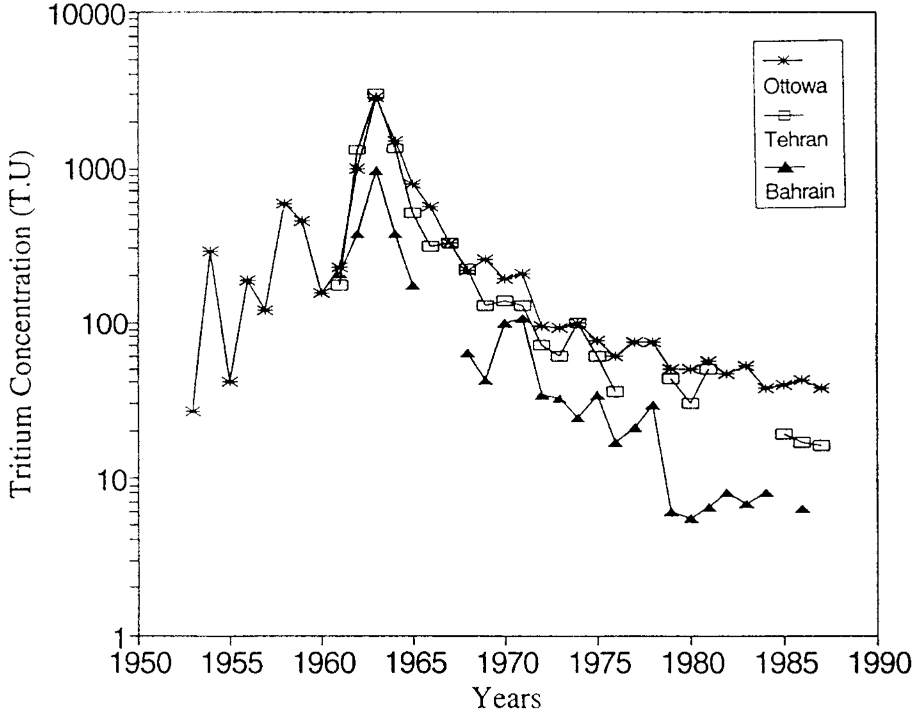


Figure 4. Long-term data on tritium concentration of precipitation at selected stations



Isotope data collected within the framework of hydrogeological applications are effectively used for improved understanding of the processes involved in the occurrence and transport of water and for quantitative evaluation relevant to transport processes within the context of system identification. They are an integral part of hydrogeological investigations to be conducted in the assessment, development and management of groundwater resources, and the cost of undertaking isotope studies is a very small fraction of the overall costs involved.

B. SUMMARY INFORMATION ON IAEA ACTIVITIES

Development and application of nuclear techniques in hydrological and hydrogeological studies has been included within the scope of activities of the Agency since its inception. Thus, the Agency has been involved in providing support to research, development and application of nuclear techniques in water sciences during the last three decades.

Activities of the IAEA in the water sector have the main objective of providing a forum for the dissemination of information on, and the assessment of the use of nuclear techniques in the overall domain of water resources, and promoting more widespread use of the proven techniques. In this regard, the main elements of the activities include:

(a) Implementation of technical cooperation projects in member countries;

(b) Support for theoretical and applied research;

(c) Organization of meetings and training courses;

(d) Collection of basic data needed;

(e) Distribution of isotopic standards and quality assurance of isotopic analyses through international intercomparisons;

(f) Publications.

At present, a total of 70 technical cooperation projects are being implemented in member countries in the field of isotope hydrology, with a budgetary allocation of about US$ 2 million for the 1993-1994 biennium. The majority of these projects deal with the application of environmental isotope techniques in regional scale hydrogeological investigations, the ultimate aim being the transfer of the know-how through this applied work, and the provision of equipment, training and expert services, as required.

The IAEA is currently providing direct financial support to 65 research projects being carried out by national institutions in member countries. Within this programme component, coordinated research programmes on specific topics are also designed, supported and implemented, and six such coordinated research programmes are presently in progress.

The meetings and training courses organized and publications issued by the IAEA provide a means for exchange and dissemination of information on an international scale. Some major publications are cited in this document [3,4,5,6,7,8,9,10,11,12], and a full list of IAEA publications in the field of isotope hydrology is separately provided to this conference.

C. EXAMPLES OF RESULTS FROM ISTOPE APPLICATIONS IN THE ESCWA REGION

A number of earlier isotope investigations have been conducted in the regional aquifer systems of the countries in the ESCWA region, the results of which have already been published. A regional technical cooperation project entitled "Isotope hydrology in the Middle East" (RER/8/002) in which eight countries have actively taken part (Islamic Republic of Iran, Jordan, Kuwait, Lebanon, Saudi Arabia, Syrian Arab Republic, Turkey and United Arab Emirates) was completed at the end of 1994. The project involved applied isotope field investigations in the selected aquifer systems of each country. The findings and results of these isotope studies will soon be published by the Agency in a technical document. A few examples of results from earlier reported studies and the regional project are briefly mentioned here, to illustrate the potential applications of isotope techniques in regional scale groundwater systems.

A detailed survey of isotope concentrations of the groundwaters of Saudi Arabia is reported by Shampine et al. [13]. The survey has enabled mapping of variations of the stable isotopic content of major aquifer units in Saudi Arabia, as shown in figure 5 [13]. The variations observed were interpreted in terms of delineating the replenishment areas of the aquifer units as well as depicting paleowaters in some aquifer systems using also extensive C-14 dating of groundwaters. Most of the regional aquifer units are paleowaters replenished during earlier pluvial periods, and substantial parts of the groundwaters have ages in the range of 10,000 to 30,000 years (see figure 6). Recent recharge of these aquifers under the present climatic conditions is minimal (if any), and extraction of water from them will most likely result in mining of the groundwater.

In an earlier study conducted by the IAEA in Qatar, the origin and replenishment of groundwater in a shallow aquifer, and its hydraulic interconnection to a deeper confined aquifer system were investigated and the results published by Yurtsever and Payne [14]. The results of tritium monitoring of wells in the upper shallow limestone aquifer indicated areas where the groundwater was being effectively replenished by direct rainfall (see figure 7). An average replenishment rate in the range of 7-24 million cubic metres per annum (3-11 mm per year) was estimated for the northern part of the aquifer based on tritium results. The cause of salinity increase in the shallow groundwater of southern Qatar was delineated to be mainly due to upward leakage from the underlying confined aquifer of Umm er Radhuma and also partly due to sea-water intrusion. The stable isotope and hydrochemical data used for this purpose are shown in figures 8 and 9 respectively.

Figure 5. Mean concentration of stable isotopes in selected aquifers of Saudi Arabia (Shampine et al. 1979)

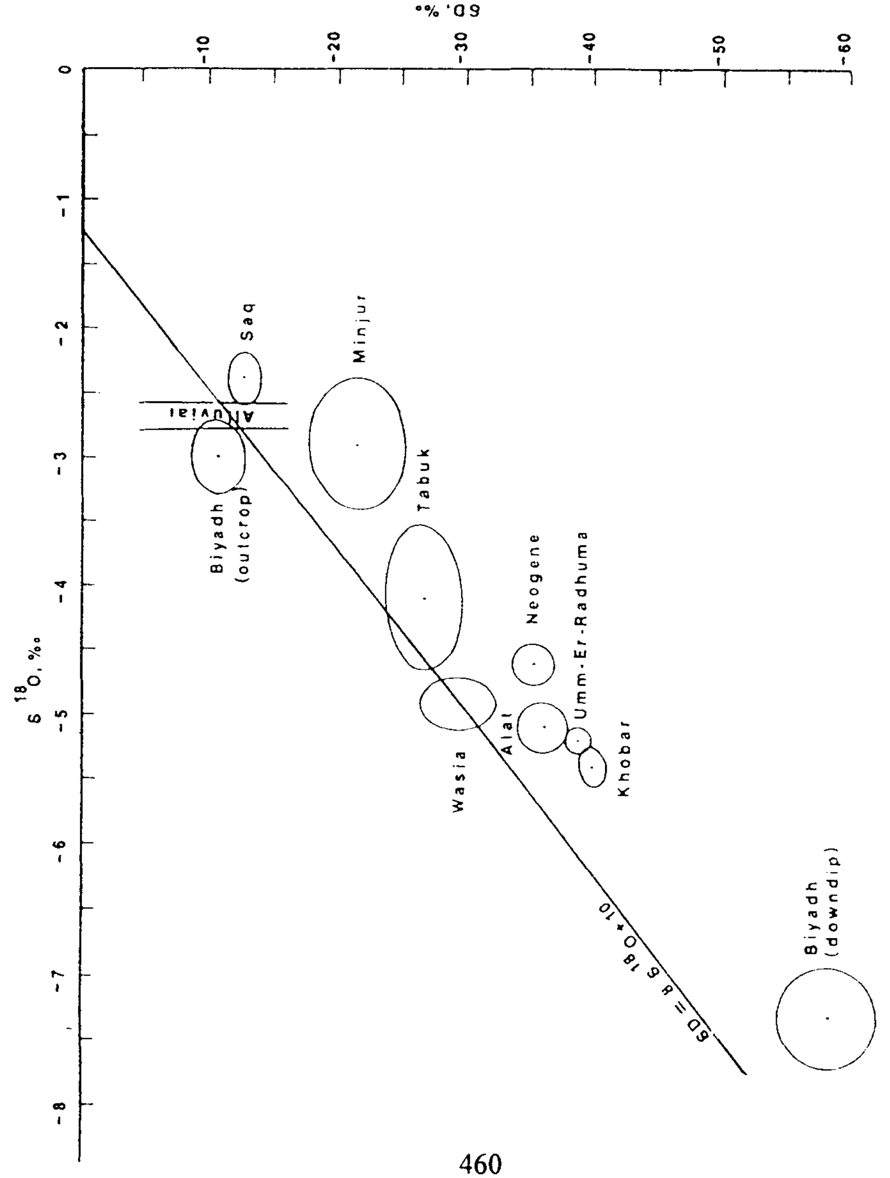


Figure 6a. Frequency distribution of C-14 ages in major aquifers of Saudi Arabia (Shampine et al. 1979)

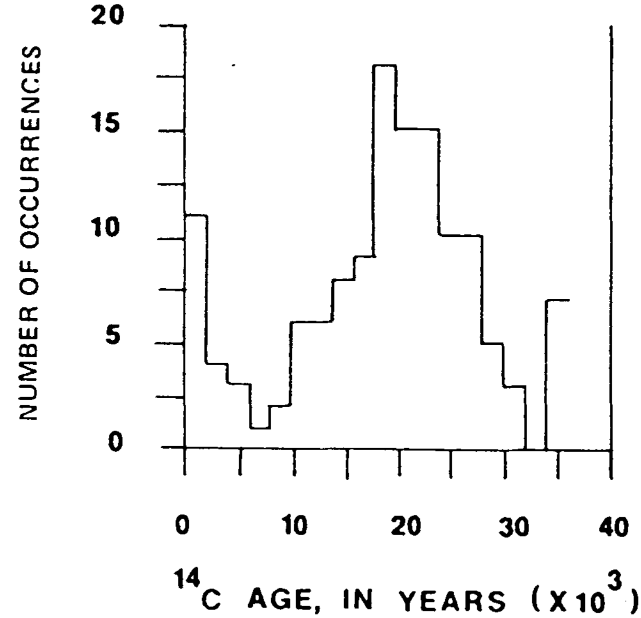


Figure 6b. Frequency distribution of the distance of C-14 sample locations from the outcrop areas
(Shampine et al. 1979)

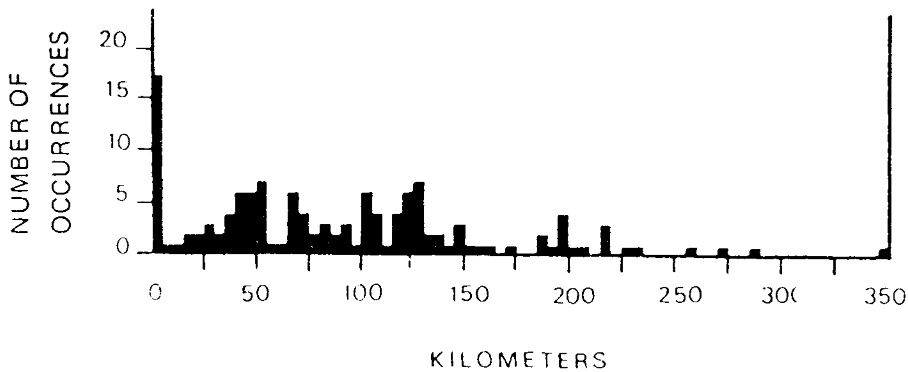


Figure 7. Sampled wells and isolines of equal tritium content for shallow groundwater in Qatar (Yurtsever et al. 1979)

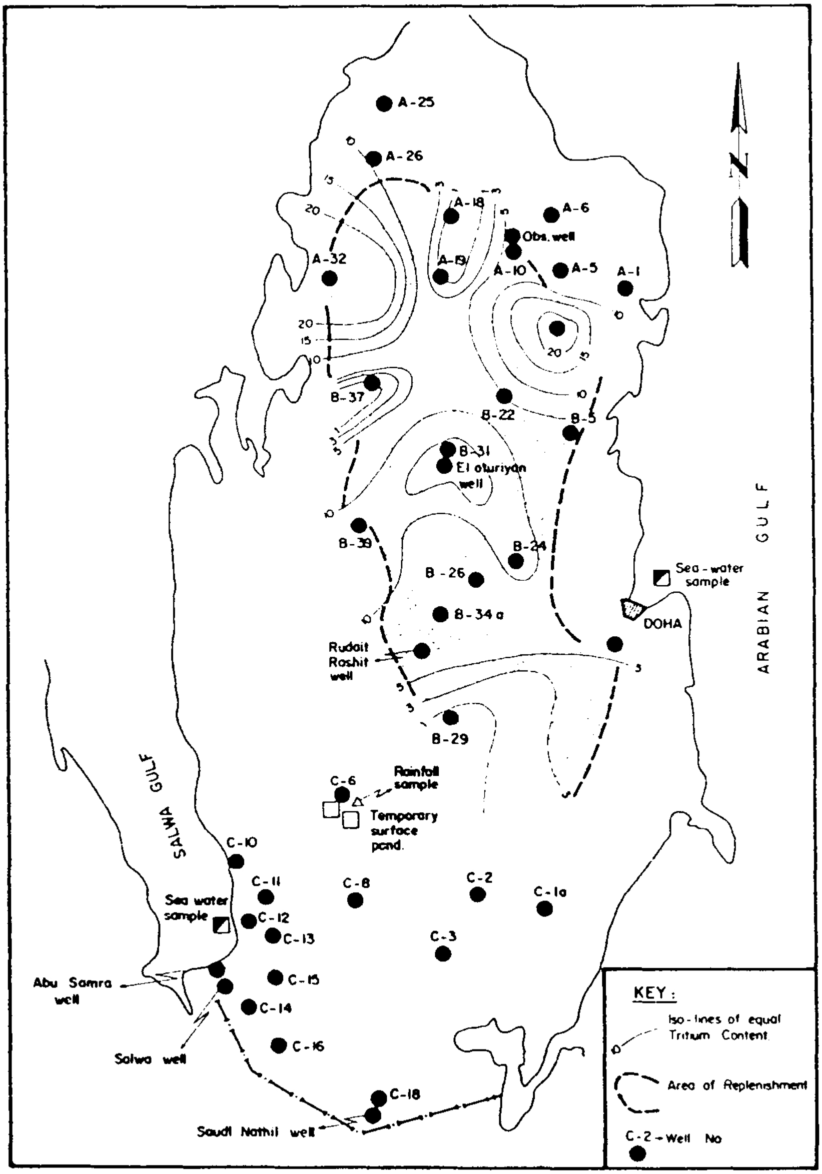


Figure 8. Stable isotopic variations in sampled wells in Qatar, as a basis for origin and mixing of waters (Yurtsever et al. 1979)

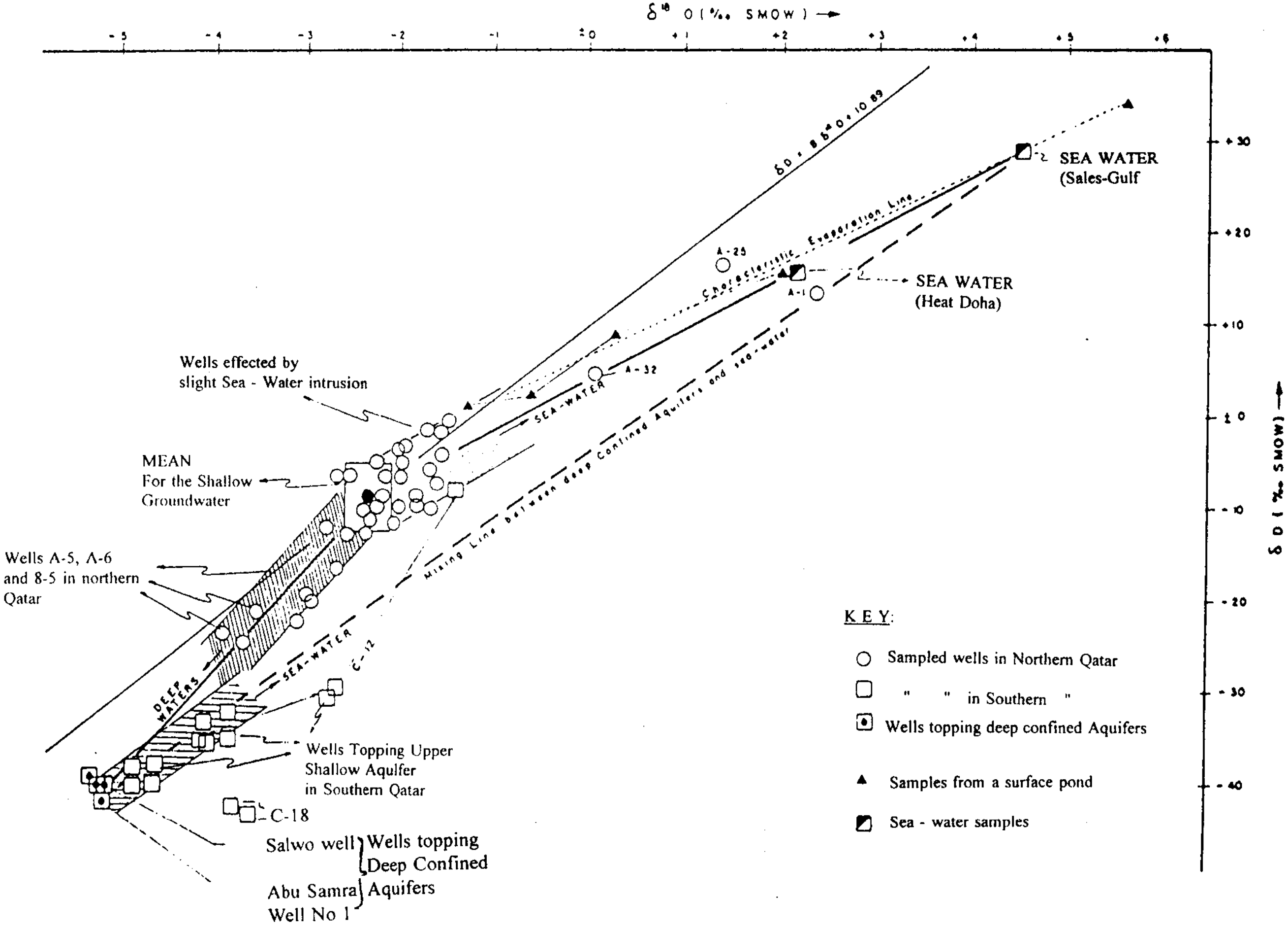
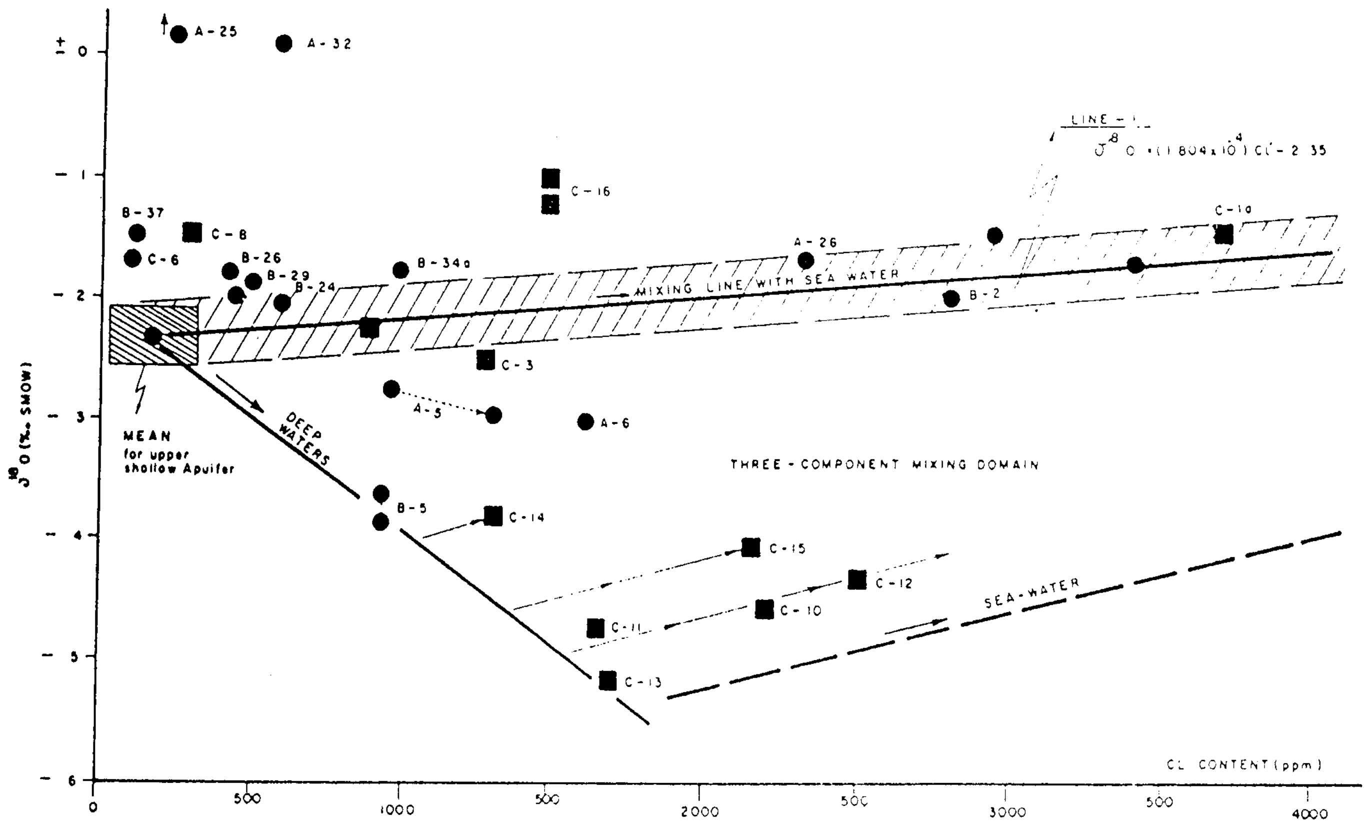


Figure 9. Oxygen-18 vs. Cl plot of sampled wells in Qatar as a basis of mixing processes (Yurtsever et al. 1979)



Within the scope of the above ongoing regional technical cooperation project of the Agency in the Middle East, major karst springs (Figeh and Barrada springs) used for water supply of Damascus city were the subject of detailed isotope investigations, to study the origin of waters in the springs and to estimate the size of the groundwater reservoir associated with these springs [15]. The stable isotopic content of these springs is given in figure 10. Based on the altitude variations of the stable isotope content in the study area (figure 11), the main source and replenishment area of the springs were delineated to be from precipitation falling on the catchment area at elevations higher than 1,700 metres. The results of tritium measurements are used for estimating the mean turn-over time of the underground karstic reservoir feeding the springs, which is about 50 years (see figure 12). Based on this estimate, the underground reservoir associated with Figeh spring should have a volume of around 3.9 billion cubic metres.

Figure 10. Stable isotopic content of major karst spring in Damascus basin (Kattan 1991)

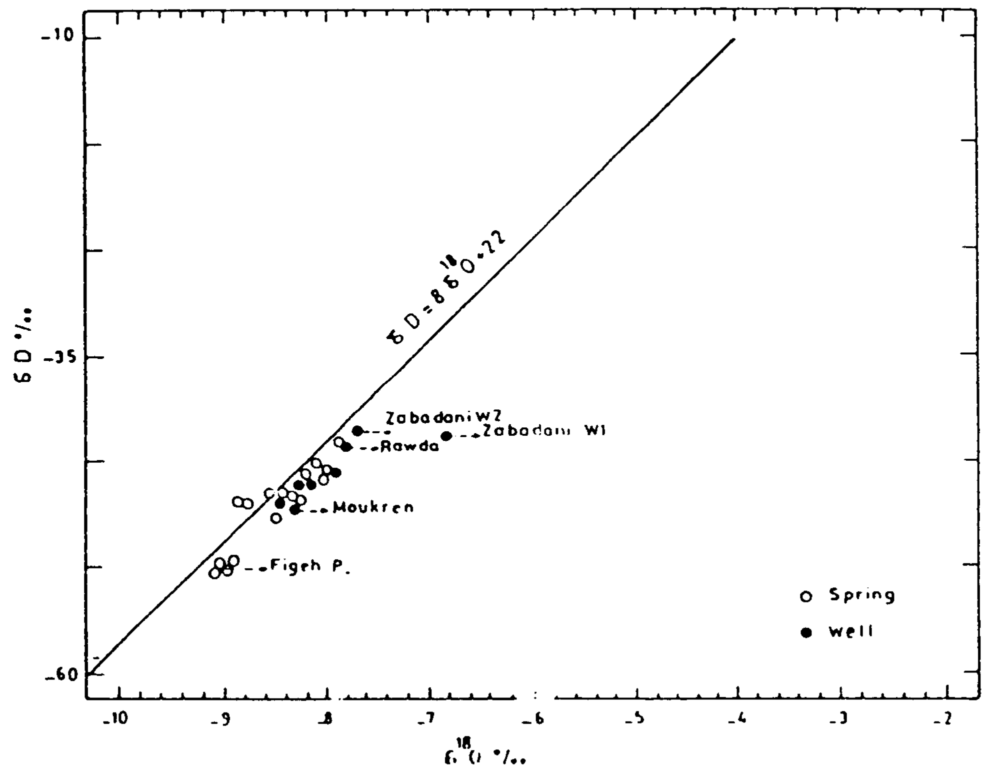


Figure 11. Oxygen-18 vs. altitude relation in Damascus Basin as a means of delineating source and area of recharge of springs (Kattan 1991)

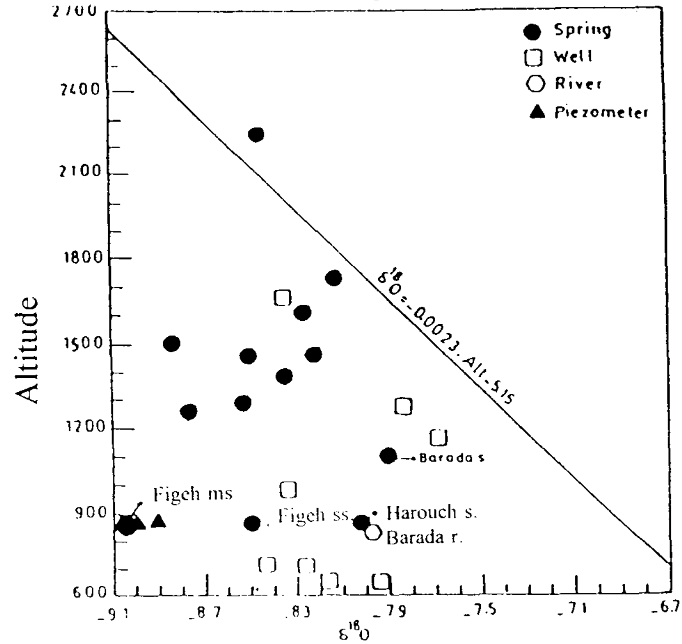
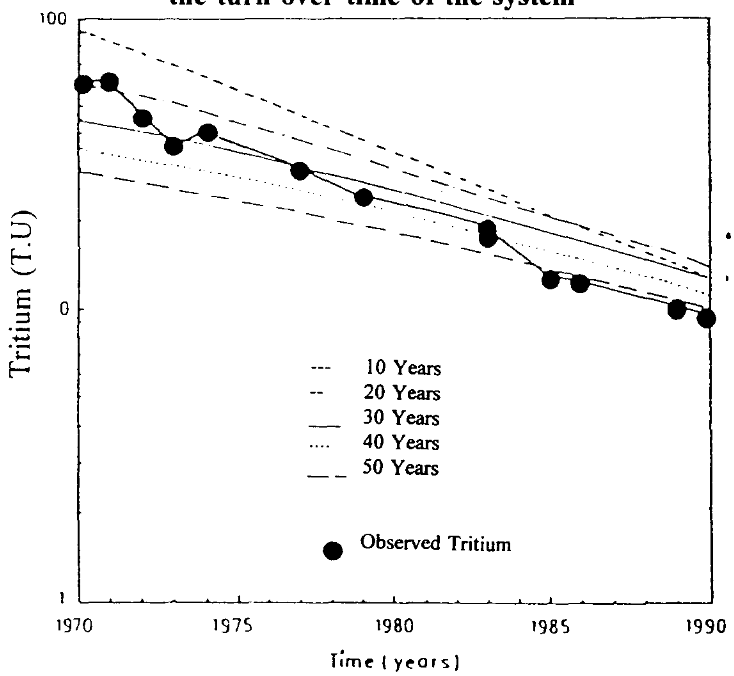


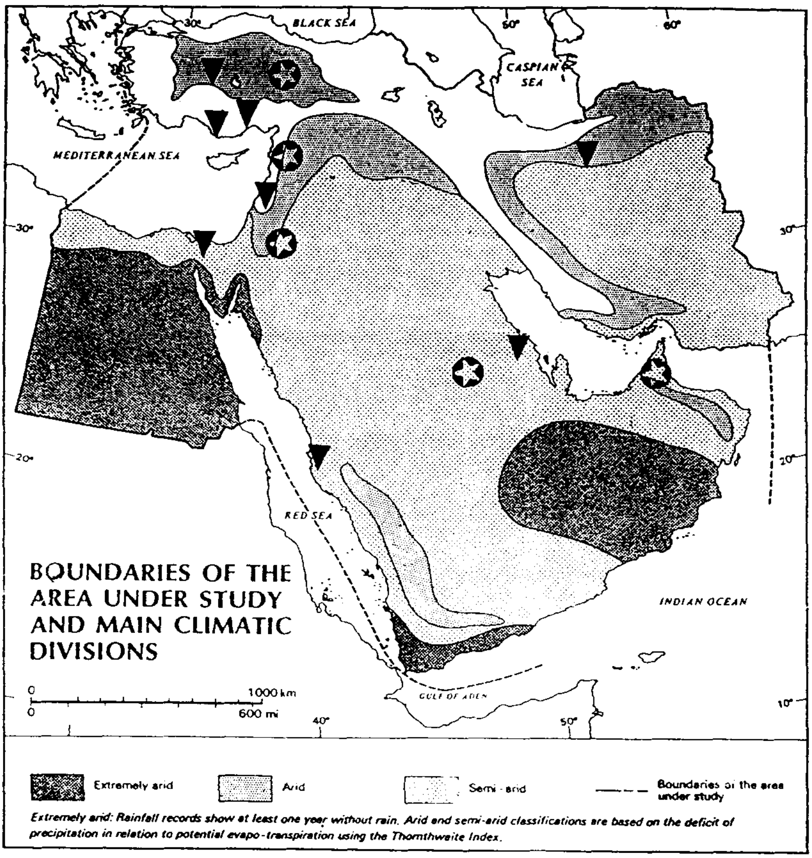
Figure 12. Model calculated and observed tritium concentration at Figeh spring, as a basis for estimating the turn-over time of the system



D. CONCLUSIONS

Methodologies based on the environmental isotope applications in hydrology are well established and should be considered an integral part of hydrogeological investigations on water resources assessment, development and management. The basic input data required for applications of environmental isotopes in the ESCWA region are already available from network stations of the IAEA in the region, and more detailed similar data will be available in future from national networks recently initiated in some countries of the ESCWA region (Jordan, Saudi Arabia, Syrian Arab Republic and United Arab Emirates) (figure 13). The analytical facilities necessary for undertaking isotope analyses of water samples are also available in the region, such as the Isotope Hydrology Laboratory of the Water Authority of Jordan, which is fully equipped to provide analyses for all of the commonly used isotopes (O-18, H-2, H-3, C-14 and C-13).

Figure 13. Precipitation stations in the ESCWA region in which monitoring of isotope content is being carried out as basic data



▼ Stations in the IAEA\WMO Global Network

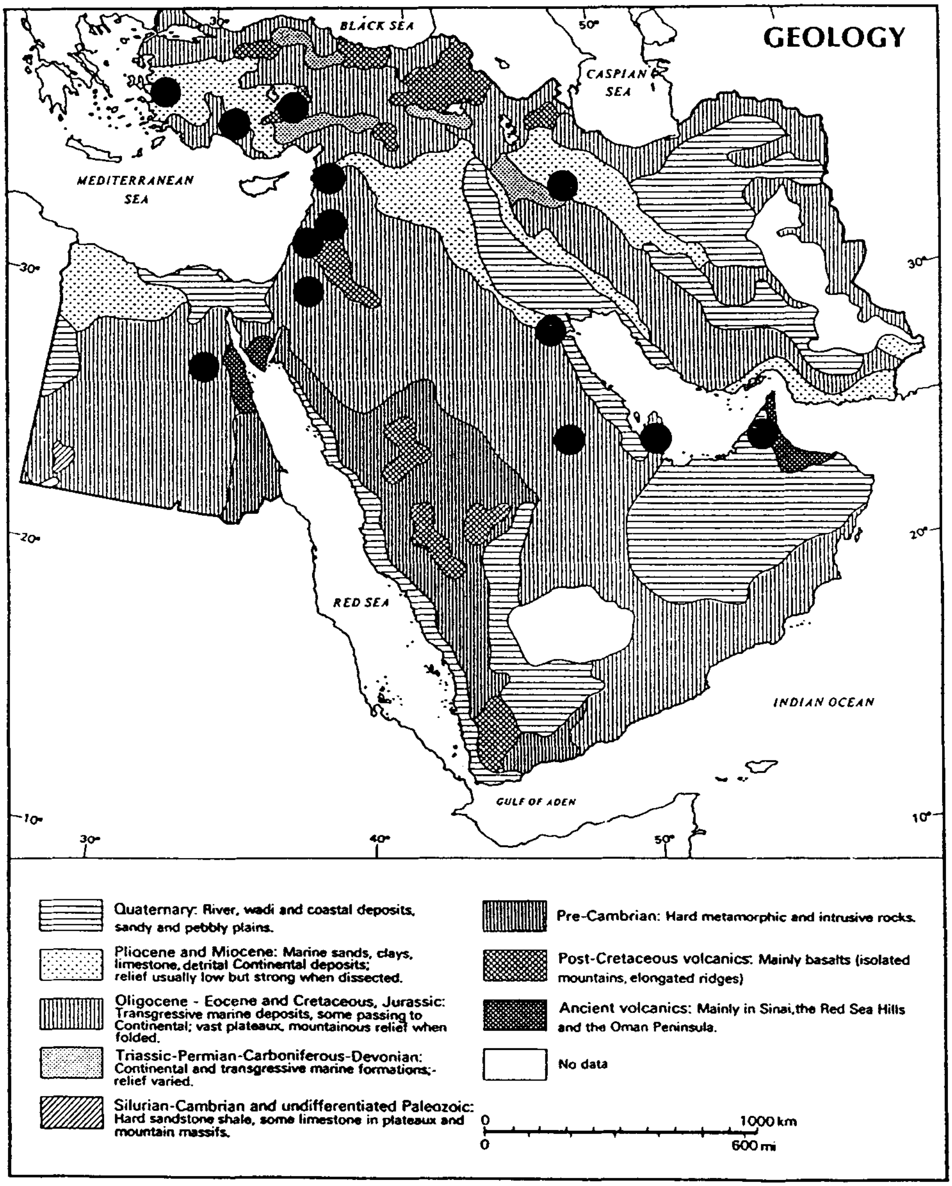
Stations within national monitoring network

The Agency's recently completed regional technical cooperation project, entitled "Isotope Hydrology in the Middle East", has provided transfer of the technology and know-how in the field of isotope applications in hydrology. At present there is a core of well-trained local staff in most of the countries in the ESCWA region, who are fully capable of planning, implementing and evaluating results of isotope field applications for future studies within their national programmes for water resources assessment, development and management.

A new follow-up regional technical cooperation project in the ESCWA region, entitled "Isotope Hydrology Techniques in Water Resources Management" (RAW/8/002), is being implemented by the Agency. The project emphasizes the application of isotope methods to problems related to groundwater pollution, sea-water encroachment in coastal aquifer systems and detailed investigations in the unsaturated zone as a basis to estimate direct recharge to the aquifer systems. The results and findings will also be published by the Agency upon completion of the project. The locations of aquifer systems where isotope field investigations have been completed or are presently being conducted within the scope of the above IAEA regional projects are shown in figure 14.

Isotope methodologies developed and verified during the last three decades of international efforts should be considered an integral part of exploratory hydrogeological investigations and they can substantially contribute to optimum and sustainable development and management of water resources. In this regard, they also have a potential role to play in achieving the objectives and mandates delineated in Agenda 21 as regards development and protection of freshwater resources in general and scarce water resources of the ESCWA region in particular. In addition to the activities being undertaken and projects being implemented by the IAEA in the field of isotope hydrology, it would be most desirable for isotope methodologies to be incorporated into overall national activities related to water resources and to projects being implemented by other international organizations and specialized agencies of the United Nations.

Figure 14. Study areas in the ESCWA region where isotope field investigations have been completed or are being conducted for groundwater studies



REFERENCES

1. IAEA. 1993. Guidebook on nuclear techniques in hydrology 1983 edition, Technical Report Series No. 91, Vienna.

2. ———. 1981. Stable Isotope Hydrology: Deuterium and Oxygen-18 in water cycle, Technical Report Series No. 210, Vienna.

3. ———. 1970. Isotope Hydrology 1970, Proceedings of a Symposium, 1970, Vienna.

4. ———. 1974. Isotope Techniques in Groundwater Hydrology, Proceedings of a Symposium, Vienna.

5. ———. 1979. Isotope Hydrology 1978, Proceedings of Neuherberg Symposium, Vienna.

6. ———. 1980. Arid Zone Hydrology: Investigations with Isotope Techniques, Vienna.

7. ———. 1981. Statistical treatment of environmental isotope data in precipitation, Technical Report Series No. 206, Vienna.

8. ———. 1984. Isotope Hydrology 1983, Proceedings of Vienna Symposium, Vienna.

9. ———. 1984. Mathematical models for interpretation of tracer data in groundwater hydrology, IAEA-TECDOC-381, Vienna.

10. ———. 1987. Isotope Techniques in Water Resources Development, Proceedings of Vienna Symposium, Vienna.

11. ———. 1991. Isotope Techniques in Water Resources Development, Proceedings of Vienna Symposium, Vienna.

12. ———. 1980. Nuclear Techniques in Groundwater Pollution Research, Proceedings of an Advisory Group Meeting, Vienna.

13. Shampine, W.J. et al. 1979. An Evaluation of Isotope Concentrations in the Groundwater of Saudi Arabia, Isotope Hydrology 1978, Proceedings of a Symposium, vol. 2, IAEA, Vienna.

14. Yurtsever, Y., and B.R. Payne, 1979. Application of Environmental Isotopes to Groundwater Investigations in Qatar, Isotope Hydrology 1978, Proceedings of a Symposium, vol. 2, IAEA, Vienna.

15. Kattan, Z., 1991. Environmental Isotope Study of the Major Karst Springs in Damascus Limestone Aquifer Systems, IAEA Workshop on Isotope Hydrology in the Middle East, Ankara.

XXV. THE UNESCO RESPONSE TO AGENDA 21, WITH EMPHASIS ON FRESHWATER-RELATED ISSUES

by

*Abdin M. A. Salih**

Introduction

The main results of the United Nations Conference on Environment and Development (UNCED), which took place in Rio de Janeiro, Brazil, in June 1992, were the following:

(a) Rio Declaration;
(b) Agenda 21;
(c) Convention on Biological Diversity;
(d) Framework Convention on Climate Change;
(e) Statement of Forest Principles.

Although the successful follow-up of these results depends first and foremost on national action, international cooperation is essential to support and supplements national efforts. Because of its broad mandate and long experience, UNESCO is involved in many aspects of UNCED follow-up, with particular emphasis on Agenda 21 and the conventions on biological diversity and climate change.

Even before the Rio Conference, most of the UNESCO programmes were coincidently already in support of UNCED objectives. Environment and development problems have been a major focus of the work of UNESCO for the past 40 years. Beginning with the Arid Zone Programme in 1951, numerous UNESCO programmes have been launched to address research, education, training and policy needs related to specific environment and development issues (e.g., water resources management and conservation of biological diversity) and ecological systems (e.g. islands, tropical forests, mountains and arid lands).

Since the Rio Conference, UNESCO has given "priority importance to activities concerned with the implementation of the relevant chapters of Agenda 21 and of other UNCED results, within the competence of the organization, both in the present biennium and in planning programmes for 1994-1995 and beyond" (Executive Board, 141st session, Decision 7.2.1). UNESCO is addressing UNCED follow-up primarily by reorienting its existing programmes.

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A. Focus on Agenda 21

Agenda 21 is widely adopted as the international programme of action for global sustainable development into the twenty-first century. It reflects a new political commitment to sustainable development at the highest level. However, it is a complex document with many chapters, divided into one or more programme areas, each of which contains a wide range of activities to be undertaken by Governments, international organizations, non-governmental organizations, and/or the private sector. Science, education and capacity-building activities are listed not only in the "cross-cutting" chapters, but also in the "topical" chapters, such as those concerning biological diversity and oceans.

In contributing to the implementation of Agenda 21, the primary goal of UNESCO "to combat poverty, create equitable social and economic conditions, address issues related to population dynamics and ensure a healthy environment and sustainable use of resources for the benefit of present and future generations," is considered. Due to its broad cross-cutting mandate, UNESCO contributes to a greater or lesser extent to almost all of the 40 chapters of Agenda 21 (see annex).

In addressing these overriding concerns, however, priority has been given to seven areas where UNESCO is expected to be among the United Nations agencies making the most substantial contribution:

(a) Education, public awareness and training (chapters 25 and 36);

(b) Science (chapters 31 and 35);

(c) Capacity-building in developing countries and transfer of environmentally sound technology (chapters 34 and 37);

(d) Oceans, coastal areas and small islands (chapter 17);

(e) Biological diversity (chapter 15);

(f) Freshwater resources (chapter 18);

(g) Land ecosystems and resources, including combating desertification (chapters 10, 11, 12 and 13).

Of particular importance are chapters 35 (science) and 36 (education, public awareness and training), for which UNESCO will play a lead role as "task leader" for facilitating coordination within the United Nations system.

UNESCO also contributes, to a lesser extent, to the implementation of other chapters, such as those on the atmosphere, hazardous waste management and biotechnology, as well as those dealing with the social and economic dimensions of environment and development issues, such as human health and human settlements.

In this presentation, however, the author will concentrate only on issues directly related to UNCED freshwater recommendations, with emphasis on the UNESCO International Hydrological Programme (IHP) and its response to these recommendations.

B. AGENDA 21 AND FRESHWATER RESOURCES

Agenda 21 freshwater resources (chapter 18)

The main components of chapter 18 are the following:

(a) Support the assessment of national water resources and the establishment of water management guidelines, taking into account the impact of human activities on the hydrological cycle;

(b) Study the impact of social transformations (e.g., population growth and urbanization) on water quality and quantity;

(c) Support hydrological observation programmes within the Global Terrestrial Observing System;

(d) Promote participation by developing countries in research and observation programmes related to the hydrological cycle by strengthening technical support, postgraduate training for specialists and a lectureship scheme,;

(e) Strengthen information for decision makers, education and public awareness programmes about freshwater issues.

However, Agenda 21 has also addressed many issues directly related to freshwater resources within the following frameworks:

(a) Land ecosystems and resources (chapters 10, 11, 12 and 13);
(b) Oceans, coastal areas and small islands (chapter 17);
(c) Convention on Biological Diversity;
(d) Framework Convention on Climate Change.

The great resemblance of these requirements to UNESCO environmental programmes, especially its freshwater programme, can easily by detected from the following brief review of the components of the international hydrological programme.

C. UNESCO International Hydrological Programme

1. *Goals and objectives*

UNESCO international scientific cooperative programmes in water resources (IHP, and earlier IHD) were established because both the international scientific community and Governments have realized that water resources are often one of the primary limiting factors for sustainable socio-economic development in many regions and countries of the world, and therefore require an internationally coordinated programme for their rational management. Thus, the general objectives of the IHD, and later the IHP, were to improve the scientific and technological basis for the development of principal methods and techniques as well as to provide the human resources base necessary for the rational development and management of water resources. The pursuit of this objective has been fundamental to the search for solutions to basic problems related to, among others, lack of reliable water supplies and sanitation, shortage of food and fibre, inadequate supplies of electrical energy, pollution of surface water and groundwaters, erosion and sedimentation, floods, drought and navigation.

Since the inception of the IHD in 1965, and later the IHP in 1975, great progress has been achieved regarding methodologies for water resources and management as well as in capacity-building in the water sector. Notwithstanding the achievements attained, the general objectives remain valid, but perhaps with some changes in emphasis. The main components of these changes include the current emphasis given to water resources management for sustainable development and the adaptation of hydrological sciences to cope with the anticipated climate change and the preservation of the environment.

2. *IHP structure and implementation*

The IHP is planned, executed, coordinated and monitored at global, regional, subregional and national levels. This is accomplished through National IHP Committees, the Intergovernmental Council (IC) of the IHP and its Bureau, committees, working groups, rapporteurs and regional hydrologists. IHP programmes are generally executed in close cooperation and harmony with related UNESCO environmental programmes (MAB, IGCP, IOC), other United Nations specialized organizations (WMO, FAO, WHO, UNEP, IAEA, ESCWA), regional organizations (such as ACSAD and ALECSO) non-governmental scientific organizations (IAHS, IAH, IAHR, IWRA) and research and academic circles. It remains to be mentioned that the finances of the IHP projects are provided through both the regular UNESCO budget, the concerned country's own resources, and extrabudgetary sources obtained from various funding bodies and agencies (such as UNDP, World Bank, and UNEP).

3. *Relevance to Agenda 21 requirements*

Noting the above objectives and implementation method, all of the previous IHP cycles (I, II, III, IV and IHD) were very successful in achieving appreciable progress in almost all of chapter 18 requirements.

IHP-IV (1990-1995), in particular, dealt with the general theme "Hydrology and Water Resources for Sustainable Development in a Changing Environment," which is well within the requirements of chapter 18 and related chapters of Agenda 21. It addressed that theme through three main subprogrammes, namely:

(a) Hydrological research in a changing environment;
(b) Management of water resources for sustainable development;
(c) Education, training, and the transfer of knowledge and information.

In response to a clear directive from the UNESCO Executive Board, all of the projects implemented within the biennium 1994-1995 have given great consideration to Agenda 21 requirements. Such considerations have greatly influenced the shaping of the IHP-V (1996-2001) programme. More details on this programme will be presented in the following section.

D. The proposed IHP-V: Hydrology and water resources development: a vulnerable environment (1996-2001)

1. *Point of departure from previous IHPs*

During the preparations for the United Nations Conference on Environment and Development, a number of international meetings, which were either directly or indirectly related to hydrological water resources, were held in many parts of the world. The International Conference on Water and Environment (ICWE), held in Dublin from 26 to 31 January 1992, provided the major input on freshwater problems, calling attention to the serious problems of optimizing the use of freshwater resources in the years ahead. Its statement, principles and recommendations have been accepted worldwide as the main agenda on water issues.

Freshwater issues also came up at the International Conference on an "Agenda of Science for Environment and Development into the 21st Century (ASCEND)", which was convened by ICSU in Vienna in November 1991 in order to make a contribution to the formulation of the future directions of world science as well as to the preparation of UNCED. The water scarcity was pinpointed as among the major problems that affect the environment and hinder sustainable development, and are of the highest scientific priority.

The recommendations of the above-mentioned major international conferences, together with the chapter on freshwater in Agenda 21, formed the basis for preparing the documents of IHP-V. The concept paper of this document points out that if future water resources development and management schemes are to be sustainable, they will have to deal effectively with the following four major issues:

(a) Environmental and social consequences;
(b) Land-water linkage;
(c) Allocation of water among competing uses and users;
(d) Achieving effective implementation.

2. *Framework and general outline of IHP-V*

In general, IHP-V plans to stimulate a stronger interrelation between scientific research, application and education. The emphasis should be on environmentally sound integrated water resources planning and management supported by scientifically proven methodologies.

Within these major issues eight themes, given below, have been identified as a support structure for the whole programme. They cut across different hydrological scales and different climatic regions, but have integrated water management in a vulnerable environment as a common issue. The proposed themes are seen as cornerstones within which projects could be flexibly implemented. Owing to the special importance of water problems in the humid tropics and the arid/semi-arid zones, as well as in urban areas, these regions should gain increased attention. The eight proposed themes are:

1. Global hydrological and biochemical processes;

2. Ecohydrological processes in the surficial zone;

3. Groundwater resources at risk;

4. Strategies for water resources management in emergency and conflicting situations;

5. Integrated water resources management in arid and semi-arid zones;

6. Humid tropics hydrology and water management;

7. Integrated urban water management;

8. Transfer of Knowledge, Information and Technology (KIT).

To avoid a purely hierarchical structure of the IHP-V programme, any theme should emphasize both methodological aspects as well as a process for knowledge transfer. All must include interactions in the biotic and abiotic environments as well as in decision-making. This may call for a different organization of the programme.

The products should be considered as the outcome of the worldwide efforts of member States and regional and international organizations. UNESCO, while conducting a large number of activities itself, will coordinate all IHP-related activities through the Intergovernmental Council of IHP regardless of the method of implementation.

E. IHP IN THE ARAB REGION

Many reports and regional meetings have, more or less, agreed on the followings as priority areas in the Arab region:

(a) Integrated sustainable water resources management under arid and semi-arid conditions (with special emphasis on resource assessment, demand management, augmentation of supply, conservation, quality deterioration, environmental assessment, conflict resolution and management, legislation and regulatory frameworks);

(b) Capacity-building and institutional development;

(c) Database and information systems;

(d) Public awareness and participation;

(e) Research and development.

These areas have also been identified, and actions for solving them have been recommended by many international meetings and programmes, including the Mar Del Plata Action Plan (1977), the Delft Declaration (1991), the Dublin statement (1992) and in Agenda 21 of UNCED (1992) as well as in many other regional and national inputs. These topics have also been dealt with, in one way or another, in all of the IHD/IHP programmes of UNESCO since 1965 and are currently being considered in its forthcoming medium-term IHP-V plans (1996-2001).

Unfortunately, little or no progress at all has been achieved, in most Arab countries, in these areas, which are vital for coping with the indigenous water scarcity in a sustainable manner. To achieve a positive impact in these areas, genuine regional programmes and action plans are urgently needed through a well-coordinated project where national, regional and international professionals and financial resources are well tapped and efficiently utilized. The theme suggested in the forthcoming UNESCO-

IHP-V could provide an excellent framework for dealing with almost all of these problems if such a regional set-up is implemented.

1. *UNESCO/ROSTAS activities in hydrology*

ROSTAS programmes in hydrology are closely coordinated with IHP themes and implementation strategies. Hence, many benefits have been gained from the UNESCO IHP training programmes and publications for the last 30 years. The current activities for the biennium 1994-1995 have been planned and implemented through the following levels of involvement:

(a) Regular programme activities;
(b) Priority areas pursued through extrabudgetary sources;
(c) Participation projects;
(d) Participation in regional activities organized by other organizations.

(a) *Regular programme activities*

Activities in this category are divided into two types: theme(s) selected for highly concentrated ROSTAS efforts and routine regular activities. The themes currently selected for concentrated effort include "Groundwater Protection" and "Rainfall Water Management", while the regular activities include support of regional training courses, strengthening national IHP committees, regional meetings of IHP committees, and special thematic sessions in international conferences. Two active working groups have been established in the areas of concentration, and two state-of-the art reports have been published together with a package of identified priority topics that have been consolidated in project documents prepared for extrabudgetary funding sources.

ROSTAS involvement in IHP-V will cover almost seven of the eight themes (except for humid tropics) but owing to budgetary limits it may concentrate on three or four themes from its regular budget. It is hoped that the other areas, which are very important to the Arab region, can be tackled through other forms of funding.

(b) *Priority areas pursued through extrabudgetary sources*

ROSTAS identified many priority themes of a regional nature that cannot be financed from the ROSTAS modest regular budget. It has prepared outlines, preliminary concept papers or project documents for some of these themes and is actively seeking financial support from funding agencies. Its current individual and joint efforts in this direction include:

(a) A water resources assessment project including the updating and restructuring of the document "Water Resources Assessment in the Arab Region", jointly with ACSAD and possibly ESCWA;

(b) A comprehensive project on "Groundwater protection";

(c) A comprehensive project on "Rainwater management", jointly with ACSAD;

(d) Support for translation of important IHP publications into Arabic;

(e) Development of hydrological softwares using multimedia techniques (including CD-ROMS), jointly with ACSAD;

(f) Training and capacity-building activity in the water sector, jointly with ACSAD;

(g) Sustainable development and management of resources.

UNESCO/ROSTAS welcomes cooperation with any regional or international organization in any or all of these activities.

(c) *Participation projects*

These are projects outside the regular work plan, financed by UNESCO as a result of direct requests from the countries of the Arab region. It is unfortunate that, up to now, very few countries of the region have made significant use of this facility in the area of water resources. A special effort is being made to establish active national IHP Committees to make a better use of this facility, perhaps through a coordinated regional project.

(d) *Cooperation with other organizations*

ROSTAS is responding, whenever possible, positively to requests for cooperation and participation in regional activities organized by other regional and international water agencies. It believes that there is a need for closer interagency cooperation in planning and implementing joint priority programmes, perhaps through a joint regional project.

F. THE INTERDISCIPLINARY CHALLENGE

The diversity of UNESCO programmes in environment and sustainable development provides an important opportunity to promote UNCED interdisciplinary and intersectoral approaches and activities. At the same time, the establishment of a Bureau for the Coordination of Environmental Programmes will ensure a coherent overall policy and foster inter-programme and inter-agency cooperation. Four intersectoral initiatives have already been launched to chart new directions across established programme lines. A committee of outside experts has been appointed by the Director-General to stimulate these initiatives.

In line with that approach, ROSTAS has formed a team of competent researchers and professionals to develop and promote a workable model for an environmentally sound sustainable development concept. The Oasis of Al-Kharga, in southern Egypt, was selected as a pilot site for this exercise, as it has been preserved from external negative development influences and considered so far, by many, as a place with little or no effects of man-made pollution. For this exercise to proceed as an intersectoral and interdisciplinary work, technical and financial resources from many UNESCO environmental programmes (MAB, IHP, SC/ENV, IGCP and EPD) as well as relevant national (universities and research institutes) and international (UNICEF and CEDARE) institutes and programmes have been sought and rationally integrated and utilized. The social as well as the community participation dimensions have been given great importance in this approach.

The work of the team has been physically linked and integrated with the work of Wadi Allaqi's MAB research team, which tackles sustainable development using the UNESCO/MAB approach and takes Wadi Allaqi Biosphere Reserve, which includes Lake Nasser in southern Egypt, as a model site. More pilot schemes in several selected Arab countries are planned to be established as part of the ROSTAS/ECO programme for the medium-term plan (1996-2001). The results of these integrated schemes will be widely disseminated to relevant recipients in the Arab world as possible applicable models of sustainable development and then compiled and prepared as education and training packages, which will be regularly evaluated, improved and presented to selected priority target groups in the Arab region.

G. CONCLUDING REMARKS

(a) Though chapter 18 is considered the freshwater resources avenue of Agenda 21, it is very clear that many aspects related to water resources are considered in other chapters, especially chapters 10, 11, 12, 13 and 17 as well as the related Conventions on Climate Change and Biodiversity;

(b) The UNESCO programme on water resources (IHD/IHP) and its related other environmental programmes (IOC, MAB and EPD) meet many of the requirements of Agenda 21 in water resources. Its forthcoming IHP-V programme, in particular, represents a good framework for building up a regional project to achieve many Agenda 21 objectives in the Arab region;

(c) The most outstanding water resources priority areas in the region have been identified and ROSTAS current and future involvements contributing to these areas have been outlined. The necessity for regional cooperation has been stressed, if an effective impact is to be achieved;

(d) The interdisciplinary challenge is an important dimension of Agenda 21. UNESCO and ROSTAS efforts in that direction have been indicated.

REFERENCES

1. Abu Zeid, M., 1993, "Evaluation of Surface Water Resources in the Arab States", unpublished report prepared for ACSAD, June 1993, in Arabic.

2. "Detail Programme for the Preparation of Arab Water Security", 1992, ALECSO, Tunis, Tunisia.

3. "Groundwater Protection in the Arab Region", 1995, UNESCO/ACSAD publication (K.F. Saad et al., editors).

4. "International Conference on Water and the Environment: Development Issues for the 21st Century", 1992, the Dublin Statement and report of the conference, 26-31 January 1992, Dublin, Ireland.

5. Khouri, J., 1990, "Water Resources Assessment Activities in the Arab Region", a paper submitted to UNESCO/WMO meeting in July 1990, Geneva, Switzerland, ACSAD, Damascus, Syrian Arab Republic.

6. Mar Del Plata Action Plan, 1977, United Nations Water Conference, Mar Del Plata, Argentina, 14-25 March 1977.

7. "Rainfall Water Management", 1995, UNESCO Publication (J. Khouri et al., editors).

8. Salih, A.M.A., 1994, "Water Scarcity in the Arab Region: Options for Survival", Proceedings of the 8th conference of the Islamic Academy of Science, 5-9 December 1994, Khartoum, Sudan.

9. Salih, A.M.A., and A.G. Ali, 1992, "Water Scarcity and Sustainable Development", Nature and Resources, vol. 28, No. 1, 44-48.

10. "The Delft Declaration", 1991, Proceedings of the UNDP Symp. on "A Strategy for Water Sector Capacity Building", 3-5 June 1991, Delft, the Netherlands.

11. "Water Resources Assessment in the Arab Region", 1988, Joint Publication ROSTAS-UNESCO/ACSAD/IHHE, partially updated and translated to English version, ROSTAS/UNESCO, 1994.

Annex

UNESCO AND AGENDA 21

SOCIAL AND ECONOMIC DIMENSION

Chapter

1. Preamble

2. International cooperation to accelerate sustainable development in developing countries (international trade issues).

⇒3. COMBATING POVERTY

4. Changing consumption patterns

⇒5. DEMOGRAPHIC DYNAMICS AND SUSTAINABILITY

6. Protecting and promoting human health

7. Sustainable human settlement development

8. Integrating environment and development in decision-making

CONSERVATION AND MANAGEMENT OF RESOURCES FOR DEVELOPMENT

9. Protection of the atmosphere

⇒10. INTEGRATED...PLANNING AND MANAGEMENT OF LAND RESOURCES

⇒11. COMBATING DEFORESTATION

⇒12. COMBATING DESERTIFICATION AND DROUGHT

⇒13. SUSTAINABLE MOUNTAIN DEVELOPMENT

14. Promoting sustainable agriculture ...

⇒15. CONSERVATION OF BIOLOGICAL DIVERSITY

16. Environmentally sound management of biotechnology

⇒17. OCEANS ... COASTAL AREAS AND SMALL ISLANDS

⇒18. PROTECTION OF THE QUALITY AND SUPPLY OF FRESHWATER RESOURCES

19. Environmentally sound management of toxic chemicals

20. Environmentally sound management of hazardous wastes ...

21. Environmentally sound management of solid wastes and sewage-related issues

22. Safe and environmentally sound management of radioactive wastes

STRENGTHENING THE ROLE OF MAJOR GROUPS

23. Preamble

⇒24. WOMEN

⇒25. CHILDREN AND YOUTH

26. Indigenous people

27. Non-governmental organizations

28. Local authorities' initiatives

29. Workers and their trade unions

30. Business and industry

⇒31. SCIENTIFIC AND TECHNOLOGICAL COMMUNITY

32. Farmers

MEANS OF IMPLEMENTATION

33. Financial Resources and Mechanisms

⇒34. TRANSFER OF ENVIRONMENTALLY SOUND TECHNOLOGY

⇒35.* SCIENCE FOR SUSTAINABLE DEVELOPMENT

⇒36.* PROMOTING EDUCATION, PUBLIC AWARENESS AND TRAINING

⇒37. CAPACITY-BUILDING IN DEVELOPING COUNTRIES

38. International institutional arrangements

39. International legal instruments and mechanisms

40. Information for decision-making

Note: Due to its broad, cross-cutting mandate, UNESCO contributes to a greater or lesser extent to almost ALL of the 40 chapters of Agenda 21.

⇒ AREA WHERE UNESCO HAS PARTICULARLY SUBSTANTIAL PROGRAMMES AND THUS PLAYS A PROMINENT ROLE AMONG UNITED NATIONS AGENCIES FOR THE IMPLEMENTATION OF THE CHAPTER.

(*) UNESCO serves as "task leader" within the United Nations system for implementation of the chapter.

XXVI. MANPOWER TRAINING IN THE FIELD OF WATER/WASTEWATER

A. Establishment of CEHA

CEHA is the Regional Centre for Environmental Health Activities. It has become operational in 1985 after the agreement reached between the Government of Jordan and WHO for the hosting of the Centre in Amman. The Centre is part of the Environmental Health Division of the Eastern Mediterranean Regional Office (EMRO) of WHO in Alexandria, Egypt. The Centre offers services to 22 member States of the region, in addition to what is provided by the regional office in the field of environmental health.

Promotion of environmental health is a major area of WHO activities. WHO has long recognized that a healthy environment is a prerequisite for the health of individuals and for quality of life.

B. Mandate of CEHA

The main mandate of CEHA is to promote environmental health. In order to fulfil its mandate, CEHA is aiming to achieve the following:

1. Support the development and strengthening of national institutional capabilities and programmes;

2. Provide a flow of information to and between member States;

3. Promote health awareness in relation to development and environment in the region;

4. Strengthen the scientific and technical basis of environmental health work in the region.

C. WHO/CEHA environmental health technical areas

The Centre's activities constitute a component of the regional programme and are developed in close coordination and cooperation with both the regional office and WHO environmental health interventions at the country level.

The programmes include the following technical areas for the promotion of environmental health:

1. Community Water Supply and Sanitation (CWS);

2. Control of Environmental Health Hazards (CEHA);

3. Food Safety (FOS);

4. Chemical Safety (PCS);

5. Environmental Health in Rural and Urban Development and Housing (RUD);

6. Environmental Health in Refugee Camps (RCE).

D. CEHA ACTIVITIES

In achieving its objectives, CEHA basically carries out the following activities:

1. Training/human resources development (HRD).
2. Information exchange (CEHANET).
3. Special studies/applied research.
4. Technical cooperation.

Another most important task of CEHA is to follow up on the recommendations produced during regional consultation meetings, plans of action proposed in the short term, and mission reports of consultants and/or WHO staff.

E. MANPOWER TRAINING

The shortage of trained professionals/technical personnel is a major handicap to progress in the field of environmental health in the region. Training/HRD activities of CEHA are aimed at filling this gap so that there will be better changes for the fulfilment of the essential goal of WHO, which is "HEALTH FOR ALL BY THE YEAR 2000". During the first six years (1985-1990) of CEHA, its training activities were mostly concentrated on Community Water Supply and Sanitation to meet the challenges of the International Drinking Water Supply and Sanitation Decade (1980-1990).

WHO has always been concerned with the quality of drinking water and the treating of effluent for reuse, given the impact of these issues on human health. Within this framework of interest, CEHA initiated a campaign to introduce and promote the 1984 Drinking-Water Quality Guidelines, offering to hold national seminars for its member States, so that national authorities could use the Guidelines in formulating their drinking water standards. About 15 countries accepted this offer and held national seminars. Now CEHA is preparing another campaign for introducing and promoting the 1993 Guidelines for Drinking-Water Quality.

In 1991, CEHA launched a similar campaign of national seminars on "Wastewater Effluent Reuse" to introduce and promote the 1989 Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture, covering 14 member States within three years.

F. Modes of training

Training activities of CEHA offered to member States may be in the following modes: training courses; workshops; seminars; conferences; and consultation meetings. The training activities of CEHA may either be at a national level, to be held in member States, or may be at a regional (inter-country) level, usually at CEHA.

G. Criteria for identification of subjects for training

The following are the channels through which CEHA training activities are identified:

1. *National level*

(a) Officials of the country's environmental health institutions may request training in any field of environmental health;

(b) Subjects for national training may be identified by CEHA based on the recommendations produced during regional consultations;

(c) The current environmental health problems faced in the region were prioritized in the Regional Strategy for Health and Environment: one of the areas of highest priority may be the subject of a national training activity;

(d) The subject of national training may also be identified by CEHA from the recommendations of the mission reports of STCs and/or WHO staff visiting member States.

2. *Regional level*

(a) Global and regional strategies for health and environment have identified some areas of high priority: one of these areas may be identified as the subject of a regional meeting;

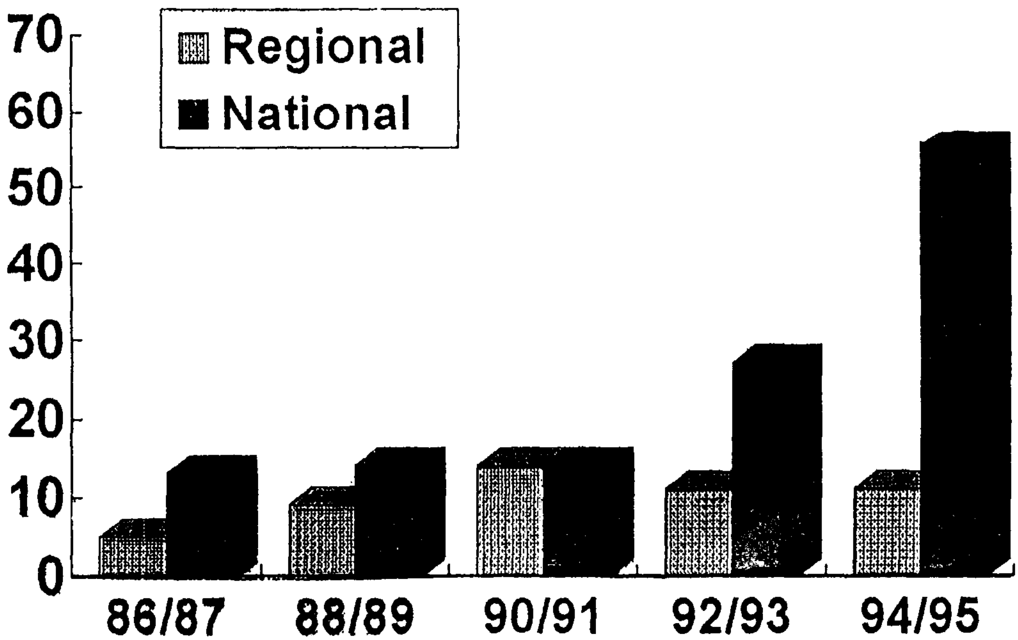
(b) WHO/HQ or any other United Nations or regional organization may propose a regional meeting for co-organization;

(c) Any regional meeting which cannot be held in a current biennium may be rescheduled to the next biennium.

H. CEHA TRAINING ACTIVITIES

Figure I shows the number of national and regional meetings held during the present and the past bienniums. From figure I, it is clear that, for training activities, emphasis is shifting from the regional level to the national level. For the cost of one average regional level meeting, about four national level meetings can be held. For a regional meeting, one or a maximum of two participants are invited from member States, whereas 25-30 or more participants take part in the national training activities. It is the policy of CEHA to organize such an expensive regional meeting for the training of trainers only. Participants in regional meetings should function as trainers during the national training activities which will be organized in their countries.

Figure I. Regional and national meetings



CEHA trained about 2,850 national staff during the first nine years (1985-1993) of the training programme through national and regional training activities. Most (90%) of this training was carried out through national level training activities, while only a small portion (10%) was carried out through regional activities. In the coming years, in every biennium, about 1,800 national staff are expected to be trained. CEHA, with its current resources, will be able to train about 9,000 national staff in different areas of environmental health by the year 2000.

I. Manpower training in water/wastewater

Table 1 shows the number of CEHA training activities through the bienniums.

TABLE 1. TRAINING ACTIVITIES OF CEHA

	National			Regional		
Biennium	Total training activities	Training on water/waste-water	Percentage	Total training activities	Training on water/waste-water	Percentage
1994-1995	57	14	24	11	3	27
1992-1993	27	14	52	11	3	27
1990-1991	14	10	71	13	5	38
1988-1989	14	12	86	8	3	38
1986-1987	13	11	85	4	3	75

It can clearly be observed that CEHA training activities have diversified over the bienniums.

XXVII. WORLD BANK ACTIVITIES IN THE ESCWA REGION RELATED TO AGENDA 21

The World Bank participated actively in the preparation of Agenda 21. This included participation in the preparatory meetings in Delft and Dublin, where essential documents on which Agenda 21 is based were drafted.

The World Bank also initiated work on a Water Management Policy Paper which was approved by the World Bank Board in 1993. The Policy Paper includes the principles of Agenda 21 and stresses the needs for a comprehensive approach to water development and management; improvement of institutional and regulatory frameworks; the use of incentives in the water sector; and the improvement of health and the environment. The Policy Paper sets out guidelines for World Bank operations in the water sector. It emphasizes that World Bank operations should assist borrowers in:

(a) Addressing key weaknesses in the water sector;

(b) Identifying priority policies, institutional reforms and needed investments;

(c) Providing technical assistance and funds for agreed priority activities.

In case inadequate progress produces misuse of resources in the water sector, World Bank lending should be limited to water supply and sanitation for poor households and water conservation.

Subsequently, the World Bank Vice President for the Middle East and North Africa issued a Strategy for Managing Water in the Middle East and North Africa. The Strategy Paper analyses the situation in the region and proposes water strategies at the national, sectoral and international levels, following the guidelines of the World Bank Policy Paper, with particular consideration of the situation in the region.

In addition to the emphasis on an integrated approach to water management, the Strategy Paper stresses the need for interactive planning and a permanent institutional capacity for sound decision-making. The preparation of country water assessments is recommended as a useful step towards national water strategies. Water conservation is singled out as an essential element of all water strategies in the region.

At the international level, riparian countries are strongly encouraged to participate in international resolution of water issues. The World Bank stands ready to provide technical, legal and intermediary support for such initiatives.

Current World Bank activities in the region consist of lending to member countries, and technical assistance and support for several regional activities. The regional activities supported by the World Bank include the Mediterranean Environmental Technical Assistance Programme (METAP) and the Mediterranean Hydrological Cycle Observation System (MEDHYCOS), which is executed by WMO. Other World Bank activities are studies of the Jordan River Basin to identify options for a long-term water development strategy, and a study of the Jordan Rift Valley.

In view of the enormous and increasing financing needs, which have been estimated to range between US$ 70 billion and US$ 130 billion for the coming 10 years in the Middle East and North Africa region, the World Bank is planning to increase its support for water development and management substantially. However, the countries themselves will undoubtedly have to mobilize more resources than in the past and change many aspects of their policies and strategies to manage the water sector satisfactorily in the interest of their peoples, their economies and the environment.

XXVIII. REGIONAL COOPERATION BETWEEN MASHREQ AND MAGHREB IN THE FIELD OF CURRENT TECHNOLOGIES IN WATER RESOURCES MANAGEMENT

by

*Kamel Mohammad Radaideh**

Introduction

The idea of the project stems from the earnest desire manifested by the participating countries to upgrade the capabilities of their water sectors in order to make them compatible with their respective needs and increasing socio-economic development and population pressures. All six countries (Algeria, Iraq, Morocco, Syrian Arab Republic and Tunisia) are faced with problems of water supply and usage. The scarcity and variability of their water resources cause problems that are compounded by the inefficient use of water, and that must be addressed by the respective national experts in this field.

The substantial growth of water needs, the limited resources of the participating countries, and their climatic, geographic and socio-economic conditions all call for the introduction into these countries of ways and means to help their water sectors. Project RAB/80/011, which terminated in 1986, involved the three countries in the Maghreb region (Algeria, Morocco and Tunisia). This project addressed some of these countries' needs, but the efforts need to be sustained over time.

Artificial recharge and reuse of wastewater, as well as control of erosion and sediment transport, are themes that constitute the main concern of those three countries. Much consideration has been given to training and exchange of experience. Competent experts in the above-mentioned fields of activity have been trained, and the Mashreq countries (Jordan, Iraq and Syrian Arab Republic) could benefit from their experience.

Project UNDP-RAB/89/003 was initiated to exchange experience among the participating countries in the Arab world and certainly to enhance interregional cooperation among these countries and open new horizons of technical collaboration in the transfer and adaptation of appropriate technologies to the advantage of all participants. The project will provide new themes of intervention for the Maghreb countries that have completed the activities of UNDP project RAB/80/011, and will extrapolate certain themes dealt with in the Maghreb and adapt them to the Mashreq.

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* Regional Coordinator.

Brief description of project RAB/89/003

This is a regional capacity-building project in Water Resources Management through networking among six countries of the Maghreb and the Mashreq. The project will provide training for planners and technicians, establish a regional network, and develop current water resources management technologies.

Participating countries:	Algeria, Iraq, Jordan, Morocco, Syrian Arab Republic and Tunisia
Duration of execution:	3 years; started 1993
Executing agency:	Government of Tunisia
Financing:	UNDP IPF (indicative planning figure) $1,154,250
Government inputs:	In kind

Major tasks of the project

1. Promote the exchange between developing countries of their acquired knowledge and experience;

2. Encourage and support integration and cooperation between the six countries;

3. Build institutions through training and human resources development;

4. Develop advanced technologies which the countries can apply within their own development programmes.

Project strategy and institutional arrangements

A preparatory phase was devoted to the prerequisite activities necessary for the project. The concept of regional and subregional cooperation was formulated.

Given the complex logistics of the proposed project, two regional offices, one in Tunisia and the other in Amman, were established. A subregional coordinator was assigned to each office. The overall coordination of the project has been given to Tunisia as regional coordinator.

The project activities will be implemented by national project teams. Each participating country will assign a National Coordinator vested with the powers of decision-making on matters related to the project.

Monitoring of activities will be provided as required by UNDP, which will also participate in multi-partite reviews and regional or interregional coordination meetings.

Organizational structure

1. The regional network steering committee (NSC) will be composed of:

(a) National coordinators of six countries;
(b) Regional and subregional coordinators;
(c) Subregional coordinator (non-voting);
(d) Regional Coordinator.

2. Subregional committee composed of:

(a) National coordinators of the subregion;
(b) Representative of UNDP;
(c) Subregional coordinator (non-voting);
(d) Regional Coordinator.

3. Network organization

<u>Mashreq subregional network on water resources management</u>

Jordan, Iraq and Syrian Arab Republic

(a) Artificial recharge (Jordan-Syrian Arab Republic);
(b) Reuse of treated wastewater (Jordan);
(c) Control of erosion, eutrophication of reservoirs (Iraq);
(d) Water resources management models (all Mashreq countries).

<u>Maghreb subregional network on water resources management</u>

Algeria, Morocco and Tunisia

<u>Secondary network (subnetworks)</u>

(a) Overexploitation of shallow aquifers;
(b) Management of water resources in Saharan regions;
(c) Control and protection of water quality.

<u>Newsletter</u>: This will facilitate communication between the two subregions. It will be published four times a year.

Pilot project: Each country will execute a pilot project within the activity charged to each country. This pilot project will provide training to the national team to achieve the goals of the project and create local criteria for the respective activities that suit local conditions. Facilities and equipment necessary to implement the pilot projects were secured and mobilization took place. Data collection has been initiated, and after the data have been interpreted a final report will be issued at the end of the project.

Training will be conducted through the following means:

(a) Study tours abroad or in the region; two were carried out (one to Italy and one to France);

(b) Seminars: one held and five planned in 1995, 1996;

(c) Workshops: two held, three planned in 1995 and four in 1996;

(d) Consultation with national and international experts.

ANNEXES

Annex I

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Executive Secretary

Special Adviser to the Executive Secretary
Regional Adviser on Energy

Chief
Energy, Natural Resources and Environment Division

Senior Economic Affairs Officer
Natural Resources Section Regional Adviser on Environment
Technical Adviser on Hydrology

Regional Adviser on Water

First Economic Affairs Officers
Natural Resources Section/ENRED

Annex II

LIST OF DOCUMENTS

Title	Symbol
Aide-mémoire	E/ESCWA/ENR/1995/WG.1/INF.1
Information notice	E/ESCWA/ENR/1995/WG.1/INF.2
Provisional list of participants	E/ESCWA/ENR/1995/WG.1/INF.3
Provisional agenda	E/ESCWA/ENR/1995/WG.1/L.1/Rev.1
Provisional programme of work	E/ESCWA/ENR/1995/WG.1/L.2
Methodologies for water sector planning	E/ESCWA/ENR/1995/WG.1/3
Assessment of water quality in the ESCWA region	E/ESCWA/ENR/1995/WG.1/4
Groundwater quality control in the ESCWA region	E/ESCWA/ENR/1995/WG.1/5
Development of water quality indices for sustainable development	E/ESCWA/ENR/1995/WG.1/6
Regional cooperation between Mashreq and Maghreb in the field of current technologies in water resources management	E/ESCWA/ENR/1995/WG.1/7
Application of isotope hydrology techniques in the ESCWA region	E/ESCWA/ENR/1995/WG.1/8
Implications of Agenda 21 for integrated water management in the ESCWA region	E/ESCWA/ENR/1995/WG.1/9
تقنية قليلة الكلفة لتنقية المياه العادمة واعادة استعمالها	E/ESCWA/ENR/1995/WG.1/10
Remote-sensing techniques for comparative studies of watersheds in selected basins in the ESCWA region	E/ESCWA/ENR/1995/WG.1/11
Planning in an arid environment	E/ESCWA/ENR/1995/WG.1/12

Title	Symbol
The establishment of a regional water training network in the ESCWA region	E/ESCWA/ENR/1995/WG.1/13
Water desalination in selected ESCWA countries: opportunities	E/ESCWA/ENR/1995/WG.1/14
Water resources information system: WHYCOS a basic tool for integrated water management	E/ESCWA/ENR/1995/WG.1/15
Isotope methodologies in water resources and examples of applications in the ESCWA region	E/ESCWA/ENR/1995/WG.1/16
UNESCO's response to Agenda 21 with emphasis on freshwater related issues	E/ESCWA/ENR/1995/WG.1/17
Manpower training in the field of water/wastewater	E/ESCWA/ENR/1995/WG.1/18
World Bank activities in the ESCWA region related to Agenda 21	E/ESCWA/ENR/1995/WG.1/19

Country papers

الورقة القطرية، جمهورية العراق	E/ESCWA/ENR/1995/WG.1/CP.1
الورقة القطرية، الجمهورية العربية السورية	E/ESCWA/ENR/1995/WG.1/CP.2
Towards Agenda 21 - chapter 18 Egyptian policy for implementation	E/ESCWA/ENR/1995/WG.1/CP.3
الورقة القطرية، الجمهورية اللبنانية	E/ESCWA/ENR/1995/WG.1/CP.4
National report: United Arab Emirates water resources	E/ESCWA/ENR/1995/WG.1/CP.5
The water sector in Yemen: status and outlook	E/ESCWA/ENR/1995/WG.1/CP.6

Title	Symbol
Country paper: State of Bahrain	E/ESCWA/ENR/1995/WG.1/CP.7
Country paper: The Hashemite Kingdom of Jordan	E/ESCWA/ENR/1995/WG.1/CP.8
National report: Qatar water activities	E/ESCWA/ENR/1995/WG.1/CP.9
The formation of the Palestinian National Water Authority	E/ESCWA/ENR/1995/WG.1/CP.10

Annex III

AGENDA

1. Opening session.

2. Election of officers.

3. Adoption of the agenda.

4. Adoption of the programme of work.

5. Presentation and discussion of the EGM documents:

   (a) Implications of Agenda 21 for integrated water management in the ESCWA region;

   (b) Methodologies for the preparation of water master plans;

   (c) Approach for the establishment of a regional water training network in the ESCWA region;

   (d) Assessment of water quality in the ESCWA region;

   (e) Groundwater quality control in the ESCWA region;

   (f) Development of water quality indices for sustainable development;

   (g) Water desalination in selected ESCWA countries: opportunities and constraints;

   (h) Application of isotope hydrology techniques in the ESCWA region;

   (i) Low-cost technique for wastewater treatment and reuse;

   (j) Remote-sensing techniques for comparative studies of watersheds in selected basins in the ESCWA region.

6. Country papers reflecting the national experiences in implementing chapters of Agenda 21 relevant to integrated water resources management.

7. Regional and international organizations' papers.

8. Recommendations of the Expert Group Meeting.

9. Adoption of the final report.

Annex IV

PROGRAMME OF WORK

Monday, 2 October 1995

9 - 10 a.m.	Registration	
10 - 11 a.m.	Opening session (Agenda item 1) Opening speeches: His Excellency Mr. Salih Irsheidat, Minister of Water and Irrigation of Jordan The Executive Secretary of ESCWA The Representative of UNEP	
11 - 11.30 a.m.	Break	
11.30 a.m. - noon	Election of officers (Agenda item 2) Adoption of the agenda and other organizational matters (Agenda items 3 and 4) Presentation and discussion of the Meeting documents (Agenda Item 5)	
Noon - 12.30 p.m.	(a)	Implications of Agenda 21 for integrated water management
12.30 - 1 p.m.	(b)	Methodologies for the preparation of water master plans
1 - 1.30 p.m.	(c)	Approach for the establishment of a regional water training network
1.30 - 2 p.m.	(d)	Assessment of water quality in the ESCWA region
2 - 2.30 p.m.	Break	
2.30 - 3 p.m.	(e)	Groundwater quality control in the ESCWA region
3 - 3.30 p.m.	(f)	Development of water quality indices for sustainable development (Case Study)
9 - 9.30 a.m.	(g)	Water desalination in selected ESCWA countries: opportunities and constraints

Tuesday, 3 October 1995

9.30 - 10 a.m.	(h)	Application of isotope hydrology techniques in the ESCWA region
10 - 10.30 a.m.	Break	
10.30 - 11 a.m.	(i)	Low-cost technique for wastewater treatment and reuse
11 - 11.30 a.m.	(j)	Remote-sensing techniques for comparative studies of watersheds in selected basins in the ESCWA region
11.30 a.m. - 2 p.m.	Country papers reflecting the national experiences in implementing chapters of Agenda 21 relevant to integrated water management	
2 - 2.30 p.m.	Break	
2.30 - 4.30 p.m.	National papers presentation (continued)	

Wednesday, 4 October 1995

9 - 10.30 a.m.	National papers presentation (continued)
10.30 - 11 a.m.	Break
11 a.m. -12.30 p.m.	National papers presentation (continued)
12.30 - 2 p.m.	Regional and international organizations' papers
2 - 2.30 p.m.	Break
2.30 - 4.30 p.m.	Regional and international organizations' papers (continued)

Thursday, 5 October 1995

9 - 10.30 a.m.	Panel discussion and recommendations of the Expert Group Meeting (Agenda item 8)
10.30 - 11 a.m.	Break
11 a.m. - 1 p.m.	Tour visit to the Royal Jordanian Geographic Centre
1 - 4 p.m.	Adoption of the final report (Agenda item 9)