

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION (CDR) and
MINISTRY OF ENERGY AND WATER (MEW)
THE REPUBLIC OF LEBANON

THE STUDY
ON
WATER RESOURCES MANAGEMENT MASTER PLAN
IN
THE REPUBLIC OF LEBANON

FINAL REPORT
MAIN REPORT

JICA LIBRARY



1217507 [1]

January, 2004

SANYU CONSULTANTS INC.
YACHIYO ENGINEERING CO., LTD

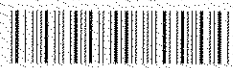
SSS



03-170

2006.5.29

登錄簿



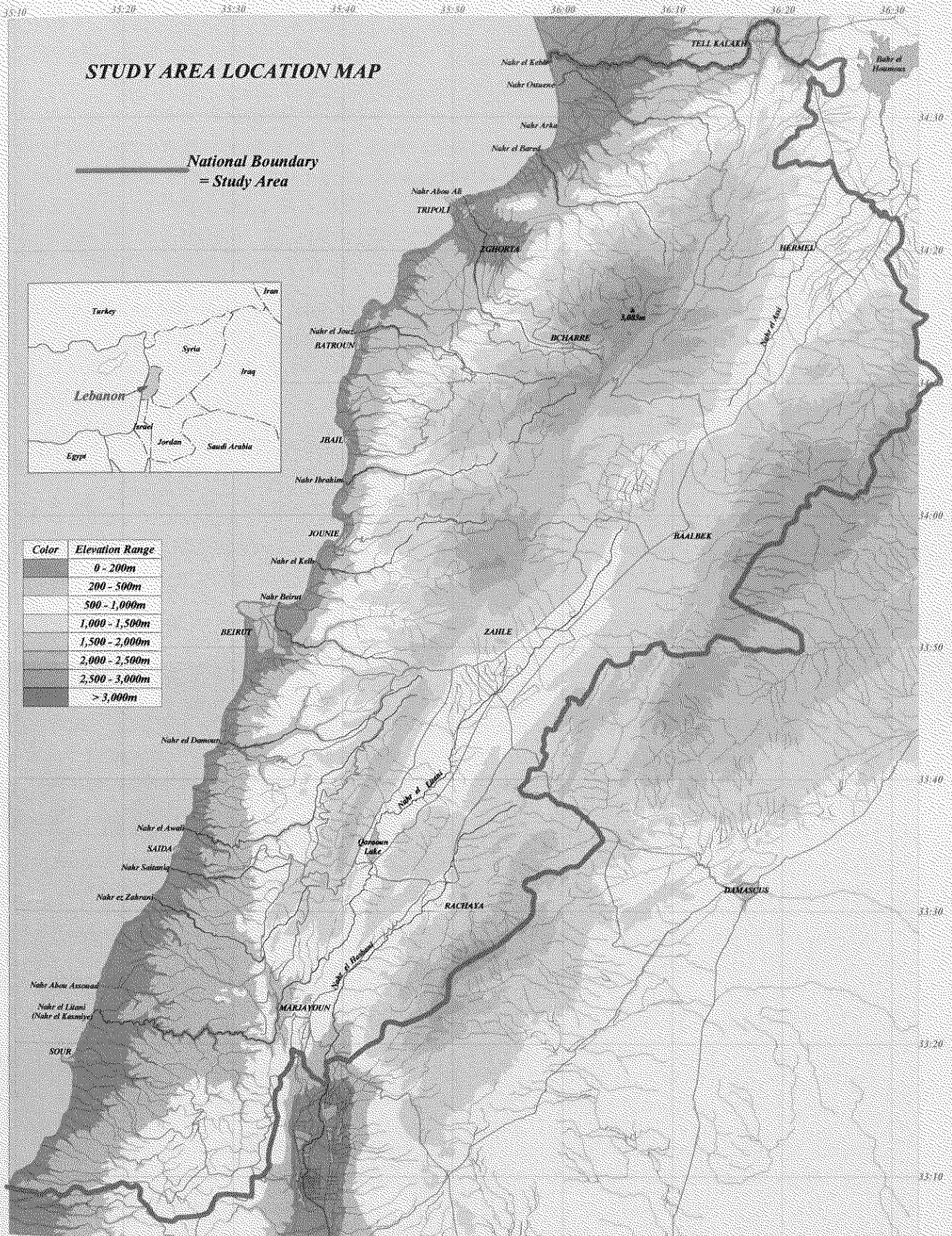
1217507 [1]

STUDY AREA LOCATION MAP

National Boundary
= Study Area



Color	Elevation Range
	0 - 200m
	200 - 500m
	500 - 1,000m
	1,000 - 1,500m
	1,500 - 2,000m
	2,000 - 2,500m
	2,500 - 3,000m
	> 3,000m



Terms

Integrated Water Resources Management means the adoption of a comprehensive approach with respect to the management of the water resources of every basin, simultaneously taking into consideration all aspect which are of relevance to these resources in terms of their sources, uses, and demands for various purposes... in such a way that all of these aspects are integrated with the goals, plans and programs of socio-economic development in the basin, and without undermining the sustainability of these resources or damaging their qualities.

Sustainable use of groundwater means the abstraction of groundwater which takes place during a specific period of time at quantities which at least equal the replenished quantities during the same period, and in such a way that neither the quantity nor the quality of available water are significantly affected on the long run.

Water policy means all principles, which are adopted by the State regarding the optimal use of water resources, their management and development to achieve certain economic, social and environmental goals.

Water resources management means all actions, procedures and measures, which are undertaken in the field, office or lab to achieve the water policy goals.

Water resources conservation means the rational management of the water resources so as to ensure their optimal use, utilization and the preservation of their sustainability, both quantitatively and qualitatively.

Water resources planning means the process of examining and evaluating all possible options on how to best use the waters of a given region or basin to satisfy the demand, and to increase availability of water resources and to protect their quality, and rationalize their uses.

Demand management means the use of measures and practices including education and awareness program, metering, water pricing, quantitative restrictions, and other devices, to manage and control the demand for water

Trans-basin water diversion means the physical transfer of water from one drainage basin to another

River basin means the land area from which water drains into a river

Runoff means that part of precipitation which appears in surface streams

Unaccounted-for-water means the difference between the volume of water delivered into a supply system and the volume of water accounted for by legitimate consumption, whether metered or not

Note: from Background information to Workshop on Groundwater Legislation Review and Water Tariff Analysis in Lebanon, 17 January 2003, by the Economic and Social Commission of Western Asia (ESCWA) in cooperation with the United Nations Development Program (UNDP)

Abbreviations

AUB:	American University of Beirut
BCS:	Bureau of Central Statistics
CAS:	Central Administration of Statistics
CDR:	Council for Development and Reconstruction
EIA:	Environmental Impact Assessment
EDL:	Electricity of Lebanon
ESCWA:	Economic and Social Commission for Western Asia
FAO:	Food and Agriculture Organization of the United Nations
GBA:	Greater Beirut Area
GDP:	Gross Domestic Product
GIS:	Geographical Information System
GP:	Green Plan
ARIL:	Lebanese Agriculture Research Institute
LBP:	Lebanese Pound
LL:	Lebanese Lira
LRA:	Litani River Authority
MOA:	Ministry of Agriculture
MEHR:	Ministry of Energy and Hydraulic Resource
MEW:	Ministry of Energy and Water
MOE:	Ministry of Environment
MOH:	Ministry of Public Health
MOI:	Ministry of Industry
MOPT:	Ministry of Public Works and Transport
MOT:	Ministry of Tourism
MSA:	Ministry of Social Affairs
NERP:	National Emergency Rehabilitation Program
NGOs:	Non-Governmental Organizations
NWMP82:	National Waste Management Plan in 1982
NWRU:	National Water Research Unit
PSP:	Private Sector Participation
SIU:	Sector Implementation Unit in MEW
UFW:	Unaccounted for water
UNDP:	United Nations Development Program
WA:	Water Authority

Units

mm:	Millimeters
m:	Meter
km:	Kilometer

ha:	Hectare
km ² :	Square Kilometer
l:	Liter
l/c/d:	Liter per capita per day
mg/l:	Milligram per liter ($\times 10^{-3}$)
ppm:	Parts per Million
m ³ :	Cubic Meters
m ³ /s:	Cubic Meters / Second
MCM:	Million Cubic Meters
MW:	Megawatt ($\times 10^6$)
KWh:	Kilowatt hour($\times 10^3$)
GWh:	Gigawatt hour($\times 10^9$)
°C:	Degree Centigrade

1 US Dollar = 1,500 LL

Chemical Compounds

BOD:	Biochemical Oxygen Demand
CaCO ₃ :	Calcium Carbonate
CH ₄ :	Methane
CO:	Carbon Monoxide
CO ₂ :	Carbon Dioxide
NO:	Nitrogen Dioxide
NO ₂ :	Nitrogen Oxides
N ₂ O:	Nitrous Oxide
O ₃ :	Ozone
SO ₂ :	Sulphur Dioxide
SO ₃ :	Sulphur Trioxide
SS:	Suspended Solids

General Definition

Catchments Area (km ²):	Watershed Area (km ²)
Runoff (MCM):	Average Annual Flow in Volume (MCM)
Runoff (mm):	Specific Yield of Runoff (mm/year) = Average Annual Flow (MCM) / Watershed Area (km ²) $\times$ 1,000
Groundwater:	Underground Water
Service Population:	Subscriber of Water Supply
Dry Season:	April to October (7 months)
Wet Season:	November to March (5 months)

**The Study
on Water Resources Management Master Plan
in the Republic of Lebanon**

MAIN REPORT

Table of Contents

Study Area Location Map	
Terms, Abbreviations and Units	
Table of Contents	
List of Tables and Figures	

CHAPTER 1 INTRODUCTION

1.1 Background Information.....	1-1
1.2 Circumstances of the Study.....	1-7

CHAPTER 2 ISSUES IN WATER RESOURCES MANAGEMENT

2.1 National Policy and Strategy for Water Resources Management.....	2-1
2.2 Issues Concerning Water Resources Management.....	2-5
2.2.1 General Description.....	2-5
2.2.2 Problems Related to Water Resources Management.....	2-8
2.2.3 Operation Institutional Support.....	2-12
2.2.4 Consideration on Reuse of Wastewater from Viewpoint of Water Quality.....	2-16
2.2.5 Scoping for Initial Environmental Examination.....	2-17

CHAPTER 3 PROCESS OF WATER RESOURCES STRATEGY FORMULATION

3.1 General Description.....	3-1
3.2 Water Demand Management.....	3-9
3.2.1 Water Demand Management in Integrated Resources Planning.....	3-9
3.2.2 Water Demand Management Measures.....	3-11
3.2.3 Impact of Demand Management.....	3-20
3.3 Water Resources Assessment.....	3-22
3.3.1 Assessment of Water Resources Potential.....	3-22
3.3.2 Surface Water Development Potential.....	3-22
3.3.3 Groundwater Resources Development Potential.....	3-27
3.4 Other Processes.....	3-29

3.4.1	Balance between Demand and Supply.....	3-29
3.4.2	Preparation for Economic Evaluation.....	3-29
3.4.3	Formulation of Development Scenarios.....	3-31
3.5	Institutional, Legal and Legislative Management.....	3-31
3.6	Watershed Management.....	3-34

CHAPTER 4 TOOLS TO SUPPORT WATER RESOURCES MANAGEMENT PLAN

4.1	GIS Database.....	4-1
4.1.1	Concept of GIS Database.....	4-1
4.1.2	Structure of GIS Database.....	4-1
4.2	Hydrological Circulation Model.....	4-5
4.2.1	Concept of Hydrological Circulation Model.....	4-5
4.2.2	Model Structures.....	4-7
4.2.3	Calibration of the Model.....	4-10
4.2.4	Water Balance Simulation.....	4-11
4.3	Digital Balancing Model (DBM).....	4-14
4.3.1	Concept of DBM.....	4-14
4.3.2	Overview of DBM.....	4-15
4.3.2	Sample of Output.....	4-17

CHAPTER 5 WATER RESOURCES OBSERVATION AND MONITORING PLAN

5.1	Surface Water Observation and Monitoring Plan.....	5-1
5.2	Groundwater Observation and Monitoring Plan.....	5-6
5.3	Water Quality Observation and Monitoring Plan.....	5-10

List of Tables and Figures

Chapter 1

Figure 1.1	Planned Working Schedule of the Study.....	1-5
------------	--	-----

Chapter 2

Table 2.2-1	Recommended Microbiological Quality Guidelines for Wastewater Use in Agriculture.....	2-12
Table 2.2-2	Anticipated Activities Caused by the Development Scheme.....	2-17
Table 2.2-3	Scoping Matrix for Each Development Scheme.....	2-18

Chapter 3

Table 3.1-1	Policy and Strategy to be Considered in Water Resources Management	3-7
Table 3.2-1	Traditional Planning and Integrated Planning Compared.....	3-10
Table 3.2-2	Leakage Control Measures.....	3-13
Table 3.2-3	Conservation Rate Structure.....	3-15
Table 3.2-4	Potential Water Savings from Efficient Fixtures.....	3-16
Table 3.2-5	Conservation Education Measures.....	3-17
Table 3.2-6	San Jose, California : Industrial Water Conservation and Cost Effectiveness, Selected Companies.....	3-20
Table 3.2-7	Impact of Demand Management Measures.....	3-21
Figure 3.3-1	Concept of Groundwater Potential.....	3-27
Figure 3.5-1	Organizations and Their Output.....	3-32

Chapter 4

Table 4.1-1	Map and Map Attribute Data List.....	4-2
Table 4.1-2	Attribute Data List.....	4-4
Table 4.3-1	Main Function of DBM.....	4-15
Table 4.3-2	Data Retention Form.....	4-16
Table 4.3-3	Output Matrix.....	4-17
Table 4.3-4	List of Excel Sheet.....	4-17
Table 4.3-5	List of Map's Attribute Data.....	4-18
Figure 4.1-1	Image of Data Composition.....	4-1
Figure 4.2-1	Hydrological Circulation Model and Concept of Water Resources Development.....	4-5
Figure 4.2-2	Flow of SSM Simulation Study.....	4-6
Figure 4.2-3	Major Basins.....	4-7

Figure 4.2-4	Sub-basin Model.....	4-8
Figure 4.2-5	Image of Model Construction.....	4-9
Figure 4.2-6	Pattern Matching.....	4-10
Figure 4.2-7	Model Verification.....	4-11
Figure 4.3-1	GIS Database System.....	4-14
Figure 4.3-2	Main Function of DBM.....	4-15
Figure 4.3-3	Sample of Input Data/Output Form.....	4-16
Figure 4.3-4	Population Map.....	4-18
Figure 4.3-5	Sample of Possible Water Supply Water Output Form.....	4-19
Figure 4.3-6	Sample of Supply Water Map.....	4-20
Figure 4.3-7	Sample of Water Demand Output Form.....	4-21
Figure 4.3-8	Sample of Total Water Demand Map.....	4-22
Figure 4.3-9	Sample of Water Balance Output Form.....	4-23
Figure 4.3-10	Sample of Water Balance Map.....	4-24

Chapter 5

Table 5.1-1	List of Hydrological Station to be Newly Established.....	5-4
Table 5.1-2	Proposed Location of Snowfall Station.....	5-2
Table 5.2-1	Groundwater Monitoring System.....	5-9
Table 5.3-1	Proposed Stations for Water Quality Monitoring.....	5-13
Table 5.3-2	Proposed Monitoring Parameters for Public Water Area.....	5-16
Figure 5.1-1	Hydrological and Meteorological Station Location Map.....	5-3
Figure 5.1-2	Snowfall Station Location Map.....	5-5
Figure 5.2-1	Groundwater Monitoring System.....	5-8
Figure 5.2-2	Concept of Groundwater Monitoring Station.....	5-7
Figure 5.3-1	Proposed Organization for Public Water Area.....	5-14
Figure 5.3-2	Procedures for Water Quality Monitoring Management for Wastewater	5-14
Figure 5.3-3	Procedures for Water Quality Monitoring Management for Drinking Water	5-15

CHAPTER 1 INTRODUCTION

1.1 Background

Following the Taif Accord in 1989 that brought the peace over the country, the government of the Republic of Lebanon (Lebanon) has proceeded aggressively to rehabilitate, reconstruct and recover the national land. The 5-year public investment program so called the NERP was established in 1992 based on the damage survey supported by the EU to make urgent reconstruction of social infrastructures in the fields of water supply, sewage, electricity, communication, transportation, solid waste, insurance and sanitation. The NERP was then succeeded in 1994 by the HORIZON 2000 program along the same line, and a huge investment amounting to US\$ 60 billion in 1995 price is being made during the period from 1995 to 2007 with water related sectors occupying a considerable part of the investment.

Lebanon is blessed with relatively rich water resources in terms of precipitation, 823 mm annually or some 8,600 million cubic meters in volume, as compared to other neighboring middle-eastern countries where extreme chronic shortage of water prevails. These relatively abundant water resources are, however, difficult to be utilized effectively due to unevenly distributed precipitation throughout a year, most rainfall occurring within a limited period of 80 to 90 days, or 50 to 60 days at least, during the wet season extending between the months of October and April, and topographical and geological characteristics of the national land. Surface waters concentrated into river channels flow down into the sea immediately because river bed slopes are too steep, and it is also difficult to impound such a water in the reservoir since geology of the most suitable sites of dam construction is of limestone. Surface water is also exposed to contamination due to improper management of sewage, industrial waste and municipal solid waste disposed into water courses without any treatment. Hydrometric measurements necessary for operational forecasting of water shortage and flood are incomplete due to the civil war. A delay in rehabilitating and reconstructing water use facilities destructed by the civil war has accelerated shortage of water especially in summer season in urban areas along the coastal line where demand of water has concentrated, giving a serious damage to the people's living environment as well as to the national economy.

Water is diverted from surface, groundwater and spring water sources to serve urban, rural and industrial supplies as well as for irrigation in Lebanon. Extensive use of groundwater due to lack of surface water for irrigation and increasing population especially in urban areas has, however, accelerated intrusion of saline water in the coastal aquifers and drainage of wastewater into pits, wells and rivers has been allowing faster spread of water pollution. Urgent measures to prevent pollution by untreated wastewater are also required by the Protocol on the Prevention of

Pollution of the Mediterranean Sea. Over-pumping of groundwater invites lowering of water level which would result in a shortfall of exploitable amount of spring water. Taking the above into account, it would be rather preferable to restraint use of groundwater and to promote exploitation of surface water of which utilization is not maximized due to delayed progress of dam and hill lake construction at present, and from the viewpoint that valuable water resources are to be preserved and managed for the most effective utilization, formulation of an integrated master plan of water resources management covering widespread water uses in the entire national land is required without delay.

In Lebanon, reconstruction and development projects after the war have been implemented by the Council for Development and Reconstruction (CDR) as a core, under the financial and technical support of the World Bank and foreign donor countries such as France and Italy. CDR, under the direct control of the Cabinet, plays the role to coordinate foreign donor organizations with the project implementation agencies of the Lebanese side, having jurisdiction over the projects that are implemented under the aid of foreign countries.

Superintending administrative organization in association with the field of water is the Ministry of Energy and Water (MEW), however, numbers of agencies such as the Ministry of Finance, Ministry of Environment (MOE), Ministry of Public Health (MPH), Ministry of Agriculture (MOA), through the construction of small scale hill lakes, participate in the implementation of water-related projects.

MEW, known formerly as the Ministry of Hydraulics and Electrical Resources (MHER, Art.1 of Decree 5469/66) is the competent authority responsible for water, electrical and mining affairs having supervision authority over organizations and institutions involved in the fields of water and electricity. MEW has been set up by the Law No.20/66 and its amendment. The Article 1 of the Law defines the power of the ministry as follows;

- To extend and generalize water and electricity projects throughout the Lebanese territory, implement them or supervise their implementation and operation,
- To apply laws and regulations related to the protection of public water resources and their use,
- To exercise administrative supervision over the autonomous offices and other organizations working in the fields of water and electricity,
- To exercise control on water and electricity concessions, and
- To apply laws and regulations related to mines.

There is still an urgent need to rehabilitate and reconstruct existing and to expand new water supply and wastewater treatment facilities, and various projects are under progress at this

moment. Reconstruction and upgrading of meteorological and hydrological observation network have also been fairly under way. In parallel with these activities, annual demand of water is projected to exceed the readily exploitable surface and groundwater resources in near future. Potential and usable water resources are limited in Lebanon and it is therefore requested urgently to formulate a nation-wide master plan on water resources management in order to expect effective, sustainable and rational use and allocation of water among water-related sectors.

Under these circumstances, in response to the request of the Government of Lebanon, the Government of Japan has made efforts towards extending the technical cooperation to establish a rational and practical water resources management master plan through dispatching necessary experts of various fields. A Preliminary Study Team was sent and the Scope of Works was consented and signed by both governments in February of this year. In May 2002, the Japan International Cooperation Agency (JICA) decided to send a Study Team consisting of eleven (11) experts of various fields headed by Mr. Y. Kimura to conduct “the Study on Water Resources Management Master Plan in the Republic of Lebanon”.

The objectives of the Study were:

1. To formulate a master plan for water resources management of the whole area of the Republic of Lebanon, and
2. To pursue technology transfer to counterpart personnel in the course of the Study.

In order to achieve the above objectives, the Study was planned to cover the following study items;

Phase I: Basic Survey

1. Review of related plans, programs and studies
2. Collection, review and analysis of related data and information
 - (1) Social and economic conditions
 - (2) Topographical data and maps
 - (3) Hydrological and meteorological data
 - (4) Soil and geological data
 - (5) Land use
 - (6) Laws, regulations, institution and policies
 - (7) Existing hydro-meteorological stations and other related facilities
 - (8) Surface water and groundwater potential
 - (9) Water use
 - a. Municipal and industrial water

- b. Irrigation
 - c. Hydropower
 - d. Treated wastewater
- (10) Water quality
- (11) Water supply and wastewater treatment system
- (12) Flood control
- (13) Environmental protection and conservation
- (14) Others
- 3. Clarification of present conditions of water resources development and management
- 4. Formulation of database compatible with Geographical Information System
- 5. Examination of water resources potential
 - (1) Surface water
 - (2) Spring and groundwater
 - (3) Treated wastewater
 - (4) Unaccounted water (physical loss)
 - (5) Integrated water balance (quantity and quality)
- 6. Water demand prediction
 - (1) Municipal and industrial water
 - (2) Irrigation
 - (3) Hydropower
 - (4) Treated wastewater reuse
 - (5) Water for ecosystem conservation
- 7. Examination of water resources development alternative
 - (1) Inventory of possible alternatives
 - (2) Strategy and scenario
 - (3) Digital water balancing model
 - (4) Initial Environmental examination
 - (5) Evaluation
 - (6) Selection of priority alternatives

Phase II: Formulation of Water Resources Management Master Plan

- 8. Formulation of water resources management master plan
 - (1) Water resources management plan
 - a. Development plan
 - b. Institutional management
 - Hydro-meteorological observation
 - Water quality monitoring

- c. Environmental conservation
- d. Watershed management
- (2) Preliminary project design
- (3) Preliminary cost estimation
- (4) Implementation plan
- (5) Evaluation
- (6) Selection of priority project(s)

9. Recommendation

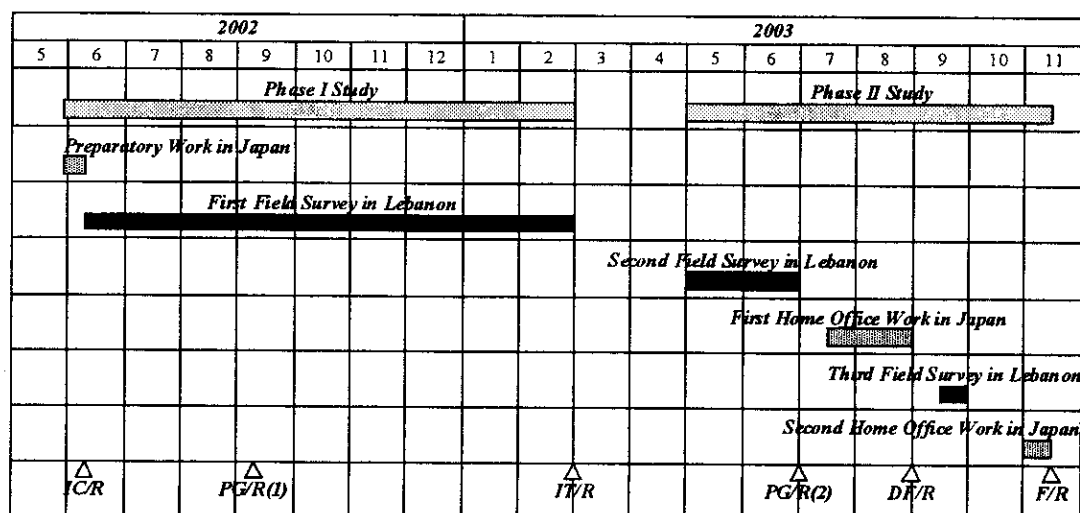


Figure 1.1 Planned Working Schedule of the Study

The Study was planned to be implemented in six (6) stages of two (2) phases as shown below;

Stage 1: Preparatory Works in Japan (Beginning of June, 2002)

Existing available data and information were reviewed and analyzed, and the Inception Report was prepared during this period.

Stage 2: First Field Survey in Lebanon (June, 2002 to February, 2003)

Collection of basic data/information and field survey/investigation is made during this stage of the Study in order to grasp the existing conditions of the study area. Water resources potential is evaluated for surface, spring and groundwater through simulation by a hydrological circulation model and water demand is projected for various water use sectors. Collected data are compiled in a database to be formulated in a form compatible with the GIS. Digital balancing model is constructed to output necessary information to support decision making for water resources development and management. Alternative plans for water resources development and management is extracted together with an inventory of possible alternatives, strategy and scenarios of development and management. Initial environmental examination are also done during this stage.

Observation of river discharge and spring flow, inventory survey of existing groundwater wells and sampling and laboratory testing for water quality are conducted entrusted to the consultants/contractors in Lebanon.

Technology transfer seminar on overall study finding and on-the-job training mainly for the digital balancing model are undertaken at the end of this stage. Progress report (1) and the interim report is prepared, submitted and explained.

Stage 3: Second Field Survey in Lebanon (May to June, 2003)

Supplemental field survey is conducted and a master plan of water resources management is finalized during this stage including water resources development and management plans, institutional management plan, environmental consideration, costs, benefits and implementation program for possible alternative plans. All of the study findings are compiled in the progress report (2).

Stage 4: First Home Office Work in Japan (July and August, 2003)

The draft final report is prepared compiling all of findings obtained since the beginning of the Study.

Stage 5: Third Field Survey in Lebanon (September, 2003)

The draft final report is presented and the technology transfer seminar will be held in Beirut.

Stage 6: Second Home Office Work in Japan (November, 2003)

Final report is prepared on the basis of the comments of the Lebanese government on the draft final report.

JICA has organized the Study Team comprising eleven (11) experts for the implementation of the Study. JICA also set up an Advisory Committee for the purpose of providing technical advices to the Study Team as listed below:

Organization of the JICA Study Team

Designation/Field	Name of Experts
Team Leader/Water Management Plan	Yoshiaki KIMURA
Deputy Leader/Hydro-geology	Ryoichi KAWASAKI
Hydrology/Meteorology	Toshinobu NAKANO
Topography/Geology/Remote Sencing	Takao FUJII
GIS/Database	Takeshi YOSHIDA
System Engineer	Makoto HOMMA
Water Use Planning	Kazuhiko OTANI

Water Supply/Sewage	Hiroataka SATO
Organization/Operational Management	Hiromasa MINAKAMI
Socio-Economy/Project Cost	Noboru OSAKABE
Water Pollution/Environment	Sanpei NAKANISHI
Coordinator	Norio SAKAGAMI

Organization of JICA Advisory Committee Team

Assignment	Name	Position
Chairman	Masahiro MURAKAMI	Professor, Infrastructure Systems Engineering Course, Graduate School of Engineering, Department of Infrastructure Systems Engineering, Kochi University of Technology
Member	Hiroyuki ITO	Senior Researcher, Water Environment Research Group, Public Works Research Institute

1.2 Circumstances of the Study

At the end of February 2003, the Interim Report of the Study was prepared compiling all of findings obtained from the Phase 1 Field Survey, consist of the results of the Study contained main analyses and figures derived on the basis of existing available data and information in Lebanon, submitted to MEW on 17th, and the contents of the report were explained on 20th February, 2003. Outline of the Study was also presented at the MEW-JICA Seminar on Water Resources Management and Capacity Building, which was held at the Lebanese Order for Engineers in Beirut on 25th February, inviting about 200 persons from the governmental, academic and private water-related sectors.

Lebanese side organized a committee to deliberate on them and comments, which were summarized from remarks and observations collected from members of the committee, were notified to Japanese side on March 17th and April 17th through the Embassy of Japan.

The committee summarized their opinion stating that “In conclusion, a general agreement was reached by all the present experts that the report is based on inaccurate and insufficient data cannot by any means be used to reach the final conclusion reached by the JICA Team. For this reason, all experts agreed that with this data a Master Plan cannot be produced. In addition, the presented work was not in line with the Lebanese Strategy described in the 10 Year Plan of the Ministry of Energy and Water. For this reason phase 2 of the project should not take place

before the Draft Interim Report is entirely reviewed, corrected and approved by the Lebanese counterpart.”

For this comment from the Lebanese side, the JICA study team points out the following:

- (1) One of the impacts of the civil war in Lebanon, it is a fact that the technical, engineering and socio-economic data/information are relatively less, but the data does not exactly lack for formulation of water resources management master plan. Additionally, the Synthetic Storage Model (SSM) is quite competent as a model for analyzing surface and groundwater simultaneously, and has demonstrated satisfactory results in the past in particular where relevant data are less. Under these conditions, JICA study team believes that the results of the analysis and the master plan give valid recommendations to the Lebanese government
- (2) Accordingly, it is specified that the water resources master plan be formulated on the basis of the existing available data in the Scope of Work (S/W), and on the work the JICA study team has conducted in line with the S/W.
- (3) Various supporting tools such as the SSM mentioned above and Digital Balancing Model (DBM) have been provided, so that the Lebanese side are expected to upgrade and update the master plan when additional data for the long term become available year by year.

For the above mentioned points made by the JICA study team, the Prime Minister's Office proposed through the Embassy of Japan in Lebanon the holding of meetings between the Lebanese side and JICA study team to discuss about the treatment of the Study after the commencement of the Phase 2 Field Survey of the Study. A number of meetings were held between the Lebanese side and the JICA study team at both the Ministry of Energy and Water and the Prime Minister's Office. Finally, at the technical discussion held on June 24th 2003 in the Prime Minister's Office, hosted by Mr. Fadi Fawaz, Chief Advisor of Prime Minister and Naoto Amaki, Ambassador of Japan, the Lebanese side explained that the issue of water resources in Lebanon has been vital amongst the top-level executives of the government of Lebanon due to the current exceedingly delicate international situation over the water use of international rivers. For this state, the government of Lebanon fears that if a report based on less reliable study results were published, it might be vested with authority and badly affect the international estimation and status of Lebanon concerning water resources. The government of Lebanon with its political decision, therefore, requested JICA to revise the final contents of the Study results.

Upon the request above, JICA withdrew the Study Team back to Japan on July 10, 2003 in the halfway through the Phase 2 Study, instead, to open a direct discussion between JICA and Lebanese side.

JICA dispatched a Consultation team headed by Mr. Akio KAGAWA, to visit Lebanon for the period between 6 and 9 August, 2003 to discuss the contents of the final outputs of the Study with the Lebanese side, in accordance with the request from Lebanese side.

A meeting between the Lebanese side and the Consultation team was held on 8 August, 2003. Lebanese side strongly requested that the formulated regional water resources management master plan and the results of examination of water resources potential and water demand prediction in Lebanon should be excluded in the final report of the Study. Additionally, Lebanese side strongly requested that all of the reports and the results and outputs of the study should not be disclosed to the public or any other party other than the Lebanese side. Finally, both side agreed to compile the following outputs for the final report of the Study.

- (1) GIS Database
- (2) Digital Balancing Model
- (3) Hydrological Circulation Model (Synthetic Storage Model – SSM)

The system supporting the formulation of water resources management master plan consists of 1) GIS database and 2) digital balancing model. Water resources-related information is exchangeable between them. The database stores the information by means of map features (polygon, line, point, etc.) and attributes (tabular data), while the model calculates possible supply water, water demand and balance between supply and demand. Input data for the model is extracted from the database and after calculation the results are transferred to the database for output and update.

(1) GIS Database

ArcView, which is a GIS tool, is applied to the database of water resources related information. Customizing ArcView, the database is equipped with operation & maintenance of data, preparation of input data for the model and output of calculation results. Besides, two soft-wares, Spatial Analysis and Oracle, are employed for preparation of geometric data (contour, mesh data etc.), security management of database and so on.

Most of attributes associated with water resources are in paper form and not digitized yet. To form database efficiently, data source and availability are identified based on “Lebanon National

Geographical Information Infrastructure Feasibility Study Final Report (CDR)” and data input is conducted in uniform format.

(2) Digital Balancing Model

The digital balancing model consists of three sub-models, 1) water demand, 2) supply, and 3) balance between demand & supply, in order to project future water demand in accordance with socio-economic frame, assess possible water supply based on surface water and groundwater potentials, and identify demand & supply balance by administrative units/watershed/region. All calculations normally require lots of data in wide range. For example, demand projection requires socio-economic data, while supply assessment requires development scenario/policy. Linking the model with the GIS database simplifies data preparation and transfer. The digital balancing model is also linked with the water balance model that calculates surface water and groundwater potentials based on hydrological and hydrogeological data extracted from GIS database. Considering applicability, user-friendly system and sustainability, the model is formed aiming the following conditions.

- **Flexibility:** Each sub-model and the water balance model are independent and linked through only data. Thus, calculation results obtained outside can be directly input or other calculation methods can be linked to the digital balancing model.
- **Structural Form:** Each sub-model consists of several modules, such as calculation, data input, data output and so on. Thus, modification of the model is able by module so that the model can be renewed without difficulty.
- **Unified Management of Data:** All necessary data associated with water resources are managed by Oracle in GIS database. This unified management ensures security of data and usage of common data.
- **Diversification of Calculation Results:** Linking the model with GIS database, the calculation results can be interpreted to different units, such as watersheds, administrative units, and particular region segregated. Besides, visualization can be easily conducted.

(3) Hydrological Circulation Model (Synthetic Storage Model)

Estimation of Water Resources Volume is made by applying a Hydrological Circulation Model.

- The existing volume of water resources, and other development potentials also, are estimated through a simulation study using appropriate hydrological circulation model so called the Synthetic Storage Model (SSM).

- Synthetic Storage Model (SSM)

The model is a mathematical in an unsteady and quasi-three dimensional states, and deals a basin-wide hydrological balance analysis for both surface and subsurface systems simultaneously.

Following the agreement, the title and constituent of the final report are as given below;

Title

The Study on Water Resources Management Master Plan in the Republic of Lebanon
FINAL REPORT

Constituent of the Report

(1) MAIN REPORT

(2) SUPPORTING REPORT

Volume 1: GIS Database

Volume 2: Instruction Manual of DBM

Volume 3: Operation Manual of DBM

Volume 4: Programmer's Manual od DBM

Volume 5: Technical Note for SSM

Volume 6: Operation Manual of SSM

CHAPTER 2 ISSUES IN WATER RESOURCES MANAGEMENT

2.1 National Policy and Strategy for Water Resources Management

Since the water is scarce over the country and is indispensable for satisfying basic human needs as well as social and economic activities such as industry and agriculture, a minimum level, at least, of water consumption must be secured by the public administrations. In planning water management approaches in order to optimize the use of limited volume of water resources, a more integrated manner is required from both supply augmentation and demand management sides. Within the limits of available volume of water and prevailing constraints on quality, benefits of water resources are to be maximized.

Integrated Water Resources Management means the adoption of a comprehensive approach with respect to the management of the water resources of every basin, simultaneously taking into consideration all aspect which are of relevance to these resources in terms of their sources, uses, and demands for various purposes... in such a way that all of these aspects are integrated with the goals, plans and programs of socio-economic development in the basin, and without undermining the sustainability of these resources or damaging their qualities.

Water Resources Policy: Objectives

Water policy involves all principles, which are adopted by the State regarding the optimal use of water resources, their management and development to achieve certain economic, social and environmental goals. A framework of water resources policy should include the following objectives;

- Augmentation of water supply to satisfy demand
- Management of water demand under better efficiency of water use
- Allocation of water resources to meet requirement from various water users
- Sustainable development of water resources
- Protection and conservation of water resources

Water Resources Strategy: Measures to realize objectives

Water resources strategy means the measures to translate the objectives given the water resources policy into realistic actions. To formulate such a strategy, water resources are assessed, database system is prepared, major water issues are extracted, extracted major issues are analyzed and ranked, development options are prepared and evaluated, and the best options are selected and implemented. The formulation of Water Resources Management Strategy requires iterative process of a long-term with periodical updating, revision and testing.

Water Resources Assessment

All the factors that influence water resources supply, utilization, development and management are examined. This process include evaluation of existing, on-going and planned water resources development and management projects, preparation of data and information basis

regarding water-related items and assessment of water-related issues.

Database System

In the database system, all the items that influence water supply and demand are involved.

- Meteorological and hydrological data including climatic factors such as precipitation, temperature, humidity, wind, sunshine, and hydrological parameters such as discharges of rivers, and springs, groundwater extraction and rate of use
- Population, its growth rate, per capita consumption of water, service rates and water supply networks
- Industrial development and water-use intensity
- Irrigation area, cropping pattern, water consumption per unit area and status of irrigation drainage
- Efficiency rate of water distribution and conveyance
- Water tariff
- Water quality data and standards
- Water use facilities
- Flood protection measures and facilities
- Hydro-power, tourism and recreational requirements
- Operational data of water sources such as dam
- Reuse of effluent treated wastewater and of sludge

Selection of Major Issues

Major problems and critical issues involved in the water-related sectors are investigated and selected.

Analysis and Ranking of Major Issues

Selected major problems and issues are put into analysis to project future trend and potential on the basis of relevant data stored in the database. Cases of different development scenarios are given in analysis in order to assess the response of factors to be reflected to the output. Ranking of the issues follows this procedure.

In the new institutional arrangement of the water sector, the MEW stays overseeing and in a controlling position, except in the case of large scale hydraulic projects which MEW directly plans or implements (article 2 of Law No.221 of May 29, 2000, amended by article 1 of Law No. 337 of December 14, 2000)

The mission of MEW, which assumes jurisdiction over the water resources in Lebanon, is as follows;

- Protect and develop hydraulic natural resources
- Study supply and demand, and global situation of water resources in Lebanon
- Prepare the national water master plan

- Design, implement and operate large hydraulic facilities
- Conserve and control the water resources including surface and groundwater
- Exercise administrative supervision over water authorities (WAs) and LRA
- Apply laws and regulations concerning preservation of water resources
- Practice the authority of administrative tutelage over autonomous WA and other entities active in the water domain
- Practice a supervisory authority on WAs
- Render opinion over mines and quarries water resources
- Grant permits and licenses for water drilling and the use of public water
- Control the surface and groundwater quality, and determine needed standards

The MEW is made up of two General Directorates, the Directorate General of Hydraulic and Electric Resources (DGHER) and the Directorate General of Operations (DGO). The DGO is expected to perform technical, administrative and financial control over the autonomous water authorities, whereas the DGHER is expected to perform the following functions:

For potable water

- Collect water from sources, transport it, and use it
- Drill wells, transport the water and exploit it
- Construct reservoirs to collect water and distribute it
- Install water transport and distribution lines
- Construct water distribution networks
- Install water treatment plants

For irrigation

- Maintain and rehabilitate existing irrigation channels
- Study and improve existing channels
- Study and implement large irrigation projects
- Promote new irrigation techniques

For flood water and drainage

- Improve river channels and protect abutting property
- Drain flood and surface water and build reservoirs to collect surface drainage for use in irrigation

It is expected that, under DGHER, Department of Groundwater and Geology keeps register of groundwater wells, and records hydro-geological behaviors of aquifers, Department of Land Acquisition and Water Rights keeps register data on water rights.

Besides the role of the MEW, Law No. 190 dated January 4, 1993 defined the mission and essential functions of the Ministry of Displaced (MD). The mission of the MD revolves around ensuring the

return of displaced persons to their original areas and homes in Lebanese cities and villages. The following functions contribute to accomplish the ministry's mission.

- Conduct socio-economic surveys and studies to evaluate the requirements of reintegration of displaced people.
- Contribute to the rehabilitation and reconstruction programs of the infrastructure and the agricultural sector in locations that suffered from displacement.

The law of August 14, 1954 and its consecutive amendments created the Litani River Authority (LRA). LRA is now a planning and operating agency for irrigation water supply of the Litani basin. In this context, its function may include those of 4 WAs, and the Council of the South. By replacing the Ministry of General Planning, the Council for Development and Reconstruction (CDR) was created in 1977 (Law 5, January 31, 1977 and its consecutive amendments). It is attached to the Presidency of the Council of Ministers, which is headed by the Prime Minister. At present, sectors relevant to water resources management (water supply, wastewater and irrigation) account for 12.7% of all the CDR projects. Unlike other public institutions, the CDR is privileged to maintain direct contracts with foreign countries and multilateral investment agencies by bypassing the Ministry of Foreign Affairs, while the responsible ministries are assumed to be the executing agencies only nominally.

To support decision making procedure for formulation of water resources management master plan, JICA Study aims at construction of a Digital Balancing Model (DBM) linked with a Hydrological Circulation Model and consisting of three sub-models for 1) water demand projection, 2) water supply assessment and 3) water balance between supply and demand, all controlled by a GIS platform linked with a database. To fulfill this purpose, it is needed to enter all of collected data into a rational database compatible with GIS and models are to be calibrated by use of actual data of meteorology, hydrology and water use. Details concerning these models are given in Chapter 4 of this report. On the Basis of the comprehensive understandings of the existing conditions related to water resources management in Lebanon, and under the present circumstances where data to establish the above system are inadequate quantitatively and also qualitatively, JICA Study provides provisional plans of water resources management based on currently available data, and conducts counterpart training so as to enable the counterpart to operate, maintain and update the system periodically by themselves, on the basis of the most up-to-date data and information on socio-economic frame and hydrology at that point of time.

A list of references

- *Current Water Policies and Practices in Selected ESCWA Member Countries*, ESCWA, UN, October 1999
- *Policy Transformation and Implementation in the Water Sector in Lebanon*, Emmanuelle Kunigk, Occasional Paper No.27, Water Issues Study Group, School of Oriental and African Studies, University of London, 1998/99

2.2 Issues Concerning Water Resources Management

2.2.1 General Description

In Lebanon, the long-term water situation between possible supply and necessary demand is becoming uncertain steadily. Water balances tend to move towards serious deficit beyond the level of availability of renewable water resources by means of over-extracting groundwater aquifers. Water shortage will affect economic growth of the country adversely. Management of water resources effectively to reduce the gap between supply and demand and to ensure sustainability of such resources is therefore essential. National efforts have been made to restraint the water crisis at present and in future by the Government under the recognition of urgency of addressing the problems before it gets critical and serious considerations are now given to water policy and institutional reforms. Inadequate attention, however, was directed to maximize the benefit of the utilized unit of water and improving the efficiency of both water allocation and water use is not sufficient.

Major issues prevail in the water sector in Lebanon are summarized below;

Supply Management

Lebanon suffers from chronic shortage of water although having abundant precipitation. Sources of water for water supply and irrigation are springs and wells, surface water, hill lakes and reservoirs. Wells are drilled plentiful in certain areas of the country and excessive consumption of groundwater is the major cause of a dramatic drop of groundwater table and intrusion of sea water along the coastal areas. There has been almost no actual control on the withdrawal of groundwater due to the lack of monitoring and enforcement and the lack of the administrative capacity to practice direct control on water withdrawal. More than 800 million cubic meters of groundwater are emptying into sea without utilized and measures to use these water as well as program for artificial recharge are few. Surface water is not utilized fully at present, with intention of constructing reservoirs for the storage of several hundred million cubic meters of water in future. However, program requires heavy investment and therefore has suffered long delays. Assessment of the possible negative environmental impact of dam construction is inadequate. Irrigation infrastructure was damaged during the civil war requiring extensive rehabilitation. Irrigation is the largest user of water, using 60 to 70% of the total supply, however, returning only a small percentage to the national economy. In the light of scarcity and importance of water in Lebanon, high Irrigation efficiencies, 70% for sprinkler irrigation and 80% for drip irrigation, are adopted complied by both administration and farmers.

Demand Management

In order to support water use efficiency, options of demand management include restructuring of tariffs, metering, regulations, measures for water conservation, use of treated wastewater, education of users for better use of water, etc. A little effort is given by MEW and Water Authorities (WA) to demand management measures recently, however, not sufficient until now.

Water Quality

The discharge of raw sewage into the surface and groundwater is creating serious health problems and degrading water quality. Excessive use of fertilizer has led to nitrate leaching which has been detected in elevated concentration in groundwater. Unregulated application of pesticides has caused the contamination of surface and groundwater. Uncontrolled disposal of solid wastes in watershed has also led to the contamination of river basin due to leaching of chemicals.

System Losses

Water distribution systems have deteriorated and it is estimated that more than 50% of them are in need of rehabilitation or reconstruction. Unaccounted rate of water distributed is estimated to be high, however, all systems except Sedon are not metered, and so it is difficult to obtain a certain extent of losses and leakage. Other issues to be mentioned are that there are illegal connections of branch pipeline to the main network of water distribution, there exist considerable amount of evaporation losses from the reservoir surface and irrigation canal, there are losses due to insufficient irrigation operation, and that recycling of industrial water is insufficient.

Wastewater Management

Wastewater collection systems are few or old where exist, inadequately maintained and often undersized. In most areas where collection systems are available, the effluent is released directly into river channels and Mediterranean Sea. Lebanon has signed several agreements to protect its water body from wastewater pollution. This needs treatment of wastewater before discharging into the sea in cities with population of exceeding 0.1 million. Numbers of wastewater projects have been prepared for implementation along the coastal zones and in the hinterland.

Service Quality

Many of water supply network systems are deteriorated with problems that the system cannot deliver water to consumers in adequate quantity with acceptable quality. Systems are sometimes undersized for increasing demand, inspection procedures are absent and proper accounting is rare. In addition, there is a growing risk of contamination from wastewater leaking into the pipeline network system.

Data Management

The lack of a comprehensive database is one of the principal factors to restrict formulation of a proper and effective water resources management plans, since actual figures of both supply potential and demand required are not clear for decision makers. Having a detailed and accurate assessment of the different sources of water supply as well as of the projected demand for various water users is the basic information to evaluate current and anticipated water problems based on which proper measures are planned and implemented. At present, river discharge measurements remain quite limited and groundwater flow measurements are not available. The reliability of data collected is also uncertain. Meteorological and hydrological data are often incomplete and

distributed over different authorities, and are not publicly accessible. Most of the data are not computerized making it difficult to use them for any kinds of analysis.

Institutional Issue

There is no central organization responsible for the coordination of decisions and actions related to the water sector, and its administrative structure is complicated. The water sector is managed mainly by three administrative organizations; the Ministry of Energy and Water (MEW) responsible for the general management of water resources and controls groundwater uses with respect to water rights, the financing of infrastructure projects and supervision of the Water Authorities (WA), the Council for Development and Reconstruction (CDR) responsible for provision of technical and financial assistance to different authorities and selection of parties to implement infrastructure projects, and WA responsible for provision of potable and irrigation water to consumers and operation/maintenance of infrastructure facilities provided by MEW. In addition the Litani River Authority (LRA) in association with irrigation authorities and local water and irrigation committee is responsible for development and management of water resources mainly for irrigation and hydro-power generation in the Litani river basin and an extended geographic area covering South Bekaa and South Lebanon. The Ministry of Environment and the Ministry of Public Health play monitoring and control function of water resources, while the Ministry of Public Works undertakes data collection and the Ministry of Interior and Municipalities together with various municipalities are responsible for the collection of wastewater.

Building the institutional capacity to create the socio-economic environment needed for a sustainable water resources is not advocated fully by the government, as brought up by many studies ever conducted.

A list of references

- *A Prototype Study for the Management of Surface Water Resources, Lebanon*, Mey Jurdi, Samira Ibrahim Korfali, Yester Karahagopian, Brian E. Davies, Department of Environmental Health, Faculty of Science, American University of Beirut, September 2000
 - *Water Resources in Lebanon, Current Situation and Future Needs*, Dr. Mutasem El-Fadel, Water Resources Center, Faculty of Engineering and Architecture, American University of Beirut, February, 2002
 - *UNDP-ESCWA Initiative on National Framework for Water Resources Management in Lebanon*, Mohamed Abdulrazzak and Loulou Kobeissi, ESCWA
 - *Water Sector Issues and Opportunities in Lebanon, A Proposed Program of Policy Initiatives*, UNDP-DAI, December 2001
-

2.2.2 Problems Related to Water Resources Management

(1) Meteorological Observation System

As aforementioned, there were 150 historical meteorological stations in 1974 in Lebanon, however at present, 48 stations only were reconstructed, rehabilitated or newly reconstructed and being operated. Since the meteorological data, especially precipitations including snowfall, are the foundation of the estimation of water resources potential, it is inevitably needed that the observation network of meteorological factors are consolidated as early as possible with plenty numbers of rain gauge stations over the country. In this concern, installation of meteorological stations is recommendable to be made at the same locations as the old ones, so that the combination of old and new sets of observed data at the same location could be a base for analyzing complicated phenomenon of climate over the country.

(2) Hydrological Observation System

As aforementioned, there operated 75 hydrological stations before the civil war in Lebanon. During the long period of almost 15 years from 1975 to 1990, hydrological observation data are almost none at all. Currently 32 stations were reconstructed and 6 were newly constructed for operation. Since the accurate and as long data as possible are the foundation for evaluation of potential and available water resources based on which a proper plan of water resources development and management is formulated, accumulation of such data is important and urgent. One third of the area of Lebanon is considered not covered yet by hydrological observation system. It is therefore recommendable to set up a program for construction of hydrological observation network and then to speed up the installation works of hydrological stations.

Furthermore at present, collected data from hydrological stations are transferred to Hydrological Department of LRA for further processing. HYDATA system is used to convert water levels into discharge and to compute daily flow hydrograph, flow duration curve, flow statistics such as mean flow, peak flow, highest daily mean, lowest daily mean, and a mean flow and runoff. However accumulated data in the HYDATA system are unusable for other data processing or analysis. This system is recommendable to be replaced by more flexible system.

(3) Groundwater/spring water managing system

In Lebanon, all of groundwater and spring water are managed by the Ministry of Energy and Water as a rule. In the private sector, every one who wishes to construct production well must submit their construction plan to the Ministry for his approval. While, in the public sector, the water of River Litani combined with Awali, inclusive of groundwater or spring water in their basins, are controlled by LRA. In all of other areas such as the Coastal Region excepting above mentioned area and River Assi Basin, both surface and groundwater are directly under control of the ministry. However, four regional Water Authorities have actually developed and managed springs and groundwater sources. Problems related to groundwater/spring water management would be summarized as follows.

Problems due to the natural conditions (must accept as they are):

- Biased rainfall in winter season,
- Large scale groundwater channels (discovered or not yet),
- Submarine spring, and
- Groundwater flow to the outside of country.

Problems due to the social conditions (possibly improved):

- Existence of huge numbers of illegal wells,
- Contamination of spring sources by lacking of proper protection,
- Contamination of groundwater by human activity,
- Missing of old data and information, and
- Ineffective data and information managing.

Problems due to the poor managing system (must be improved):

- No groundwater monitoring system covering whole country,
- No systematic observation of spring flows,
- Sea water intrusion by over-pumping,
- Lacking in well inventory,
- Lacking in spring inventory (partially existing), and
- Lacking in snowfall measurement system.

As briefly noted in each item, some problems are just come from natural system, mostly impossible to improve, only some countermeasures to mitigate them shall be considered. However, the problems caused by improper social system or institutional defects may be improved or must make an effort to mitigate them. Finally, the problems due to the poor or inappropriate groundwater management system must be improved. In particular, the groundwater monitoring system, as well as the systematic spring flow observation, is inevitably required for the groundwater study.

(4) Water Use Management

Water use management targets 1) to improve efficiency to convey and distribute the water from source to users, 2) to optimize the volume of water consumed and 3) to increase the available water by recycling, leading to a result that the limited water is utilized effectively and efficiently. Since 1994, the Lebanese government has focused on rehabilitation and modernization of water sector, particularly domestic water supply and irrigation. Water use management practiced at present is discussed below to identify problems associated.

Domestic Water

After the damage assessment survey of the existing water supply and wastewater treatment in 1992, a 3-year National Emergency Rehabilitation Program (NERP) was formulated. NERP 1 (urgent rehabilitation) was already completed, and NERP 2 (rehabilitation) and NERP 3 (expansion) are currently under implementation. NERP has been contributing to mitigate leakage in the distribution

network. In 1997, the leakage ratio estimated was 59% in average, while the present leakage ratio estimated by the JICA Study is approximately 45%, implying the great improvement in the last 5 years. Although there is still plenty scope of improvement, its cost will increase exponentially as the leakage ratio decreases. As long as the cost is concerned, a new water resource development may be economically feasible to satisfy an increase in water demand, compared to the further mitigation of leakage. An optimum ratio of leakage should be considered in terms of overall water resources management. Since mitigation of leakage involves not only replacement of network but also O/M (operation and maintenance), it is necessary to improve administrative and technical capacity of water authorities that are reformed recently. Besides, the current water tariff system charging on the base of orifice size but not volume consumed induces another reason for high leakage ratio. Subscribers are responsible for leakage in internal plumbing and saving water; however, the present tariff system leaves them careless. In Saida, the water authority has applied a meter system to observe the volume of water consumed and has a plan to install a meter to 100% of subscribers within the next few years. Its success will be a good example to change the water tariff system in order to save water.

Industrial Water

Most of industries rely on private wells and there is no regulation to monitor and control volume/quality of water source. This results in no attempt by industries to save water and re-use the wastewater. Saving water and recycling of wastewater are generally associated with the cost and benefit. If industries were linked with the public water supply system, they would save the water to minimize the cost and also invest money to re-use of wastewater. Thus, encouraging the industries to shift from private water source to the public supply system by enforcement of laws/regulations is one of ideas for water use management.

Wastewater

Coverage of sewer network is 36% in terms of population and the rest uses septic tank or drain sewage directly to the environment, such as rivers, small streams, valleys and so on. There is one wastewater treatment plant that conducts preliminary or physical treatment only. Therefore, even where there is a sewer network, almost 100% of wastewater is just drained to the environment without any treatment. It is estimated that 50% of wastewater is drained to the river channel and the rest is drained on the land. Since the agriculture in Lebanon requires irrigation during the summer, it can be assumed that wastewater drained to the river is utilized for irrigation in downstream. Re-use of wastewater is conducted without intension. As long as the discharge is relatively high, the wastewater can be diluted till no negative effect on crops. However, most of rivers in Lebanon have low discharge during the summer and some of dams to collect the winter water are located downstream from the populated areas. Therefore, periodic monitoring of river water is essential to maintain this system.

Irrigation

Irrigation is the largest sector in water consumption of Lebanon. Since the most of irrigation

schemes are not equipped with monitoring of intake volume and consumption at field, the actual consumption rate is not available. However, according to the estimate, gross consumption, (intake volume) varies from 15,000 m³/ha/year to 6,000 m³/ha/year, depending on climate, topography, soil properties, crops, irrigation efficiencies and so on. Since spatial variation of crop water requirement is small, irrigation efficiencies, such as conveyance, distribution and application, dominate the variation. For the design of irrigation schemes, the overall efficiencies adopted are 60% for surface irrigation with good supply network and 70% and 80% for pressurized sprinkler and drip irrigations respectively. Improvement of efficiencies will drastically reduces the irrigation water.

2.2.3 Operation and Institutional Support

Operation and Maintenance of a Database

The present master plan study on water resources management in Lebanon collected most of available data and integrated into a GIS database. It will be an efficient tool in formulation of strategy for planning and management of national water resources by grasping the global supply and demand, and simulating impacts of a specific input or a scenario (e.g. a new water source development, etc.), if it is properly maintained.

The proper maintenance of it will require a continuous updating of data and information that reflect the entire supply and demand of water resources in Lebanon. Such data and information should be: (1) collected continuously or periodically by various data collecting points in a coherent manner and in their entirety, (2) transferred timely to the database center through established channels, and (3) inputted promptly after careful evaluation and harmonization. This mechanism supported by many sub-systems should be established and maintained.

Historically in Lebanon, however, hydrological data including precipitation and surface flow were not entirely measured during the war, and hydro-geological data have not been measured in the past. While much of infrastructure has been reconstructed since ceasefire and reintegration of the nation, majority of hydrological data collecting points have not been recovered and no firm reconstruction plan has been formulated. Data collected in the present study, therefore, lack their entirety, that should be complemented in the immediate future. Activities required for operation and maintenance of the database, therefore, shall be twofold: to reconstruct or develop data collecting points to cover the entire Lebanon on the one hand, and to collect available data and update the information in the database on the other.

According to variety of data, they should be collected daily, weekly or monthly, seasonally and annually. They are, inter alia:

- Daily: most of meteorological data, particularly precipitation including snowfall
- Weekly or monthly: flow and quality of springs and rivers
- Seasonally: demand for water (crop patterns, operational record of water supply systems), quality of water supplied
- Annually: level and quality of groundwater, if not seasonal, growth of population and hence supply and demand; and increments in land use, deforestation, reforestation or vegetation in general

Data and Data Collecting Points

Required data can be classified into two in principle, i.e., supply data and demand data.

Supply data should include meteorological data, data on surface water including spring water, data on groundwater and other background data.

Most important *meteorological data* are precipitation including snowfall. Subordinate data may be temperature, humidity, wind, sunshine, evapotranspiration and so on. They will be collected by meteorological stations under the Meteorological Division.

Surface water including spring water is measured by hydrological stations under LRA. Volume of flow shall be measured frequently and water quality with less frequency.

Groundwater shall be measured at monitoring wells. Monitoring wells shall be designed to measure static level, pH value and electric conductivity of groundwater continuously.

Regarding the groundwater monitoring, however, development of a comprehensive well inventory is prerequisite. Inventory of 2,000 wells are completed under the present master plan study. Other 8,000 wells, if number of the officially registered wells is approximately 10,000, shall be surveyed and recorded in the inventory succeeding by MEW. Other wells, unregistered or illegal, shall also be surveyed. To do this, reform of groundwater legislation or formulation of operational decrees is indispensable.

The background data that can significantly influence global supply situation shall also be collected and updated. Such data may include construction of dams, hill lakes, river diversion and reserve for river maintenance, and less significantly will include increments of vegetation, deforestation and reforestation, etc. They will be collected in the relevant institutions including Ministry of Agriculture, Ministry of Environment, etc.

Demand data should include water demand for domestic, industrial and irrigation purposes, and basic data that influence these water demand comprising increments of population, industry and cropping patterns. A demand projection up to year 2030 is presented in the present master plan study as a result of sector-wise, seasonal and spatial demand projections. This demand projection can be used as the basic demand data for the time being. Renewal or updating of these data, however, is required when and if more reliable data become available through actual measurement.

Demand for domestic and industrial use of water shall be collected most conveniently from the water supply service providers. Such providers comprise four regional water authorities (WA), other water authorities and committees, and LRA, which is supplying domestic water to the water committees in the Bekaa and the South. Volume and quality of produced and distributed water shall be measured, and its seasonal fluctuation shall be recorded. More importantly in the long run, growth of the served population and the served area, or planned expansion of treatment plant and distribution network shall be noted and reported. MEW shall be in a position to project growth of the water supply services in all areas.

Demand for irrigation water shall be measured and reported by the irrigation service providers such as MEW and LRA. Measurement shall be made practically by volume of water supplied. While the government irrigation schemes are implemented by MEW and LRA, farmers themselves irrigate vast cultivated areas. Demand for such private irrigation that was developed individually or collectively by farmers shall also be counted for.

The background data in the demand forecast would be growth of population and industry, change in cropping patterns and expansion of irrigated area. They may be provided by census and statistics, Ministry of Industry, Ministry of Agriculture, etc.

Current Constraints in the Data Collection

As described above, plural number of ministries, and plural number of agencies even under a single ministry operate data collecting points. Ministries and their agencies concerned are:

- Ministry of Public Works and Transport operating meteorological stations
- Ministry of Energy and Water in tutelage of water authorities and LRA, and keeping well registry. It may create a groundwater monitoring unit.
- Ministry of Agriculture rendering the hill lake construction through the Green Plan and agricultural research through the Agricultural Research Institute. It is assumed to perceive privately irrigated farms as well as cropping patterns of agriculture in overall Lebanon.
- Ministry of Environment, which perceives vegetation, deforestation, reforestation, etc.
- Ministry of Public Health responsible for quality of drinking water
- Other ministries, which undertake population census, industrial statistics

Complexity due to large number of participants in the data collection is apparent, and appropriate measure to streamline the process needs to be taken in design of the data channel. Beside such complexity, each agency or organization is facing various constraints in collecting the data required.

Meteorological Division is operating currently only 48 stations out of some 150 established before the war. It does not have firm reconstruction plan. As number of stations and their dispersion seem insufficient, MEW shall consider to install number of the precipitation measuring points required to assess the gross precipitation into each catchment.

Water authorities are in transition to amalgamated 4 Regional WA's, which are not functional for the time being. Most of 21 water authorities do not properly record volume and quality of produced and distributed water and its seasonal fluctuation. As they hardly

have technical resources to measure these data, it would be necessary for MEW to provide them with assistance to establish the required discipline. Besides these 21 water authorities, there are 209 water committees who provide water supply services. MEW shall also account for volume of their supply, and therefore need to create some means to monitor them.

LRA maintains 38 live hydrological stations now and has some 90 stations damaged. A comprehensive reconstruction plan has yet to be established. To grasp catchment wise global surface water discharge, 38 gauge points are not too sufficient. Suitable number of complementary flow gauging units will have to be installed as soon as possible.

LRA and *Irrigation Department* of MEW provide the government irrigation schemes and in positions to measure volume of irrigation water supply to these schemes. Therefore, they are expected to record volume of actual supply by measurement at the water intake. Daily measurement would be preferable. Volume of water to the private irrigation should not be left out. To estimate the volume as accurately as possible, Irrigation Department and LRA need to work closely with Ministry of Agriculture.

Groundwater Unit, Geology Department of MEW, maintains registry of groundwater wells. It, however, lacks facilities to assess discharge or yield of groundwater globally. It, therefore, needs to establish monitoring wells. Number and dispersion of monitoring wells shall be such that may cover all the sub-catchments or sub-basins. The Groundwater Unit, also, needs to be enhanced in terms of technical and human resources, or a groundwater monitoring unit shall be created, while proceeding with and expediting the groundwater legislation and reform.

2.2.4 Considerations on Reuse of Wastewater from the Viewpoint of Water Quality

Wastewater is used as a source of irrigation water as well as a source of plant nutrients, allowing farmers to reduce or even eliminate the purchase of chemical fertilizer. Recent wastewater use practices range from the piped distribution of secondary treated wastewater (i.e. mechanical and biological treatment) to peri-urban citrus fruit farms (e.g. the city of Tunis) ("Water Quality – Guidelines, Standards and Health: Assessment of Risk and Risk Management for Water-Related Infectious Disease, WHO Web Site). Agricultural reuse of wastewater is practiced throughout South America, Mexico and widespread in Northern Africa, Southern Europe, Western Asia (Arabian Peninsula), South Asia and US.

The use of human wastes contributes to food production and income generation in developing countries. However, where the waste is untreated or health protection measures are not in place, such practice is exposed to the risk of transmission of pathogens.

WHO established the microbiological quality guidelines for wastewater use in agriculture in 1989. Table 2.2-1 shows the recommended guideline applied for the exposed group of workers or public consumers.

Table 2.2-1 Recommended Microbiological Quality Guidelines for Wastewater Use in Agriculture (WHO 1989)

Cat eg ory	Reuse Condition	Exposed Group	Intestinal Nematodes ¹⁾ (MPN/liter ²⁾)	Faecal Coliform (MPN/100 ml ³⁾)	Wastewater Treatment expected to achieve Required Quality
A	Irrigation of crops likely to be eaten uncooked, use in sports fields, use in public parks ⁴⁾	Workers, Consumers, Public	1	1,000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, fodder crops, pasture and trees ⁵⁾	Workers	1	None Set	Retention in stabilization ponds for 8 – 10 days or equivalent helminth removal.
C	Localized irrigation of category B exposure of workers and the public does not occur	None	N/A	N/A	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation

Remarks:

- 1) *Ascaris* and *Trichuris* species and hookworm
- 2) A more stringent guideline (200 faecal coliforms/100 ml) is appropriate for public lawns with which the public may come into direct contact
- 3) In the case of fruit trees, irrigation should cease two weeks before the fruit is picked and none should be picked off the ground
- 4) Arithmetic mean
- 5) Geometric mean

Currently, Ghadir wastewater treatment plant is the only large-scaled operating plant in Lebanon, which is located in the south of Beirut. The data on faecal coliform and Intestinal Nematodes which are discussed above, was not available from the plant. The plant provides only primary treatment of grit and scum removal, which cannot treat the faecal coliform and Intestinal Nematodes through the disinfection such as using chlorination. The equivalent concentration of microbiological concentration as raw wastewater will be anticipated.

2.2.5 Scoping for Initial Environmental Examination

(1) Development Scheme and Project Activity

Initial Environmental Examination (IEE) should be conducted for the possible alternatives proposed in JICA study in order to examine the requirement of Environmental Impact Assessment (EIA).

In Lebanon, the draft EIA decree is still under review by the Government Council and has not yet approved/enacted. However, the draft of EIA procedure is proposed. According to the draft decree, water development projects such as dams, reservoirs or development of wastewater treatment plant should require EIA procedures.

The Study is basically to examine the water supply development for irrigation, municipal and industrial purpose by utilizing the water resources of surface water, groundwater, springs, submarine springs and reuse of wastewater.

Table 2.2-2 summarizes the anticipated activity caused by the projects during construction and operation stages expected.

Table 2.2-2 Anticipated Activities caused by the Development Scheme

Development Scheme	Anticipated Projects	Activity	
		Construction Stage	Operation Stage
Development of Surface Water	• Dam • Reservoir • Canal • Intake • Pipelines • Pumping Station • Water Treatment Plant	• Land Acquisition • Construction of Access Road • Tree Cutting • Excavation • Concrete Placing	• Storage of River Water • Water conveyance
Development of Groundwater	• Well • Underground dam • Pumping Station • Pipelines • Water Treatment Plant	• Land Acquisition • Construction of Access Road • Tree Cutting • Excavation • Concrete Placing (including cutoff wall for underground dam)	• Water Pumping • Water conveyance
Development of Springs	• Pumping Station • Pipelines • Water treatment Plant	• Land Acquisition • Concrete Placing	• Water Pumping • Water conveyance
Development of Submarine Springs	• Pumping Station • Pipelines • Concrete Wall at Sea Bottom • Water Treatment Plant	• Land Acquisition • Excavation at sea bottom • Concrete Placing	• Water Pumping • Water conveyance
Development of Wastewater Reuse	• Pumping Station • Pipelines/Canal • Wastewater Treatment Plant	• Land Acquisition • Excavation • Concrete Placing	• Water Pumping • Water conveyance

(2) Scoping Matrix and Anticipated impacts

The summary of scoping matrix of the anticipated impact for each development scheme is

summarized in Table 2.2-3. The potential impacts and their mitigation measures will be clarified in more details after the location and scope of the projects are actually formulated in the study.

Table 2.2-3 Scoping Matrix for Each Development Scheme

Environmental Elements Development Scheme		Social Environment									Natural Environment								Pollution				
		Resettlement	Economic Activity	Traffic/Public Facilities	Split of Communities	Cultural Properties	Water Right/Right of Common	Public Health Condition	Waste	Hazard	Topography & Geology	Soil Erosion	Groundwater	Hydrological Situation	Coastal Zone	Flora & Fauna	Local Meteorology	Landscape	Air Pollution	Water Pollution	Soil Contamination	Noise & Vibration	Ground Subsidence
Development of Surface Water	C ¹⁾	A	B	B	B	B	A	B		B	B				A		B	B	B		B		
	O ²⁾						A	B					A		A				B		B		
Development of Groundwater	C			B			B	B		B		A						B	B		B		
	O						B	B				A	A		A				B		B	A	
Development of Springs	C			B			B	B		B		B						B	B		B		
	O						B	B					A		B				B		B		
Development of Submarine Springs	C			B			B	B					B	B	B			B	B		B		
	O						B	B						B	B				B		B		
Development of Wastewater Reuse	C			B			B	B										B	B		B		
	O						B	A	B				B						B		B		

Remarks:

"C" indicates construction stage.

"O" indicates operation stage.

"A" indicates that the development scheme is foreseen to have strong impact on the environmental element.

"B" indicates that the development scheme is foreseen to have some impact on the environmental element.

The outline of the anticipated impacts is given as follows.

Development of Surface Water

Negative impacts:

- Social impacts such as resettlement caused by land acquisition in the submerged areas in case of dam construction
- Problems on traffic issues/public facilities
- Impacts on the cultural properties in case of dam construction
- Problems on water right/right of common
- Impacts on water-borne infectious disease in case of water supply project for domestic water
- Influence on the hydrological situation of the relevant river catchment area.
- Impact on the loss of forest caused by the water impounding, and the impact on the aquatic ecosystem in the existing water area

- Noise problem of the pumping station during the operation stage.

Positive impact:

- Some impact on local economy during construction stage

Development of Groundwater

Negative impacts:

- Problems on water right/right of common
- Problems on traffic issues/public facilities
- Impacts on water-borne infectious disease in case of water supply project for domestic water
- Impact on the river situation at the river catchment depending on groundwater in case of excess use of groundwater
- Impact on flora and fauna caused by the water table change in case of developing groundwater (e.g. underground dam)
- Ground subsidence in case of excess use of groundwater during operation stage

Positive impact:

- Some impact on local economy during construction stage

Development of Springs

Negative impacts:

- Problems on water right/right of common
- Problems on traffic issues/public facilities
- Impacts on water-borne infectious disease in case of water supply project for domestic water
- Impact on the river situation at the river catchment depending on spring water in case of excess use of spring water
- Impact on flora and fauna caused by the discharge change

Positive impact:

- Some impact on local economy during construction stage

Development of Submarine Springs

Negative impacts:

- Problems on water right/right of common
- Problems on traffic issues/public facilities
- Impacts on water-borne infectious disease in case of water supply project for domestic water

- Impact on the river situation at the river catchment depending on groundwater in case of excess use of groundwater
- Impact on flora and fauna caused by the water table change in case of developing groundwater (e.g. underground dam)
- Ground subsidence in case of excess use of groundwater during operation stage
- Impact on the hydrological situation, coastal zone, marine ecosystem and water pollution due to the marine development

Positive impact:

- Some impact on local economy during construction stage

Development of Wastewater Reuse

Negative impacts:

- Problems on traffic issues/public facilities
- Impact on water quality for the downstream water area

Positive impact:

- Some impact on local economy during construction stage

Literature Cited

WHO (World Health Organization).(2002).

http://www.who.int/water_sanitation_health/wastewater/en/

C.A. Madera, M.R. Pena and D.D. Mara. (2000). Microbiological quality of a waste stabilization pond effluent used for restricted irrigation in Valle Del Cauca, Colombia

CHAPTER 3 PROCESS OF WATER RESOURCES STRATEGY FORMULATION

3.1 General Description

Strategic planning of water resources project planning may be defined as the several stages of investigation and study of national and regional priorities and of individual projects. The objective of this planning is to produce a program of viable schemes which will fulfill the targets for supplies of water which can be operated by the responsible authority, in harmony with other possible water users and without adverse effects of the environment. The terms to describe the stages in planning are subject to variations in use and interpretation. Some which have been used frequently are;

- Applications, requests, statements of needs
- Inventories of potential projects at desk study level, in terms of water need and water availability and access; the same sequence is applicable to domestic, agricultural or industrial projects.
- Identification of projects by name, during or after the inventories.
- Reconnaissance to clarify aspects; classification to determine scope of further studies,, and order of priority according to needs and present supplies, health hazards, and alternative sources.
- Pre-feasibility study and screening to compare outlines of types of scheme which may fulfill the objectives, to compare approximate costs and revenue: to identify schemes which are obviously beneficial and can be recommended for design and construction: and to determine the requirements for surveys and investigations where the schemes are complex.
- Feasibility study to establish the need, to define precisely the scheme to meet the need, recommend a program for implementation, draw attention to possible problems, calculate capital and running costs and benefits, and indicate whether the project is technically and economically viable.
- Design – preliminary designs and/or detailed designs, contract documents, cost estimates and tender documents.
- Construction, implementation of civil and mechanical aspects, including operation and maintenance.
- Monitoring of progress in construction and expenditure of selected schemes, and thereafter of metering, billing and revenue collected; and of the standard of operation and maintenance.

Major items to be considered in such strategic planning are;

River gauging

Stream flows near the mouth of a river are affected by abstractions, return flows, springs, bed losses and other human or natural activities upstream. For rapid regional and national surveys, coefficients to allow for domestic and agricultural abstractions have been used. However for scheme-specific hydrology, traverses during the dry season, from main source to the mouth are advisable: these would record inflows, diversions, abstractions, losses and etc. Very few rivers have sufficient gauging stations for

these estimations. Such traverse may be needed on most streams flowing from the Mount Lebanon Range to the coast, but they are generally not more than 30 km long.

Groundwater

One should emphasize that most of the classic methods of testing and analyzing aquifers assume homogeneous or layered sediments. In Karstic limestone formation, local conditions may be very variable. Thus any groundwater development should be phased, and groundwater piezometric levels that the aquifer is not exhausted.

Irrigation water needs

It is rightly said that irrigation is by far the largest user of water (10,000 to 15,000 m³/ha/year for traditional canal irrigation). Water-saving irrigation systems such as sprinkler and drip/mulch can greatly reduce the usage: say to 7,000 or 8,000 m³/ha/year. Nevertheless, careful monitoring, management and operation will be needed for pumped irrigation, if costs are to be covered by the benefits: high-yielding high pricing crops, and farmers who are willing and able to participate in the agriculture and infrastructure operation will be needed.

Conjunctive use, mobilization of groundwater reservoirs

The most promising prospect for increased exploitation of water resources is rightly said to be in development of groundwater. This is in two forms:

- the interception of groundwater flows which at present go to the sea (preserving enough outflow to hold back seawater intrusion)
- the drawing down of groundwater storage during the dry season, in places where the recharge of the aquifer can be expected during the following wet season.

Water sources

- An inventory of all springs should be made, including any which are not previously recorded, relatively small, or remote from communities; especially any which are not fully exploited and those which are high enough to provide supplies by gravity. Small springs should be included because, if properly capped, on yield as small as 5 liter/sec can provide a domestic supply to over 5,000 people.
- Gravity supplies are preferable, even if a long pipeline is necessary, because of the simple low-cost operation, without mechanical or electrical problems.
- On both pumped and gravity-fed domestic supplies, the distribution system should include balancing storage/service tanks for each community. These should be supplied from the main pipe. Distribution to consumers should be from these tanks, and not from the main transmission pipe. The tanks, with regulated inlets, can ensure an equitable distribution of water, cater for daily peaks in demand for which the main pipe may be inadequate; equalize pipe pressures and reduce leaks.
- All spring flows should be channeled through V-notches, weirs or flumes, which have standard

ratings. These will allow quick, easy observations of flow, without the need for current meter measurements.

- Drilled wells should be fitted with a removable cap to allow a dipper to measure the water level in the well. A small diameter piezometer should be drilled nearby to allow the undisturbed static water level to be measured.

Planning of water resources

- The planning of water resources is influenced, not only by the required amounts, qualities and locations of sources and demands – but also by other sub-sectors such as water treatment, disposal of wastewater, pollution of water resources by water discharges or by sea water intrusions; efficiency of use of water to meet domestic, industrial and irrigation needs; and reconciliation between various types of demand on particular water sources. Integrated water resources planning may include some or all of these other aspects.
- There are urgent needs for rehabilitation of existing water supply facilities, and the provision of new or expanded facilities where the lack of them may be adversely affecting health, quality of life and the general economy.

Water supply priority

- The stated policy of the government is that domestic water supplies have first priority among water demands. Annual water needs are expected to exceed the readily exploitable surface and groundwater resources within the next twenty years. Therefore measures to exploit the water resources most effectively should be supplemented by measures to reduce leakage, wastage and careless use, and to encourage water economy.
- Allocation of priorities becomes necessary where a choice has to be made between competing sectors in the use of a resource. MHER has identified priorities in the following order: domestic, industry, irrigation and hydropower. This priority for domestic supplies is particularly relevant in respect of high-elevation unpolluted springs, which are ideal for gravity-fed, safe, low-cost, simply-operated delivery of relatively small quantities. These have a significant effect on the health, productivity and quality of life of the people.
- Industries are often important for the national economy and standard of living, but they usually have skills and financial resources which allow them to have options; location, development of separate resources, recycling, in-house primary treatment and adaptation of lower-water-demand processes. In any case, for many industries, only a small part of their water has to be as high in quality as a potable domestic supply.
- Irrigation and domestic needs are those which are most frequently in conflict, particularly in areas outside Beirut. It is relevant to evaluate the effects on irrigation of giving priority to domestic needs. Traditional irrigation may use 10,000 to 15,000 m³/ha/year, and 1.2 l/s/ha or more with losses from canals and deep percolation. Therefore one farmer irrigation one ha requires as much water as 2,000

villagers at 50 l/c/d. An allocation of water for domestic use in rural areas is rarely significant in terms of its effect on area of irrigation. Although irrigation by traditional canal systems, especially on permeable soils or Karstic formation, use much more water than other users, 30% to 50% can be saved by improved efficiency: there is already a rapidly increasing trend to the use of sprinklers and drip irrigation with plastic mulching. The adoption of such economies will significantly increase the land irrigable per unit of water.

- Hydro-power development does not compete with other usage in terms of quantities used, because water is usually returned to a river. However, the timing of water releases for power needs may not coincide with times required for irrigation or domestic supplies. Hydro-power also uses height, so that water is released at a lower level: this may reduce the conveyance heads for pipelines, and/or command areas for irrigation. Therefore compromises may be needed where hydro-power is combined with other water development. Run-of-river schemes may be successful where heads and sustained flows are available. Otherwise storage will be needed for year-round firm power.
- Storage dams may be difficult and costly, especially where steep stream bed slopes increase costs per unit of storage, where flashy floods require large spillway capacity and deposit sediments which take up water storage capacity, where construction materials are not readily available, where geological conditions may threaten stability or cause leakage from the reservoir, and where fertile land or houses are inundated by the works. Water leakage has been the main problem, and the detailed geotechnical, hydro-geological and hydrological studies are necessary as part of design, requiring several years.

Domestic water supply

- Communities not served yet or only inadequately served should be provided with at least a minimum standard of service before raising the standard of existing services.
- Priority should be given to restoration of damaged or inoperable facilities, and increasing the capacity of existing system, including network improvement and balancing storage, repairs to source works, detection and control of leakage and wastage.

Industrial water supply

- It has often been found possible for industries to reduce water use by improved processes, so that saving in water costs balance costs of improved processes.
- Incentives to control water use through improved processes and recycling may include legislation, differential tariff charges, advice and technical assistance and public awareness campaigns.

Irrigation water supply

- Damage to the existing infrastructure and delays in further development have reduced the irrigated areas. The priorities for rehabilitation, expansion and possible new development will depend not only on the availability of water and the cost of the works but also on agricultural, economic,

marketing and social factors such as; 1) the number and type of beneficiaries (land owners, tenants, labor) and importance of agriculture in the local and national economy, 2) the existing area irrigated, cropping pattern and intensity, soil fertility and yield and income per ha, 3) existing water source, means of abstraction and application and water use per ha, 4) additional area of fertile soil under command, 5) optimum cropping patterns to suit soils, water flow pattern/growing seasons, markets, prices, 6) attitude of to paying or taking responsibility for operation and maintenance, changes in amount or source of water, adopting improved irrigation practice and/or cropping pattern, increases in cropping area or intensities and consequent increases in costs and works.

Thus water resources management strategy and policy in various areas should include the following considerations, as summarized in Table 3.1.1;

Supply Management

- Monitoring and control of surface and groundwater resources
- Strengthening of administrative capacity to practice direct control of water withdrawal
- Measures to use submarine springs
- Measures to reinforce groundwater storage
- Measures to fully use surface water by means of dam/hill-lake construction
- Assessment of possible negative environmental impact of dam construction
- Measures to retard melting snows
- Measures to retain rain water on the ground surface

Demand Management

- Rehabilitation of water supply distribution facility to reduce leakage (Leakage Control)
- Conservation measures to save water consumption (universal metering, tariff, retrofit and plumbing codes, public education)
- Strengthening of water supply service quality (service ratio)
- Reuse of treated wastewater for urban and irrigation use
- Industrial water recycling
- Rehabilitation of irrigation infrastructure
- Measurement and control of water consumed for irrigation
- Education and establishment of farmer's association for better operation of irrigation

Water Quality Management

- Consolidation of monitoring system of water quality
- Conservation measures for excessive use of fertilizer, pesticide and disposal of solid waste
- Strengthening of administrative and laboratory capacity of water sample testing

Wastewater Management

- Construction of wastewater collection and treatment systems

Data Management

- Consolidation of meteorological, hydrological and hydro-geological observation and monitoring system
- Construction, operation and maintenance of a database
- Strengthening of administrative capacity for data observation and management

Institutional Management

- Simplification and strengthening of administrative structure for coordination of decisions and actions related to the water sectors
- Establishment of the Water Resources Management Center

Watershed Management

- Reforestation
- Construction of snow dam(s)
- Environmental conservation

Table 3.1-1(1) Policy and Strategy to be Considered in Water Resources Management (1/2)

Policy and Strategy	No.	Measures	Projects/Programs
Supply Management ➤ To maximize use of surface water	1-1	To make an inventory of springs	➤ Spring inventory survey
	1-2	To accumulate reliable hydrological data	➤ Improvement project of hydrological observation & monitoring system
	1-3	To assess water resources potential	➤ Operation/updating of the models
	1-4	To develop surface water resources	➤ Surface water diversion projects
			➤ Dams/hill lakes projects
			➤ Trans-basin diversion projects
	1-5	To reinforce retarding effect of melting snow	➤ (Snow dam construction)
	1-6	To reinforce retaining effect of rain water on ground surface	➤ Reforestation
	1-7	To develop submarine springs	➤ Submarine springs development projects
	1-8	To make an inventory of wells	➤ Well inventory survey
	1-9	To accumulate reliable groundwater data	➤ Construction of hydro-geological observation & monitoring system
	1-10	To assess groundwater resources potential	➤ Operation/updating of the models
	1-11	To sustainably develop groundwater resources	➤ Groundwater development project
	1-12	To reinforce groundwater recharge/storage	➤ Recharging well/Underground dam
Demand Management ➤ To conserve environment ➤ To use non-conventional source of water	1-13	To assess impacts of water resources development projects	➤ IEE and EIA
	1-14	To promote wastewater treatment and reuse	➤ Construction of wastewater collection and treatment system
	2-1	To reduce unaccounted-for-water in distribution system	➤ Rehabilitation of distribution facility
	2-2	To save industrial water	➤ Promotion of industrial water recycling
	2-3	To save irrigation water	➤ Rehabilitation and modernization of irrigation infrastructure
	2-4	To conserve piped water	➤ Installation of universal metering devices
			➤ Introduction of water prioritizing and t
			➤ Water legislation with penalty for illegal use of water
			➤ Public education
	2-5	To conserve irrigation water	➤ Monitoring of water consumption for irrigation
			➤ Research on less water intensive or salt tolerant crops
			➤ Improvement of irrigation operation

Table 3.1-1(2) Policy and Strategy to be Considered in Water Resources Management (2/2)

Policy and Strategy	No.	Measures	Projects/Programs
Water Quality Management ➤ To preserve/improve water quality	3-1 3-2 3-3	To accumulate reliable water quality data To strengthen laboratory capacity of water samplings To undertake pollution control	➤ Construction of water quality observation & monitoring system ➤ Capacity building for water analysis ➤ Water quality legislation and enforcement
Data Management ➤ To consolidate reliable database	4-1 4-2 4-3	To construct, operate and maintain database To construct, operate and maintain supporting tools for formulation of water resources management master plan To strengthen administrative capacity for data management	➤ Related to 1-2, 1-9 and 3-1 ➤ Establishment of water resources management center
Institutional, legal and legislative Management ➤ To strengthen and reinforce institution and legislation related to water sectors	5-1 5-2 5-3	To establish and reinforce water legislation To strengthen water related institution To develop water resources management strategy	➤ Legislation including particularly groundwater institutions ➤ Strengthening including reform and capacity building of water related institutions ➤ Water resources management center
Watershed Management ➤ To preserve sustainable water resources	6-1 6-2	To preserve watershed desirable for water resources management To conserve environment	➤ Implementation of reforestation program ➤ Environmental conservation program

3.2 Water Demand Management

3.2.1 Water Demand Management in Integrated Resource Planning

As demand of fresh water increases and renewable water resource becomes scarce, the value of water resources or the cost of water supply is becoming more expensive. Therefore, Demand management has become more important today than before proportionally to the increasing value of water resources.

Unlike most of the Middle East countries, Lebanon has reasonable amount of rainfall and therefore the potential of water resources development is high and the water resources can be developed at a relatively low cost. When the cost of resources development is low, demand management may not be an attractive option to initiate. Therefore, demand management initiatives are still in relatively early stage in Lebanon. However, although it may be early to initiate, many potential benefits of water demand management are recognized as:

- Eliminating, downsizing, or postponing the need for capital projects of water supply and sewerage system,
- Improving the utilization and extending the life of existing facilities,
- Avoiding new source development costs,
- Improving drought or emergency preparedness,
- Educating customers about the value of water,
- Improving reliability , safety margins and dependable yields
- Protecting and preserving environmental resources.

Among these benefits, eliminating, downsizing, or postponing the need for capita projects of water supply and wastewater system is the most attractive benefit.

Currently, international attention is paid to water demand management in order to ensure that capital is not wasted on the supply side of the water industry rather than strategically invested on the demand side. Integrated resource planning (IRP) is one of the leading methods to deal with this issue, which considers demand management option as well as supply option during planning stage. The centre point of this method is the costs and benefits of supply side measures (new dams, pipelines, treatment plants, ground-water source) are compared with demand management measures (leakage reduction, pricing, education, regulations, retrofitting, financial incentive for customers).

IRP is a comprehensive form of water utility planning that encompasses least-cost analysis of demand management and supply management options, as well as open and participatory decision making, explicit consideration of risk and uncertainty, and recognition of the multiple institutions concerned with water resources and the competing policy goals among them (Duane D. Baumann, 1997). A comparison of traditional utility planning and integrated planning is shown in Table 3.2-1.

Table 3.2-1 Traditional Planning and Integrated Planning Compared

Criteria	Traditional planning	Integrated planning
Orientation of the Planning Process		
Resources Options	Supply options, little diversity	Supply and demand options, diversity is encouraged
Resource evaluation criteria	Maximize reliability, minimize prices	Multiple criteria, including resource diversity, risk management, environmental quality, and public acceptance
Resource selection	Based on a commitment to a specific option	Based on the development of a mix of options
Resource ownership and control	Centralized, utility-owned	Decentralized, utilities and others
Planning Procedures		
Nature of process	Closed, inflexible, internally oriented	Open, flexible, externally oriented
Judgment and preferences	Implicit	Explicit
Decision tools	Dispute resolution	Consensus-building
Stakeholders' identity	Utility and its ratepayers	Multiple interests
Stakeholders' role	Disputants	Participants
Planning Objectives		
Scope of objectives	Single	Multiple, as determined in the planning process
Supply reliability	Constraint	Decision variable
Environmental quality	Constraint	Objective
Role of pricing	Cost recovery	Economic signal
Efficiency	Operational concern	Resource and priority
Trade-offs	Hidden	Openly addressed
Uncertainty	Uncertainty should be reduced	Uncertainty should be analyzed
Risk	Risk should be avoided	Risk should be managed

Source: Beecher (1995)

This approach provides benefits in a number of ways, including the followings (World Water Congress, 1999):

- There is more likelihood that the appropriate cost effective investment will be made in demand management, rather than a focus on a few select strategies,
- There is the potential for education in the cost of infrastructure provision, which is

particularly important in developing countries and emerging economies, where levels of service provision are often low, despite high losses and low levels of efficiency, and where capital funds are short; and

- There is the potential for a water utility to find out more information about its customer base, through the required attention to water end-use, which will ensure that demand forecasting and customer communication will be improved.

This approach requires a focus on water end-use. In other words, it requires a greater knowledge of where and how water is used by customers. Surveys, good metering, and analysis of demand data and other relevant data (demographic, weather-related, appliance changes), all are required.

Where possible, the water utility uses integrated resource planning methods in which the cost effectiveness of demand management measures is assessed from the combined perspective of the utility and the customers.

The water utility works with regulatory agencies to ensure that water utility regulation provides sufficient regulatory incentives to ensure that cost effective demand management measures attract reasonable levels of investment and that the cost of such measures can be recouped.

3.2.2 Water Demand Management Measures

There is a large variation in the types and scope of demand management activities. This is explained by the differences in climate, land use, political system, wealth level, water supply levels, etc. Demand management measures are explained below by being organized into the following four categories.

- Un-accounted-For Water (UFW) Control
- Water Conservation (beneficial reduction in water use)
- Wastewater Reuse
- Industrial Recycling

(1) Unaccounted-for Water Control

The leakage of water supply system means waste of water and loss of value. The supplied water abstracted from the source, then transmitted, treated and distributed to water customers is costly. This costly water is just wasted from the leakage-prone network without any beneficial use.

Unaccounted for water is composed of physical loss or leakage and none-physical loss or commercial loss, which includes illegal use, metered volume under-reading and unpaid volume of water. There are numerous methods for reducing the amount of unaccounted for water, some of them are listed below:

- replace/renovate deteriorated old network
- change the approach of leakage detection/control

- detect and repair underground leaks
- introduce pressure management
- change the domestic metering practice
- improve the design and operation of the distribution system
- change construction materials, especially for service pipe

Leakage control measures are summarized in the Table below. Major leakage control activities may be categorized into passive control and active control. Passive leakage control is a measure to find and repair a leak that occurs when there is a loss of pressure from supply, or to repair a significant leak that is apparent at the surface; both of which relying on the customer information. Active leakage control is regular surveys to reduce existing leakage by means of detection, repair and monitoring, by forming leakage detection and repair team. Even if leaks are repaired, they can recur with time. So continuous efforts are required to keep the network in an appropriate condition. Preventive control may be categorized in one of the active control measures, which reduces potential leaks through adequate planning, designing, construction work and maintenance. The active control may be effective if the network has an appropriate condition for regular repair. However, if the network is highly deteriorated and the leakage ratio is very high, i.e., more than 40-50 %, replacement of the network may be a more economical measure than the leakage detection and repair measure.

Table 3.2-2 Leakage Control Measures

Work process	Measures
1. Preparation	• Establishment of leakage management and planning organization • Training of staff and technology transfer • Provision of equipment • Updating record drawings and mapping
2. Planning	• Conduction of network analysis • Formulation of leakage control strategic plan • Development/selection of leakage detection technique • Evaluation of economic leakage level (cost of leakage and cost of leakage control)
3. Preliminary survey	• Surveys, maps and illegal connections • Production loss survey (source-water metering) • Consumption loss survey • Analysis of unaccounted for water
4. Monitoring	• Installation of monitoring pressure gauge and loggers • Installation of monitoring district meter • Installation of monitoring meter at strategic location • Monitoring activities
5. Rehabilitation	• Rehabilitation and renewal of distribution network
6. Active leakage control measures	• Regular leak detection (sounding, high-flow measurement, monitoring district flow etc) • Repairs of detected leaks • Distribution system pressure control to reduce area's overall leakage
7. Preventive control measure and others	• Change of material of pipe and valve • High standard of construction and supervision in the laying of pipeline • Control of illegal connections
8. Universal service connection metering	• Large users metering • Public users metering • Domestic users metering • Meter accuracy check • Meter testing, calibration, repair, and replacement • Establishment of periodical meter reading system (every two months)

(2) Water Conservation ¹

There are many water conservation measures that are usually operated simultaneously by the water utility in order to obtain a certain conservation goal.

a) Universal metering

Metering will discourage the careless, excessive use of water. According to one estimate, the introduction of meters can alone produce a 20 percent savings in water use (NRRI. 1994).

A full-metered system is an essential feature for the implementation of the conservation strategy as well as the leakage control. It is needed to put into effect the conservation-oriented tariff structures. It is also an important element for the policy of demand management that will provide better information to derive future water demands.

b) Water pricing

Pricing measures are conservation strategies because they involve understanding the true value or cost of water and conveying information about that value, through prices, to water customers.

Pricing water service depends on the practice of metering water-service customers. Once meter counters are installed and the consumptions are monitored, pricing works as a tool of demand management, which can manipulate water and wastewater demand.

Water for necessities (sanitation, cleaning and cooking) is far less responsive to price than water for more discretionary uses (unconscious wastage, lawn watering, car washing, swimming pools). The wastage can be minimized and the excess use optimised by the pricing mechanism.

There are many types of conservation-oriented rate structure depending on different objectives of the utilities and considering that the peak demand should be reduced. Besides conservation objective, the pricing strategy must be consistent with overall system goals such as cost-recover and revenue adjustment, and should be approved by regulatory or other governing bodies. Table 3.2-3 shows some of the alternative conservation rate structures.

¹ Most part of this section is adopted and modified from "USEPA Water Conservation Plan Guidelines, Appendix A Water Conservation Measures" <http://www.epa.gov/owm/water-efficiency/wave0319/appendia.pdf>

Table 3.2-3 Conservation rate Structure

Rate	Definition	Objectives
Metered service	Customer bill vary with water usage	Send a price signal to customers, promoting efficiency and discouraging waste
Uniform rates	Price per unit is constant as consumption increases	Reduce average demand
Increasing-block rates	Price per block increases as consumption increases	Reduce average (and possibly peak) demand
Seasonal rates	Prices during season of peak use are higher than off-peak season	Reduce seasonal peak demand
Excess-use rates	Prices are significantly higher for above-average use	Reduce peak demand

Source: Constructed from NRRI. (1994)

c) Retrofit program

Water utility can promote conservation through a retrofit program. Retrofit involves making an improvement to an existing fixture or appliance in order to increase water-use efficiency. Retrofit program usually targets plumbing fixtures.

A basic retrofit fixture currently prevailing in water conscious countries may include low-flush toilet, low-flow faucet, and low-flow showerheads. Water utility can actively distribute retrofit fixtures. Water utility also may regulate water use by enforcing standards of low water-using fixtures and appliances.

Potential water savings from efficient fixtures is summarized in table below. With conventional fixtures, the water consumption per capita is 266 litres in total, while if efficient fixtures are adopted it will be 133 litres. Half of the water can be saved with efficient fixtures.

Table 3.2-4 Potential Water Savings from Efficient Fixtures

Fixtures	Fixture capacity		Per capita water use	Per capita water savings
		liter equivalent	(l/c/d)	(l/c/d)
Toilets				
Efficient	1.5gallons/flush	5.7	23	-
Low-flow	3.5gallons/flush	13.2	53	30
Conventional	5.5gallons/flush	20.8	83	60
Conventional	7gallons/flush	26.5	106	83
Showerheads				
Efficient	2.5 (1.7)gallons/min	9.5 (6.4)	31	-
Low-flow	3.0 to 5.0 (2.6)gallons/min	11.4 to 18.9 (9.8)	47	16
Conventional	5.0 to 8.0 (3.4)gallons/min	18.9 to 30.3 (12.9)	62	31
Faucets				
Efficient	2.5 (1.7)gallons/flush	9.5 (6.4)	26	-
Low-flow	3.0 (2.0)gallons/flush	11.4 (7.6)	30	4
Conventional	3.0 to 7.0 (3.3)gallons/flush	11.4 to 26.5 (12.5)	50	24
Sub-total (toilets, showerheads, and faucets combined)				
Efficient	-	-	79	-
Low-flow	-	-	131	52
Conventional	-	-	195	116

Cloth Washers				
Efficient	42 to 47.5gallons/load	159 to 79.8	48	-
Low-flow	-	-	-	-
Conventional	55gallons/load	20.8.2	62	14
Dishwashers				
Efficient	9.5 to 12gallons/load	-	6	-
Low-flow	-	-	-	-
Conventional	14gallons/load	-	9	3

Total				
Efficient	-	-	133	-
Low-flow	-	-	-	-
Conventional	-	-	266	133

Source: Amy Vickers. (1990).

(a) Efficient = post 1994, Low-flow = post 1980, Conventional = pre 1980

(b) For showerheads and faucets: maximum rated fixture capacity (measured fixture capacity). Measured capacity equals about two-thirds the maximum.

(c) Assumes four flushes per person per day; does not include losses through leakage.

(d) Assume 4.8 shower-use minutes per person per day.

(e) Assume 4.0 faucet-use minutes per person per day.

d) Information and education

Information and education are critical for the success of any conservation program. Information and education measures can directly ensure water savings, when customers change their water-use habits. These savings can be difficult to estimate. Also, public education alone may not produce the

same amount of sustained water savings as other, more direct approaches (such as leak repairs and retrofits). However, educational measures can enhance the effectiveness of other conservation measures. For example, it is widely believed that information play a role in how water customers respond to changes in price. More generally, customers that are informed and involved are more likely to support the water system's conservation planning goals. The following table shows some typical education measures.

Table 3.2.5 Conservation Education Measures

Measures	Contents
Understandable water bill	Customers should be able to read and understand their water bills. An understandable water bill should identify volume of usage, rates and charges and other relevant information.
Information available	Water systems should be prepared to provide information pamphlets to customers on request. Public information and education are important components of every water conservation plan. Consumers are often willing to participate in sound water management practices if provided with accurate information. Furthermore, providing information and educating the public may be the key to get public support for a utility's water conservation efforts. An information and education program should explain to water users all the costs involved in supplying drinking water and demonstrate how water conservation practices will provide water users with long-term savings.
School program	Utilities can provide information on water conservation and encourage the use of water conservation practices through a variety of school programs. Contacts through schools can help socializing young people about the value of water and conservation techniques, as well as help utilities communicate with parents.
Public education program	Utilities can use a variety of methods to disseminate information and educate the public on water conservation.
Workshops	Utilities can hold workshops for industries that might be able to contribute to water conservation efforts. These might include, for example, workshops for plumbers, plumbing fixture supplies and builders, or for landscape and irrigation service providers.

(3) Wastewater Reuse

a) Wastewater reuse planning

The increase of water demand, the scarcity of water resources or the requirement of water pollution control has promoted the integration of water reuse into water resources management strategies. The wastewater reuse is also promoted by improvements in treatment process reliability, health risk assessment, and public confidence in the reuse systems. It is important that public acceptance of water reuse is vital to the water reuse. To optimise the net benefits from the implementation of wastewater reuse, an integrated planning is essential. Planning for wastewater reuse typically involves definition of the project, quality of requirements of water for a specific application, cost estimation, and identification of potential treated wastewater market.

b) Application of treated wastewater

Treated wastewater is most commonly used for non-potable (not for drinking) purposes, such as agriculture, landscape, public parks, and golf course irrigation. Other non-potable applications

include cooling water for power plants and oil refineries, industrial process water for some facilities such as paper mills and carpet dyers, dust control, construction activities, concrete mixing, artificial lakes, and toilet flushing.

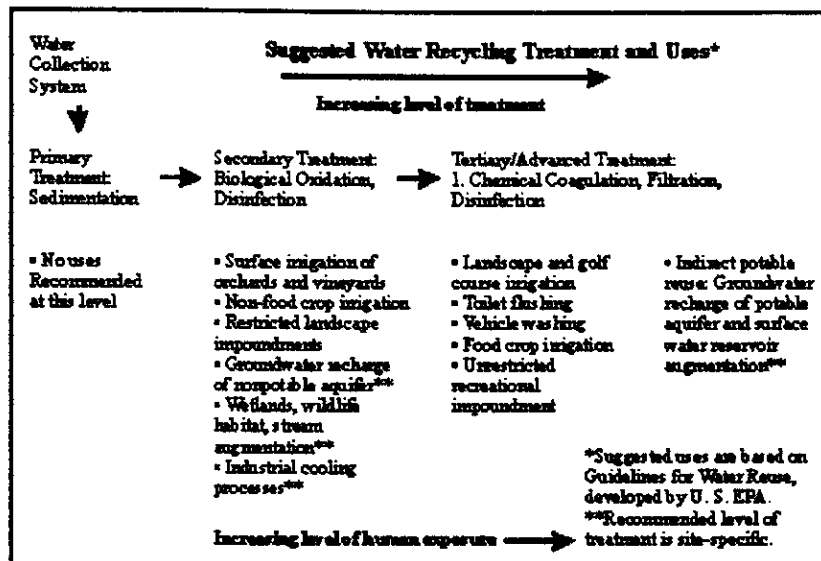
Potential application for reuse of treated wastewater in urban areas is to satisfy secondary water requirements. The development of dual distribution systems (one line for domestic water supply and the other for treated wastewater) is a growing practice worldwide, and particularly in areas with high rates of urban water usage. Dual distribution systems segregate the potable water supply from the non-potable system. Thus, a high quality system can be provided for drinking water and in-building applications. As for treated wastewater, it is provided for use in irrigation and fire protection. When retrofitting an existing system, the high cost of installing a second distribution system can often render a project economically unfeasible; however, it is more economically favourable to install the dual system as part of a new development. Dual distribution systems can be developed in two ways. One approach is to construct a city-wide system in which the wastewater is returned to a municipal wastewater treatment plant for processing before being redistributed to the population. The second approach is using small-scale individual systems where "gray water" from sinks, bathtubs, showers, and other sources of dilute non-fecal wastewater is redistributed to the system. This system is frequently applied to toilet flushing within business buildings and apartment complexes. In the urban application, protection of public health is a prime concern in the implementation of the dual distribution system water reuse.

Significant regional and seasonal variations exist in the water use patterns. For example, in urban areas, industrial, commercial, and non-potable urban water requirements account for the major water demand. For agricultural application, irrigation is the dominant component of water demand. Water requirements for irrigation applications tend to vary seasonally, whereas industrial water needs are more consistent.

Although technologically feasible at high cost, the direct use of treated wastewater for domestic needs is not recommended. Depending upon treatment and quality control, treated water may theoretically be used for many other purposes. However, its use will be generally restricted for various reasons including quality constraints, greater treatment requirements, availability of better quality water, economics, legal restrictions and public acceptance.

c) Treatment requirements

There are a variety of purposes for treated water reuse. Following chart shows types of treatment processes and suggested uses at each level of treatment. In general, primary treatment water is not recommended for any purpose; secondary treatment is required for surface irrigation and industrial cooling water; and tertiary treatment is required for food crop irrigation and toilet flushing.



Note: While there are some exceptions, wastewater in the United States is generally required to be treated to the secondary level. Some uses are recommended at this level, but many common uses of recycled water such as landscape irrigation generally require further treatment.

Source: USEPA. <http://www.epa.gov/region9/water/recycling/index.html>

(4) Industrial Water Recycling

a) Application of industrial water recycling

Industrial water recycling has been implemented successfully for industrial process in many countries². Industrial applications for recycled water include cooling water; process water; commercial laundries; car washing establishments; pulp and paper industries, steel production; textiles; electroplating and semiconductor industries; and boiler-feed water. Major type of wastewater recycled in industries is cooling and boiler water, which is very easy to put into a recycling process. While textile and food processing industries are not major recycling industries because these industries require high quality of water for processing or higher treatment. Industrial uses vary greatly and additional wastewater treatment beyond secondary treatment is usually required according to quality requirements.

Advanced approaches for industrial recycling include cascading use of industrial process water between successive processes within an industry, and agricultural reuse of industrial plant effluent of cooling water and boiler water.

b) Incentive of industrial water recycling

Without any incentive and control, the industry is not willing to recycle the water. Industrial recycling can be promoted by several factors: increased cost of water supply; regulation of

² Japan is one of the leading countries in industrial recycling. Industrial water recycling has been operated more than 40 years and 78 % of industrial water is recycled and only 22 % comes from external sources.

groundwater use because the industry relies frequently on private wells; enforcement of industrial pollution control requirements, by which industries have to optimise discharge, and introduction of incentive program for recycling. In deciding how much to recycle, industries weigh the costs of getting water and treating it prior to disposal with those of adding equipment to treat and reuse wastewaters with in the plant.

c) Payback (costs and benefits) of recycling

Table 3.2-6 gives some ideas about advantages of industrial recycling. Given the proper incentives, industries of many types showed that they could cut their water needs 40 –90 percent with available technologies and practices, while at the same time protecting water from pollution. In the same cases, the payback period on the conservation investments was less than 12 months.

Table 3.2-6 San Jose, California: Industrial Water Conservation and Cost-Effectiveness, Selected Companies

Company	Water Use (1000 m ³ /year)		Water savings (%)	Payback Period on Investment (Months)
	Before conservation	After Conservation		
IBM ¹	420	42	90	3.6
California paperboard Corp.	2,473	689	72	2.4
Gangi Bros. Food Processing	568	212	63	10.8
Hewlett-Packard ¹	87	42	52	3.6
Advanced Micro Devises	2,098	1,318	37	7.2 ²
Tandem Computers	125	87	30	12.0
Dyna-Craft Metal Finishing	193	140	27	2.4

¹ Water use rates apply only to one or more processes involving conservation measures.

² Payback based only on that portion of water savings with which costs could be associated.

Source: Postel. (1997).

3.2.3 Impact of Demand Management

Like water supply option, the implementation of demand management option generates both financial and social costs and benefits, or impacts. Table 3.2-7 identifies major impacts of demand management measures. For example, the major cost of leakage control is the operating costs; the social cost of public acceptance is very high in conservation; and the environmental benefits of wastewater reuse and industrial recycling may be outstanding.

In water resource planning, a least cost plan based on the evaluation of the financial, social and environmental costs of water supply and demand options, shall be figured out.

Table 3.2-7 Impact of Demand Management Measures

Management Items	Management measures	Physical, Social and Environmental Impact (Cost/Benefit)	
Leakage	Rehabilitation of network	+	Water saving and decrease in capital investment for water supply system
		-	Increase in capita investment for distribution network
	Active leakage control	+	Water saving, Decrease in capital investment for water supply system
		-	Increase in O&M cost of leakage control
Conservation	Universal metering	+	Reasonable use of water, decrease in capital investment for water supply and wastewater system
		-	Meter installing cost
	Pricing	+	Reasonable use of water, decrease in capital investment for water supply and wastewater system
		-	Public acceptance
	Retrofit program	+	Reasonable use of water, decrease in capital investment for water supply and wastewater system
		-	Program cost, replacement and promotion costs, public acceptance
	Information and education	+	Reasonable use of water, decrease in capital investment for water supply and wastewater system
		-	Campaign costs
Wastewater Reuse	Crop irrigation use	+	Additional or alternate reuse for irrigation, rich nutrient reuse and water pollution mitigation
		-	Investment cost of conveyance of water to application sites
	Urban use	+	Increase in water supply and water pollution mitigation
		-	Tertiary treatment costs and investment cost of conveyance and distribution network
Industrial Water Recycling	Control of groundwater use	+	Water saving and mitigation of sea water intrusion
		-	Regulation cost and investment cost of industrial recycling
	Control of industrial effluent	+	Water saving and mitigation of water pollution
		-	Regulation cost and investment cost of industrial recycling

Note: “-” indicates negative impact and “+” positive impact

3.3 Water Resources Assessment

3.3.1 Assessment of Water Resources Potential

Through the SSM simulation study, many hydrological parameters such as rainfall amount, recharging volume, evapo-transpiration volume, surface runoff, groundwater level, groundwater flow, and so forth, on a daily basis in every sub-basin are calculated and stored in a hard disk. The SSM calculates water balance in combination of surface and groundwater systems, based on precipitation, evapo-transpiration, infiltration ratio, runoff coefficient, permeability, and strativity of the ground. In the course of simulation, SSM estimates the volumes of groundwater movement and elevation of groundwater table on a daily basis. Using the output file on groundwater elevation, the contour map of groundwater at any day can be drawn up. Thus, the volumes of information obtained through the simulation become quite large amount.

The model simulation will give necessary information for assessment of water resources. For surface water resources, such information given are 1) total precipitation in the catchment basin, 2) water transferred or running into the basin from the other basin, 3) water once infiltrated into the ground and flowed up to the ground and therefore counted as the gain of surface water., 4) all infiltration volume so called "recharge", 5) water volume lost by evapo-transpiration, and 6) water volume actually taken from the river through the simulation.

For groundwater system, the model simulation will produce 1) recharge from surface system, 2) inflow from other groundwater basin(s), 3) water extraction by pumping up, 4) outflow to surface system by spring up, and 5) outflow to other groundwater basin(s).

In addition to the simulation made under the current conditions with artificial water diversion from groundwater aquifer, natural situation without artificial water diversion will be simulated to assess water resources potential of the country.

3.3.2 Surface Water Development Potential

(1) Development Strategy

Definition of surface water development potential is the maximum volume of surface water available for the future water use, and surface water is defined as water flowing in river. Since most of spring water flows into river regardless of their use in upstream, spring water is included in surface water in this Study. Besides, the potential analysis of spring water separated from surface water is not possible due to limitation of spring discharge data.

Surface water development depends on water resources management policy. For example, the volume of surface water to be developed depends on the drought return period adopted. If the downstream eco-system or recreational water were significant, an idea of maintenance discharge

would need to be introduced. Considering the present and future use of surface water, 1) return period of drought year, 2) maintenance discharge and 3) direct intake/storage facility of water are examined as development strategy.

Drought Year

Determination of the return period of drought year is associated with the safety degree of water supply and cost for water development. If the long return period were adopted for water development, the water supply would be secured against severe drought but simultaneously the cost for development would become large. For example, a development plan for 10-year return period drought costs more than that for 5-year return period drought; however, insecure water supply hinders growth of the socio-economy. To adopt the feasible target of return period, the future socio-economic framework and hydrological conditions in Lebanon need to be considered.

Since Lebanon has a high potential for economic development and actually economy is very active after the cease of civil war, the stable supply of water is one of crucial factors to sustain the economic development. It means that the safety degree of future water supply should be set as high as other developed countries.

10-year return period drought may be adopted for the water use planning in the country, considering cases in the developed countries. It implies that the water supply will be secure against 10-year return period drought.

Maintenance Discharge

In general, maintenance discharge is defined as discharge maintained even during the drought for navigation, fishery, scenery, prevention of saline problem, prevention of river mouth clogging, protection of river structures, maintenance of groundwater table, preservation of eco-system, water quality control of river flow and so on. The present water use, such as domestic water, industrial water and irrigation, is necessary to be considered for the water resources development from the water right point of view; however, it is examined separately from the maintenance discharge. Thus, the maintenance discharge does not include the present water use.

Considering the future socio-economic framework and necessity of nature preservation, maintenance discharge should be introduced with the following reasons.

- 1) **Tourism:** Tourism is an important sector in Lebanon and the rapid growth of this sector is expected. The water flow also contributes to maintain the scenic areas.
- 2) **Recreational Use of Water:** In the summer, Lebanese enjoys the scenery of water flow. Area along river is already developed with restaurants, cafes and so on, wherever there is water flow with nice view.
- 3) **Preservation of Eco-system:** There are flora and fauna existing along the watercourses. Considering the significance to preserve existing eco-system, some discharge has to be

maintained.

Direct Intake/Storage Facility

Surface water is developed by either direct intake from river and spring or storage facilities, such as dams, and hill lakes. In general, development without storage facilities costs lower compared to development with storage facilities. Therefore, the surface water development gives the priority to the direct intake, and the storage facility is considered when the direct intake cannot satisfy the water demand.

(2) Development Potential by Direct Intake

Definition of Terms

Surface water development potential by direct intake is expressed by the following equation.

$$Q_{sp} = Q_{355} - Q_m - Q_u$$

Where Q_{sp} : surface water development potential

Q_{355} : drought discharge in the target drought year

Q_m : maintenance discharge

Q_u : present water use (domestic, industrial & irrigation)

Development Potential

The following conditions and assumptions can be adopted to estimate the surface water development potential in each river basin.

- 10-year return period drought is adopted as the target for stable water supply. Annual discharge data of as long as available should be used to determine a year of 10-year return period drought.
- Maintenance discharge should be applied to rivers where is some flow during the dry season. Volume of the maintenance discharge may be assumed to be 50% of the drought discharge (Q_{355}).
- Potential estimate can be based on daily discharges collected from LRA (Litani River Authority). Correlation of river basins with discharges and specific discharge (discharge divided by catchment area) may be applied to fill data gaps to maintain at least last 10 years daily discharge.
- Observed discharge data are the result of subtraction of present water use (domestic, industrial and irrigation) in upstream from natural discharge. Since the calculation should deal with the observed discharge data, it can be assumed that the present water use is already considered. Thus, the above equation for the surface water development potential becomes " $Q_{sp} = Q_{355} - Q_m$ ".

(3) Development Potential by Storage Facility

In Lebanon, the surface water development is mainly conducted by storage facilities, such as dams and hill lakes, due to high seasonal fluctuation of river discharge. Besides, topographical features that most of rivers flow in gorges hinder the surface water development by direct intake. In the following section, the surface water development potential by storage facility is discussed based on the proposed surface water development by MEW and LRA.

Existing and Proposed Surface Water Development Projects

MEW and LRA are the main executing authorities for planning and implementation of the surface water development. In 1999, MEW formulated the 10-Year Work Plan for the period of 2000 to 2009 as the mid-term plan, to conduct the study, land acquisition and construction associated with water resources development, domestic water supply, wastewater treatment, irrigation and river rectification. Its project components have been revised several times depending on the progress. As of March 2003, there are 19 dams and 17 hill lakes proposed in the 10-Year Work Plan as the surface water development projects.

In 1999, LRA also formulated the 5-Year Plan for the period of 1999 to 2003. LRA tasks in the field of surface water development are almost same as MEW and only difference is its service area. Since MEW has the overall responsibility for water resources development, LRA proposals in the 5-Year Plan associated with surface water development in Bekaa and south Lebanon are included in the MEW's 10-Year Work Plan.

Although CDR has sought the external fund for projects and simultaneously MEW has implemented some projects using the internal fund, completion of all projects within the period for the 10-Year Work Plan might be optimistic, particularly dam projects that require a long consideration of technical and environmental aspects. Thus, it is necessary to decide priority of each project in accordance with the future water demand.

Dam Storage Volume and Development Potential

Since the development potential is not only function of the storage volume but also the inflow discharge and recovery period to be allowed, the development potential of dams can be evaluated based on the following conditions and assumptions. Evaluation of the development potential by dam is limited to projects proposed in the 10-Year Work Plan formulated by MEW because the Study does not cover identification of dam/hill lake potential sites. Besides, MEW has already identified those potential sites.

- Since 10-year return period drought is the basis for assessment of water resources, consecutive daily discharges of 10 years period at least are applied to estimate dam inflow as long as discharge data are available or correlation with neighboring river basin is conducted to fill data gaps.
- It is assumed that observed discharge data are the result of subtraction of present water use in upstream from natural discharge. Thus, the present water use is already considered in

discharge data.

- The same maintenance discharge determined in evaluation of the potential by direct intake is applied to dam outflow.
- As mentioned in the above, the present intake is already considered in discharge data. As a result, it can be assumed that the present water use in downstream is secured as long as the dam drains the maintenance discharge.
- Seepage depends on geological characteristics of dam site; and is excluded from the dam storage simulation.
- Rough estimate shows that evaporation from the reservoir induces around 5% decrease in development potential. Thus, evaporation from the reservoir is excluded from the dam storage simulation.
- Since the storage volumes of hill lakes are relatively small (less than 1 million m³/year), it is assumed that the storage volume recovers annually and is equal to the development potential.

Based on the above conditions and assumptions, the development potential by dam is simulated by the following equations.

$$Q_{in} = Q_{gauge} \times A_{dam} / A_{gauge}$$

$$Q_{sd1} = Q_{in} - Q_m$$

$$Q_{sd2} = Q_{sd1} - Q_d$$

$$C_t = C_{t-1} - Q_{sd2,t} \times 86.4 \geq 0$$

$$Q_{out} = Q_{in} + (C_t - C_{t-1}) / 86.4 - Q_d$$

Where Q_{in} : dam inflow discharge (m³/s)

Q_{gauge} : daily discharge at gauging station (m³/s)

A_{dam} : catchment area of dam (km²)

A_{gauge} : catchment area of gauging station (km²)

Q_{sd1} : surplus/deficit of discharge at dam (m³/s)

Q_m : maintenance discharge (m³/s), 50% of 1/10Q₃₅₅ where available

Q_{sd2} : surplus/deficit of discharge at dam after intake of developed water (m³/s)

Q_d : newly developed water by dam (m³/s)

C : empty capacity of dam reservoir (1,000 m³)

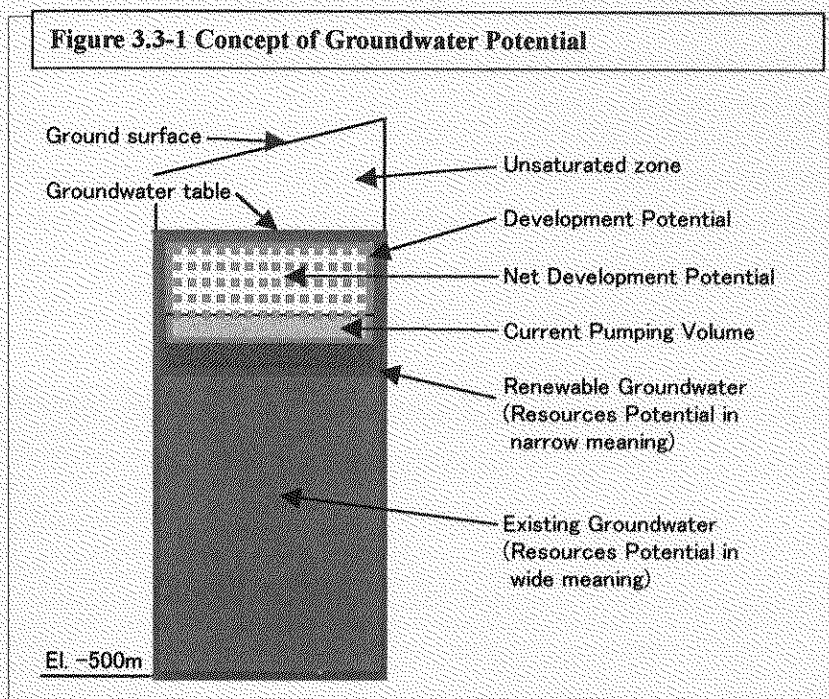
Q_{out} : discharge drained from reservoir to downstream (m³/s)

t : time series (day)

3.3.3 Groundwater Resources Development Potential

(1) Resources Potential and Resources Development Potential

In the case of groundwater system, a water resources potential has two meanings. One is the total volume of existing groundwater contained in a certain basin or area, and it is a quite huge volume because the total thickness of all aquifers sums up to around 1,300m and they have rather high effective porosity (strativity). Another is theoretically available groundwater volume every year, in other words it is a renewable groundwater and almost same meaning of the total of yearly net recharge and groundwater inflow at a certain basin. Both of the groundwater volumes are estimated through SSM simulation study as explained so far.



On the other hand, a groundwater resources development potential has rather restricted meaning that the groundwater volume which can be developed safely for long years, in other words it is water volume available for a sustainable groundwater development. The groundwater resources development potential also has two categories: the total

development potential and the volume excludes the groundwater volume already utilized for every purpose. These concepts of groundwater potentials are simply illustrated in Figure 3.3.1.

(2) Groundwater Resources Development Potential

Groundwater resources potential is rather easily estimated through SSM simulation. However, the groundwater resources development potential can not be directly calculated from the simulation but it needs farther consideration. In this section, the groundwater resources development potentials are examined separately: for the cases of sub-basins in inland and at coastal, and the offshore submarine springs.

Groundwater resources development potentials in inland and coastal sub-basins

Inland sub-basins mean sub-basins which are not directly contacted with the Mediterranean Sea, and the most of sub-basins in SSM are included in this category. Because of steep inclination of the Lebanon Mountain Range, these sub-basins have enough high elevation to avoid a seawater intrusion by pumping, and the groundwater development potential can be estimated from the net recharge volume and existing groundwater withdrawal.

While, coastal sub-basins which contact with the sea directly with groundwater developments within the basins have a risk of seawater intrusion every time. When considering groundwater development potential in these coastal sub-basins, the potential estimated from yearly recharge amount and the potential which does not cause seawater intrusion should be compared. And, in the case of Lebanon, every coastal sub-basin has enough high groundwater inflow because of the steep topography, and therefore, the potential estimated from yearly recharge is usually smaller than the later, meaning that the former is the safety side estimation. Thus, the groundwater development potential should be estimated from yearly recharge amount.

In Lebanon, groundwater in a certain basin easily moves out or in to/from the other basin beyond the boundary, so that the net recharge volume cannot be accounted directly as a safety pumping rate for long period because the pumping causes a new groundwater movement and it may influence to any spring yield in or out of the basin. It is rather difficult to estimate exactly the safety-pumping rate in this meaning but in the Study it is set as 1/3 of the net yearly recharge volume tentatively. The groundwater development potential, and the net development potential (development potential – current groundwater withdrawal), are thus simulated by the SSM model.

Groundwater resources development potential at offshore

Because of the hydro-geological characteristics of Lebanon, there are many submarine springs along the coastal line or offshore. Spring water was recharged in the inland sub-basins and runs down through mainly confined aquifers and finally flow out to the sea bottom because its piezometric head is higher than the depth of the sea. The studies on submarine springs by AUB or NCRS said a huge amount of fresh water springs out from the bottom of the sea. One of them, the study report on submarine springs by AUB, submitted to IDRC, Ottawa, Canada, February 2000, said the total annual discharge from all the springs (but only in Chekka Bay) may exceed 700 MCM.

Although the exact location or yield of each submarine spring is unknown, the maximum limit of the submarine spring water development can be estimated through SSM simulation. The maximum fresh water volume flowing out from those submarine springs must be less than the total groundwater volume that flows out to the sea, supposedly actually spring out volume is only certain percent of the total flow-out amount though.

3.4 Other Processes

3.4.1 Balance between Demand and Supply

Future water demand is compared to possible volumes of water supply and water resources development. The balance between water demand and supply is examined by river basin and administrative unit. Thus, water demand (domestic water, industrial water, irrigation and hydropower) and water resources for development (surface water, groundwater, spring water) in each river basin are identified spatially and quantitatively, and the regional characteristics of balance can be distinguished, for example shortage of domestic water along coastal area. The results of balance examination contribute to formulation of water resources management plans in accordance with regional characteristics of water use and available water resources.

3.4.2 Preparation for Economic Evaluation

Economic evaluation means the analysis of a project from a viewpoint of the country as a whole to judge whether an investment will generate worthwhile public benefit. In economic evaluation, financial cash inflow and outflow should be adjusted according to the principle of cost-benefit analysis. After adjustments of cash flow, Economic Internal Rate of Return (EIRR), Net Present Value (NPV) and Benefit-Cost Ratio (B/C) are calculated. From those figures, it becomes evident whether this project is meaningful and efficient from the viewpoint of a country.

On estimating the economic cost and benefit, the following conditions and assumptions may be applied.

Price Level

The basic price for cost and benefit estimates are set at prices of base year. Base year of the Study is 2002 as previously discussed. Foreign exchange rate is set at LBP 1,507 to US\$ 1.00 based on the official exchange rate at the end of year 2002.

Opportunity Cost of Capital

Opportunity cost of capital represents the permissible economic rate of return for projects. In Lebanon, 12 or 14% of opportunity cost of capital is generally applied to assess the economic viability. In this study 12% of opportunity cost of capital is applied from the viewpoint of social purpose and basic human needs for water resources development.

Economic Value

In economic analysis, financial goods/services of cost (input)/benefit (output) have to be converted into economic value.

To convert financial values of non-tradable goods and services into economic values, the following points have to be considered: (a) exclusion of all taxes and duties, and (b) conversion factors for shadow pricing; skilled labor, unskilled labor, and consumer goods (e.g. 80% of conversion factor

is applied for converting unskilled labor cost in the "Project Appraisal for Ba'albeck Water and Wastewater Project, May 2002" by World Bank.).

On the other hand, economic values of tradable goods and services are estimated based on the international market prices.

Economic Life

Various components with different character are used and installed for construction of the facilities and equipment/machinery for the Project. However, the economic life of each component is hard to define correctly because it varies depending on the conditions such as maintenance and weather.

In the various study reports of the country, the economic life of the facilities and equipment/machinery is put together and set at from 30 to 40 years. However, the economic life is to be assumed by each component according to the following manner as applied in the Awali Conveyor Project for Beirut Water Supply;

- Dam and Tunnels	: 100 years
- Civil works	: 40 years
- Distribution System	: 50 years
- Mechanical and electric Equipment	: 15 years

The components, if its economic life is less than economic evaluation period, have to be considered a periodical replacement during the evaluation period.

Time Horizon for Evaluation

The economic evaluation period is set over the years until the target year of 2030.

Cost Estimation

To facilitate the financial and economic analysis, unit costs for broad elements of the Project are analyzed from various existing reports and information. Unit costs also serve to develop the tariff structure in the financial analysis. The basic method of the Project Cost estimation is summarized as follows:

- The project costs are estimated based on the unit costs of respective projects such as; 1) water resources development, 2) extension and rehabilitation of municipal water supply system, 3) extension of sewage network system and wastewater treatment plant, and 4) extension of irrigation system.
- All costs related to water resources development such as dam, reservoir, and well are allocated to final consumption system (municipal water system and irrigation system) in proportion to respective size of the demand and use.
- Operation and maintenance costs of these projects are estimated respectively as a percentage of the capital cost of the above projects.

- All these financial costs are converted into economic costs as mentioned above.

3.4.3 Formulation of Development Scenarios

Present and future demands of water required by various water user sectors are combined with potential and available resources of both surface and groundwater simulated by the hydrological circulation model to produce necessary data and information for formulation of the strategy and alternative scenarios of water resources development and management. Possible alternative plans of water resources development, such as construction of reservoirs and groundwater dams, are input into the model to evaluate amount of water usable in future, and simulated results are evaluated from engineering, economic and environmental points of view to find out optimal solution of water resources development and management.

3.5 Institutional, Legal and Legislative Management

A department or division responsible for operation and maintenance of database and for enhancement of data collecting mechanisms needs to be created within MEW, because the works expected are so diverse and an integrated and systematic efforts shall be continuously exercised from a single source.

Water Resources Management Center

To collect global supply and demand data, reconstruction of meteorological and hydrological stations and construction of monitoring wells are urgently required, and capacity building in water authorities is also needed. To grasp yield of groundwater and volume of private irrigation, new water legislation shall be pursued. These actions need to be programmed urgently by the qualified staff that may mobilize financial and technical resources. A Water Resources Management Center (WRMC) may be created within MEW to undertake these exercises. Activities thereof, such as planning for reconstruction of meteorological stations, preparation of water legislation, etc., have been made in the past in each of the government units without horizontal coordination. But, here in WRMC, they will be made coherently for pursuit of a single target of the integrated water resources management. WRMC shall be manned with qualified specialists consisting of a hydrologist, a hydro-geologist, a water supply engineer, an irrigation engineer and a GIS specialist besides technicians and computer operators. These specialists should be those, who can fully technically communicate with their counterparts in the Meteorological Division, LRA, water authorities, and others. A director of WRMC, who shall lead these specialists, should be a water resources management specialist, who can help policy formulators by drafting a water resources management strategy with full perception of the Lebanon's water balance and practicable development scenarios.

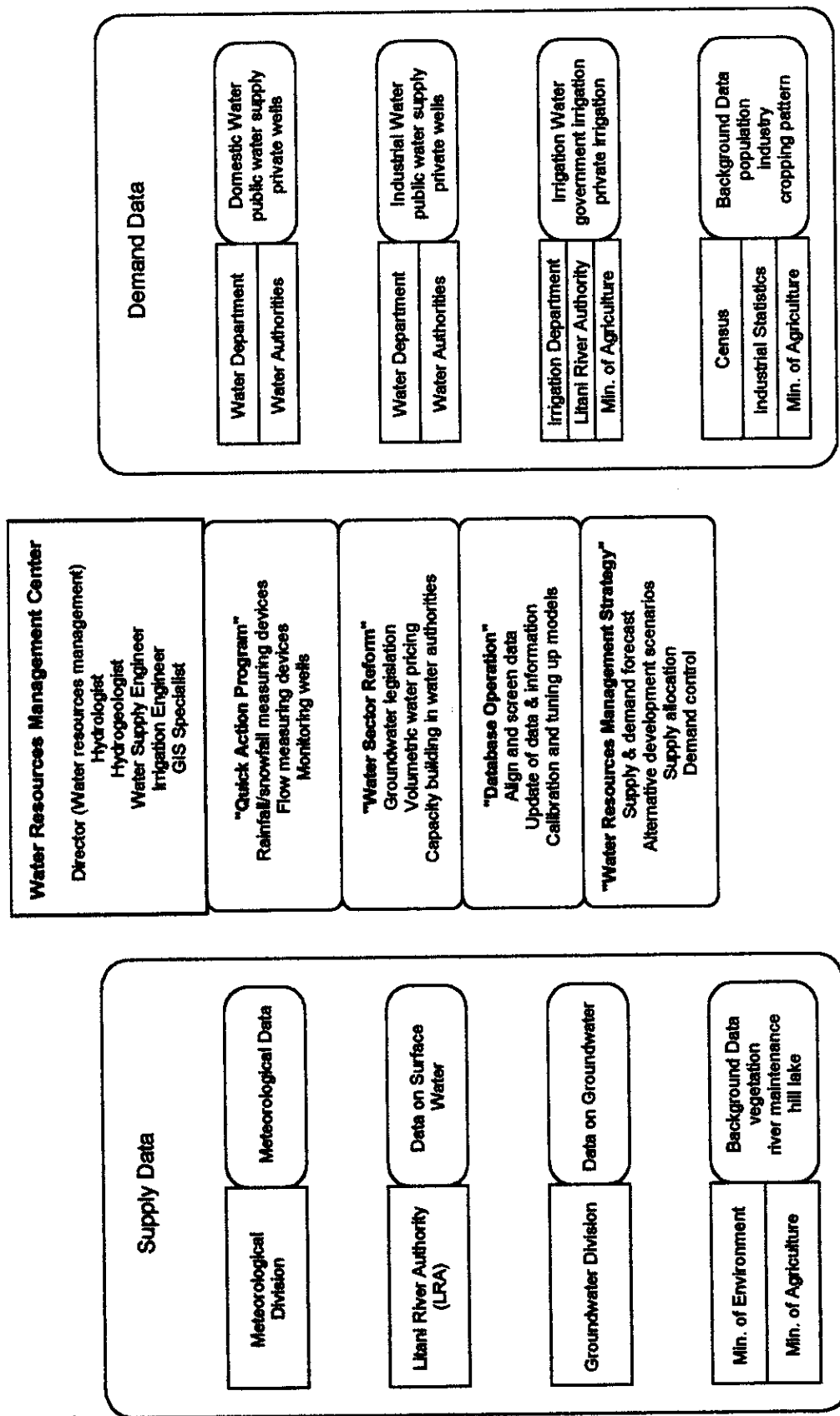


Figure 3.5.1 Organizations and Their Outputs

The first job of WRMC will be to formulate a quick action program for reconstruction of meteorological and hydrological stations and construction of monitoring wells. If financial resource is limited, inexpensive rainfall and snowfall measuring devices and flow measuring devices may be installed in a short period of time without a large investment. For monitoring purpose, wells of small diameter may be drilled, and device to measure water level, pH and electric conductivity shall be installed. If this action program is implemented with a suitable fund, collection of the entire supply data will become possible, and the fatal deficiency of the database may be remedied.

The second job, which should be pursued simultaneously with the first one, will be to interact with other divisions of MEW, LRA and water authorities to work out more accurate demand data or demand projections for the domestic and industrial water supply and the irrigation water supply. This job would include promotion of the water sector reform including the groundwater legislation, volumetric water pricing and the capacity building on the side of the water supply organizations. It is targeted to enhance and streamline water supply organizations and control over groundwater exploitation for the more accurate measurement and the possible demand control in the not too distant future.

The basic job of WRMC is continuous and ceaseless updating of supply and demand data and calibration of hydrological and hydro-geological models in the database. It is expected that the Meteorological Division and LRA (surface flow) have already aligned and screened the data by eliminating and correcting irregularities caused by misreading, mistranscription or malfunction of measuring devices. It will be still necessary to screen the data series before they are finally inputted, as have been learned by the master plan study team.

The final and central job of WRMC is forecasting of the water balance and formulation of strategy or master plan on the integrated water resources management based on the former. If the future imbalance or shortage of supply in a certain geographical area is foreseen, various development scenarios shall be worked out and applied in close coordination with the related organizations, and a concrete measures for development of supply or control of demand have to be proposed.

To create, align the personnel, give legal authority, and technical and financial resources to this WRMC, a decree or a resolution of the Council of Ministers may be necessary. Such a decree or a resolution shall establish the following effects:

- WRMC shall and is able to collect all the data and information required to measure and estimate supply of and demand for water in collaboration by all the related agencies and individuals.
- It shall be a technical institution. Its technical advice, recommendation or report shall be duly respected by the related agencies, which formulate policy, plan or project that may influence the supply of and the demand for water.
- Its advice to the agencies, which collect the data and submit them to it, to improve

quality of the data shall not be neglected.

- It is able to freely seek for technical and financial assistance from bilateral and multilateral sources.
- Its operational budget shall be allocated on the priority basis.

3.6 Watershed Management

It is reported that in old times a considerable part of the national land had been covered with the famous Lebanon Cedar bringing the prosperity to the area. It is easily imagined that rain water was retained on the ground surface, deposit of snow lasted for a longer time in the shade of a Cedar tree, and surface flows were kept in rivers throughout a year at those times. At present, colonies of the Cedar remain in a quite limited part of the land, ground surface is exposed directly to the sunshine without vegetation in most parts, and most of water created by rain and snow has been lost unused to the sea.

It is essential that the land surface is covered by forest for sustainable conservation of watershed. Fortunately, creation of the natural Cedar reserves has been practiced in some parts in Lebanon, and it is recommendable to accelerate this activity for future successful management of water resources.

Current activity performed in the Al-Shouf Cedar Reserve, Ain Zhalta-Bmohray Cedar Forest and the Barouk Cedar Forest are the example to be promoted more and more in future.

CHAPTER 4 TOOLS FOR DECISION MAKING IN WATER RESOURCES MANAGEMENT

4.1 GIS Database

4.1.1 Concept of GIS Database

Tremendous amount of information is needed to manage water resources. Since the information of different status is managed for various objectives, evaluating and analysing the information consume lots of time. In order to solve the problem, it is very important to collect and computerise required information, and to manage the information unitary at the same dimension. The database is needed to use the collected information from various viewpoints. Since the most of information has position information, it is effective to introduce GIS for managing water resources data. GIS can compare and analyse many information, and can express the result easily. GIS is a powerful tool for explaining synthetic evaluation. Therefore, in the JICA Study, the GIS database was prepared for the data management, parameter analyses for DBM (Digital Balancing Model) and map expression of data associated with water resources.

4.1.2 Structure of GIS Database

GIS database (map and attribute data) for water resources management in Lebanon was built in the JICA Study. Map data is expressed two-dimensionally on paper or a computer. However, as the earth is an ellipse, it is necessary to apply the projection which distortion is minimum for latitudes. Therefore, "Lambert Conformal Conic" is applied to projection of these map data. This projection is one of the best methods for middle latitudes. This GIS database consists of map data and attribute data, and is managed by ArcGIS (Software of GIS). The attribute data are divided in 3 database, such as map attribute database, DBM (digital balancing model) database and observational database.

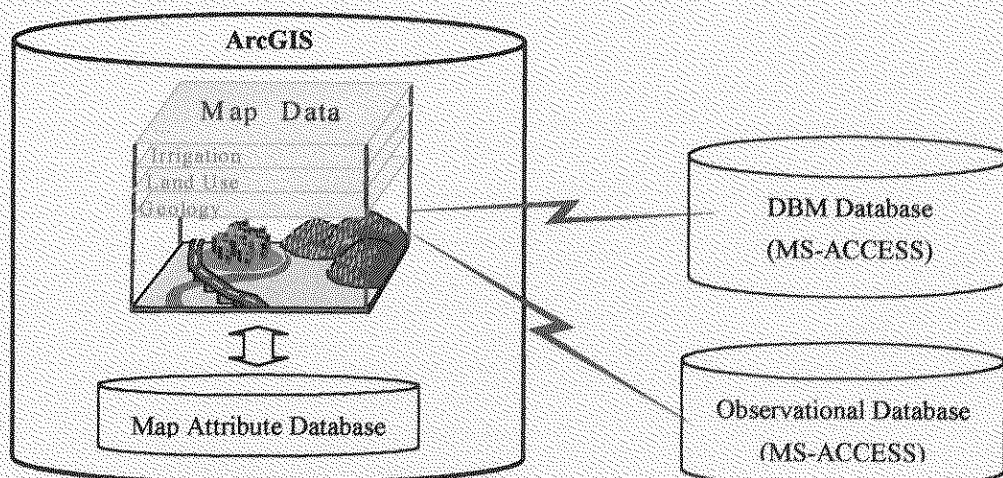


Figure 4.1-1 Image of Data Composition

Table 4.1-1 shows the list of map data.

Table 4.1-1 Map and Map Attribute Data List (1/2)

No.	Map Name	Type	Description	Main Attribute Data
1	Border	Polygon	National boundary of Lebanon	area, code number, name
2	Caza	Polygon	Boundary of Caza	area, code number, Caza name
3	Mohafaza	Polygon	Boundary of Mohafaza	area, code number, Mohafaza name
4	NewWaterAuthority	Polygon	Boundary of new water authority	area, code number, new water authority name
5	Town	Point	Position of town or village	town name, category
6	WaterAuthority	Polygon	Boundary of water authority	area, code number, water authority name
7	WaterSupplyZoning	Polygon	Boundary of water supply system	area, water supply system name, water authority name
8	Tiles	Polygon	Boundary of paper topographic map (1/50,000)	-
9	DemandArea	Polygon	Boundary of demand area. Demand area is Caza area, but Beirut, suburb of Beirut and Saida are water authority area.	area, code number, demand area name
10	SupplyArea	Polygon	Boundary of watershed	area, code number, supply area name
11	Barycenter	Point	Calculation point of SSM model	x, y coordinate value
12	Base	Polygon	Formwork of Lebanon	-
13	Contours	Line	Line of contour at intervals of 50 meters	elevation
14	Fault	Line	Line of fault	-
15	Geology	Polygon	Boundary of geology classified by category	geology name
16	Hydrogeology	Polygon	Boundary of hydrogeology classified by category	hydrogeology name
17	Lake	Polygon	Boundary of Lake	area
19	LandUse2000	Polygon	Boundary of land use in 2000 classified by category	land use code
21	River	Line	Centerline of river	category, river name
22	SubBasin	Polygon	Calculation unit area of SSM model	area
23	WatershedArea	Polygon	Boundary of watershed	area, watershed name, code number
24	Catchment	Polygon	Boundary of catchment area of dam	area, dam code number
25	Dam	Point	Position of existing and planning dam	dam code number, dam name, dam spec
26	Road	Line	Centerline of road	category
27	WasteWaterPlant	Point	Position of existing and planning water treatment plant	code number, plant spec
28	WaterSourceTransmission	Line	Line of water supply pipeline form sources to towns (not exact line)	-
29	WaterTreatmentPlant	Point	Position of existing and planning wastewater treatment plant	plant name, capacity

Table 4.1-1 Map Data List (2/2)

No.	Map Name	Type	Description	Main Attribute Data
30	Climate	Polygon	Boundary of climate zone	zone code number
31	Irrigation	Polygon	Boundary of existing and planning irrigation	code number, area, name, start year, climate code number
32	Hydro	Point	Position of hydrological station	station number, station name, river name
33	Meteoro	Point	Position of meteorological station	station number, station name
34	WQ_Groundwater	Point	Position of water quality survey site for groundwater	results of investigation
35	WQ_IndWasteWater	Point	Position of water quality survey site for industrial wastewater	results of investigation
36	WQ_Litani	Point	Position of water quality survey site in Litani river and Qaroun	results of investigation
37	WQ_MuniWasteWater	Point	Position of water quality survey site for municipal wastewater	results of investigation
38	WQ_Qaraaoun	Point	Position of water quality survey site in the Qaroun	results of investigation
39	WQ_SeaWater	Point	Position of water quality survey site for sea water	results of investigation
40	Spring	Point	Position of spring	spring name, x, y coordinate value
41	Borehole	Point	Position of borehole	-
42	Well	Point	Position of well inventory survey	results of investigation
43	FS_river	Point	Position of river of field survey	results of investigation
44	FS_sea	Point	Position of seawater of field survey	results of investigation
45	FS_spring	Point	Position of spring of field survey	results of investigation
46	GeoGrid250	Raster	Elevation raster data (cell size: 250 m)	-
47	TopographicMap (1-27)	Raster	Raster of topographic map	-
48	Satellite	Raster	Raster of satellite map	-

Table 4.1-2 shows the list of attribute data.

Table 4.1-2 Attribute Data List

Category	Attribute Data
DBM Database	Surface water development potential by each watershed
	Groundwater development potential by each watershed
	Dam development potential by each dam
	Sewer coverage ratio by each Caza from 2002 to 2030
	Wastewater reuse ratio by each Caza from 2002 to 2030
	Population by each Caza from 2002 to 2030
	Growth rate of population by each Caza from 2002 to 2030
	Per capita consumption for residential and tourism from 2002 to 2030
	Number of tourist in Lebanon from 2002 to 2030
	Growth rate of industry in Lebanon from 2002 to 2030
	Number of establishment by each Caza from 2002 to 2030
	Industrial class by each Caza
	Recycle class of industrial water by each Caza from 2002 to 2030
	Public water supply coverage ratio for domestic water by each Caza from 2002 to 2030
	Public water supply coverage ratio for industrial water by each Caza from 2002 to 2030
	Leakage ratio by each Caza from 2002 to 2030
	Crop area ratio by each irrigation perimeter and Caza
	Cropping pattern by each irrigation perimeter and Caza
	Area ratio of irrigation method by each irrigation perimeter and Caza from 2002 to 2030
	Crop water requirement
Observational Database	Daily discharge of each gauging station
	Daily rainfall of each station
	Fiver discharge in JICA Study
	Fiver water quality in JICA Study
	Sea water quality in JICA Study
	Spring discharge in JICA Study
	Spring water quality in JICA Study

4.2 Hydrogeological Circulation Model

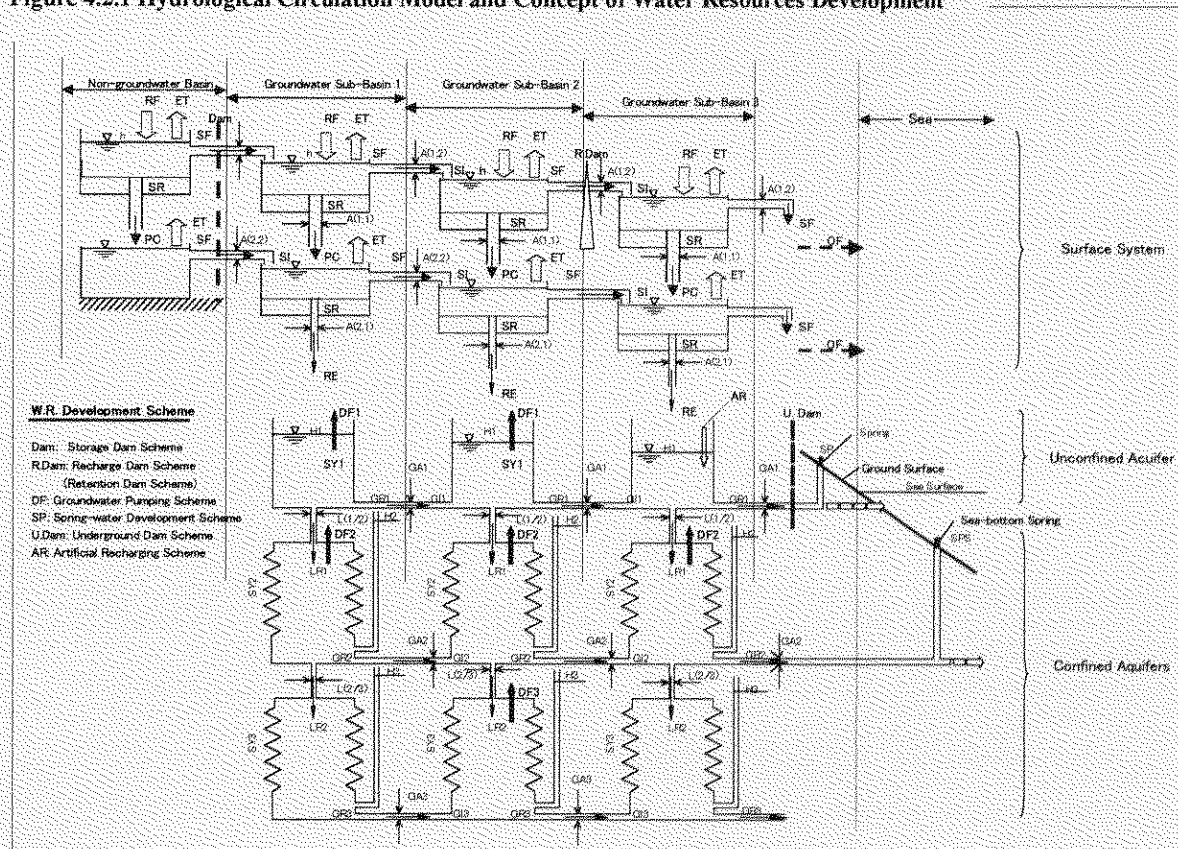
In the Study, a water balance simulation model named Synthetic Storage Model (SSM) developed in Japan was adopted for the model of water balance simulation study. It is a kind of “Hydrogeological Circulation Model” directly based on the natural hydro-geological circulation. In this chapter, only the concept of the model, model structure, calibration procedures, and the results are explained. Further details on the concept, structure, required and applied data, procedures of simulation, inputs and outputs, and etc. of the model are to be presented as a «Technical Note on SSM».

4.2.1 Concept of Hydrogeological Circulation Model

(1) Concept of the model

The concept of hydro-geological circulation is summarized as Figure 4.2.1.

Figure 4.2.1 Hydrological Circulation Model and Concept of Water Resources Development



As shown in the Figure, the natural water circulation is started from a precipitation (RF in the figure). Some part of the precipitation is evapo-transpired and return back to the air (ET), some portion is captured in the soil as a retention water (SR), some portion is percolated into the deeper unsaturated zone (PC), and the remain flows out to the downstream zone (SF). In the next

(Downstream) zones also, they have a precipitation, losses by ET, SR, PC, and a gain of inflow from upstream zone. Those upper tank series in the figure are called as “Surface System”. The second row of tanks within the surface system is called as “Delay System” but practically it means unsaturated zone. In Lebanon, the second tanks are usually lacking, because of the situation of foundation geology.

Normally through the second tanks, or directly from the uppermost tanks, some portion of the precipitation infiltrates into saturated zone, as a recharging of groundwater (RE). The groundwater system is divided into two categories: unconfined aquifer system of the uppermost row, and confined aquifer system of the lower rows. Groundwater table (H1) of the unconfined aquifer is simply decided by the gains of groundwater in a certain sub-basins such as groundwater inflow minus outflow (GR1), recharge amount (RE), and its storage coefficient (SY1). Further, some part of groundwater is leaking into confined aquifer system (LR). Confined aquifer has no groundwater table but has a piezometric head (H2) decided by the balances of inflow and outflow (GR2), and leakage (LR) under the condition of storage coefficient (SY2).

In both of surface and groundwater systems, the precipitation water pours into the sea finally. In the case of groundwater, when the water table intersects the ground surface, groundwater comes out to the ground as a spring (SP). Under the sea also, if the aquifer has enough high water head than the depth of the sea, it springs out to the bottom of the sea, forming a submarine spring (SPS).

(2) Flow of SSM simulation study

To carry out the SSM simulation, the procedures are divided into major four steps: 1) Preparation of the data sets, 2) Construction of the model, 3) Calibration of the model, and 4) Water balance simulation, as summarized in Figure 4.2.2.

Figure 4.2-2 Flow of SSM Simulation Study

