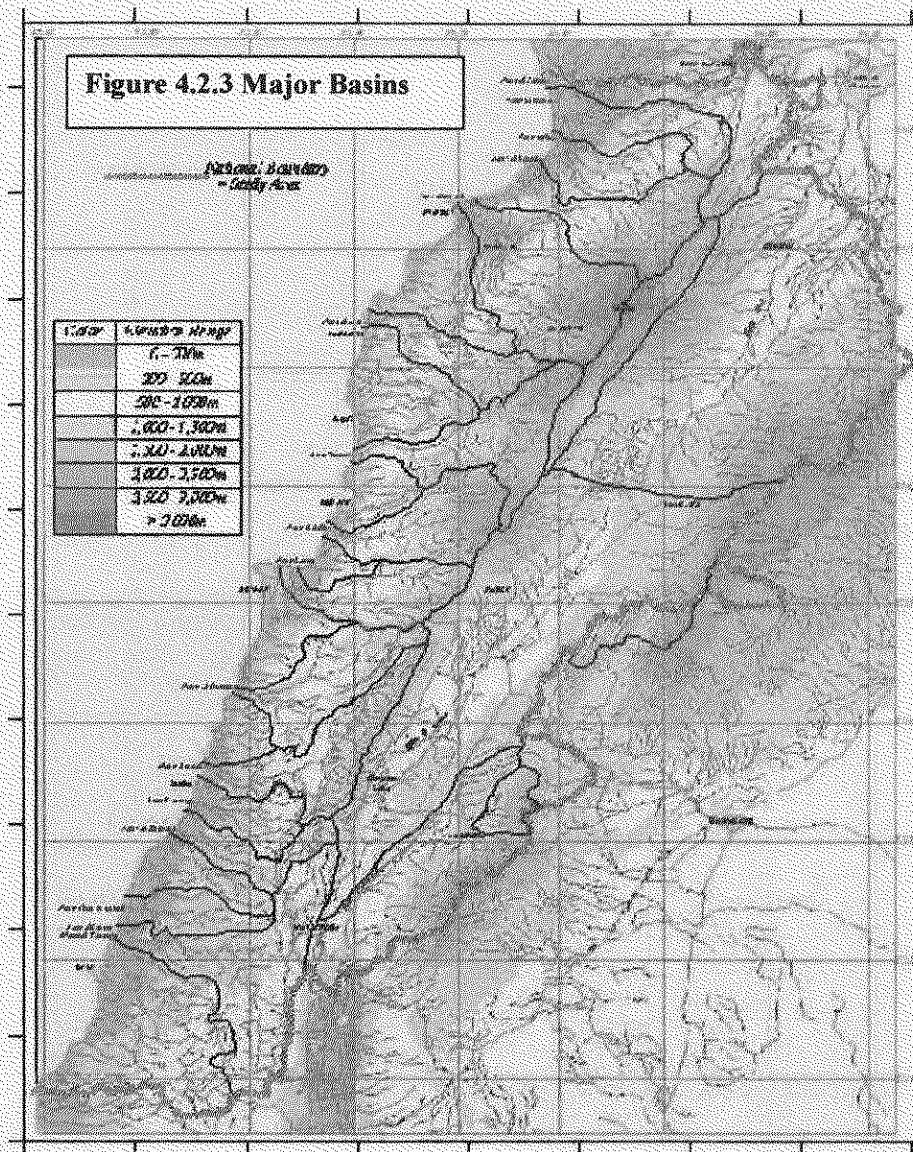


4.2.2 Model Structures

(1) Construction of Plane Model (Sub-basin Division)

To construct a plane model is to sub-divide the target area into proper number of sub-basins. This procedure is the most important process, which determines almost all of the quality of the model. In accordance with the purpose of study, the target area was, at first, divided into 17 major river basins, 10 remaining coastal basis, and 2 inland individual basins, as shown in Figure 4.2.3.

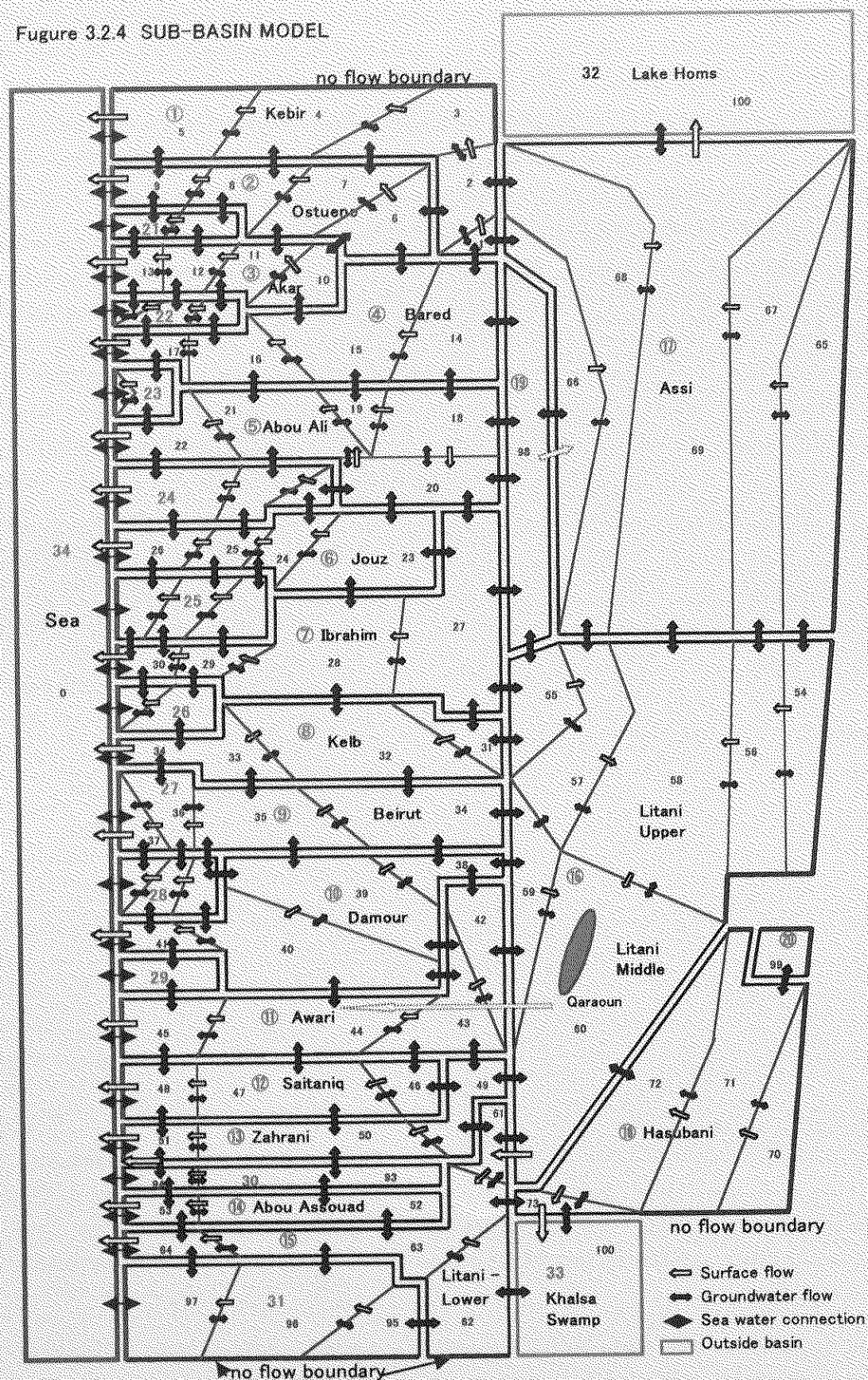


Then, most of the major basins are further sub-divided into some sub-basins, except the some special basins, taking the geomorphologic condition into consideration. Lebanon and Anti-Lebanon Mountain Ranges characterize topography of Lebanon. They are running in parallel in the direction from NNE to SSW. And, the slopes of these mountain ranges have some steps, being clearly distinguished at

500, 1100, 1600, and 2100m. These steps are also reflecting the basic geology, and therefore, most of the river basins are further sub-divided into four or five sub-basins by these steps. Thus, the target area is finally sub-divided into 99 sub-basins. The total sub-basin division is summarized as Figure 4.2.4.

In the figure, every river basin, remaining basins, and some individual basin are separated by double line boundary. A single blue line shows sub-basin boundaries within a certain basin, and

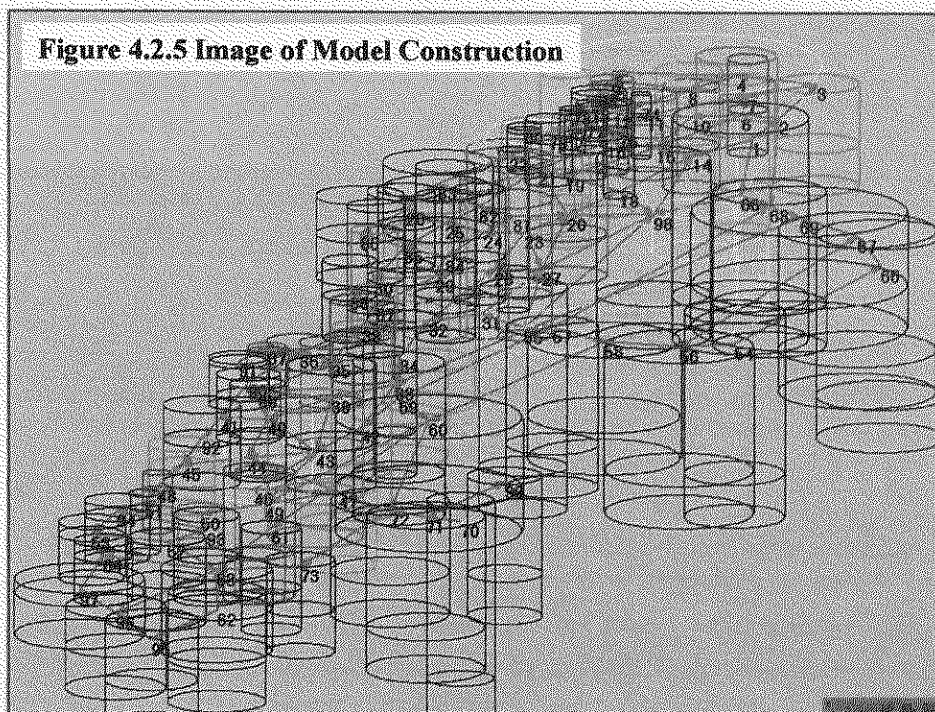
Figure 3.2.4 SUB-BASIN MODEL



each sub-basin is marked its sub-basin number. Surface flows marked by white arrow are started from the highest sub-basin and ended to pour into sea, completed within the river basin in one-way. While, groundwater flows (or links) are not one-way and beyond the river basin boundaries. Groundwater flow goes either side in accordance with the water table elevations of both sides, from the higher side to the lower side. The outer boundaries shown by thick black lines means “no-flow boundary”. The left side end of the figure means sea (marked 34), while, the right upper and the left lower small sub-basins enclosed by red line are outside basins of the country (marked 32 and 33 respectively). Boundaries between the target area and these special sub-basins are “fixed head boundary”

(2) Construction of Vertical Model

After the sub-basin division was completed, each sub-basin is given its vertical structure. At first, the topographic cross-sections of all of river basins are taken, then, the boundary elevations and the representative elevation are examined. The former are the elevations of the upper and the lower ends of each sub-basin, and the later is the elevation of central part of the sub-basin which can represent the elevation of whole sub-basin, and the groundwater level is measured from this elevation.



After setting the sub-basin boundaries into the cross-section, the aquifer structure is to be considered such as an impervious foundation boundary, positions and thickness of aquicludes (bottom of unconfined aquifer), and so forth. However,

in this case, there is no groundwater hydrograph on both unconfined and confined aquifers, therefore, it has no meaning to set the aquifer structure (separation of the unconfined and confined aquifer). Thus, in this time only the impervious foundation boundary was set as -500m above msl. Finally, the sub-basin model is constructed and hold in the software as the image shown in Figure 4.2.5.

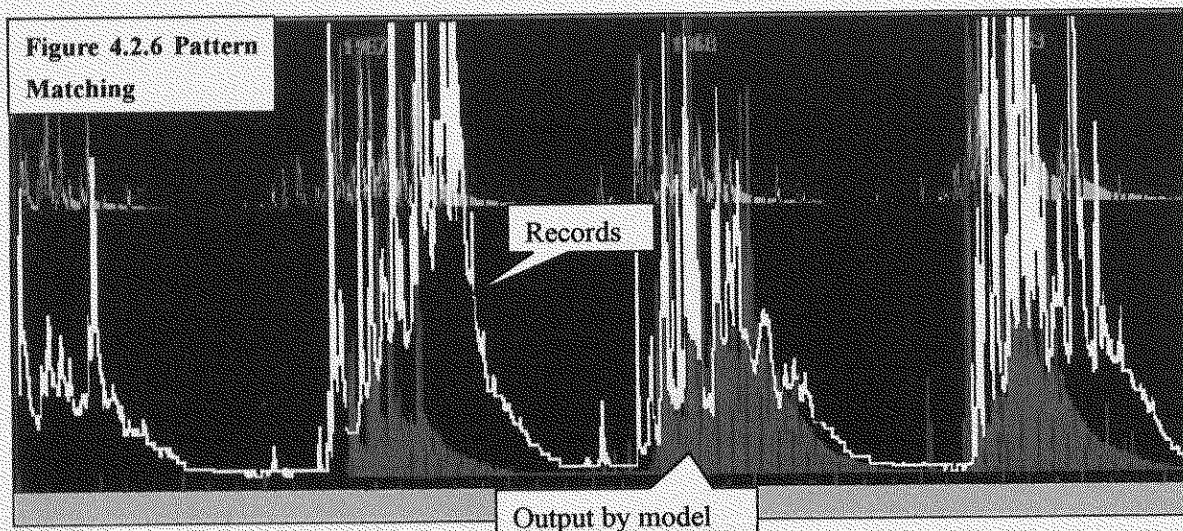
4.2.3 Calibration of the Model

After construction of the model, it must be verified by actual records, the surface structure by river runoff records and the groundwater structure by groundwater hydrograph. The both structures are calibrated modifying their parameters a little by little until the output of the model matches to the verification data.

(1) Calibration of surface water system

Surface water system is modelled by a series of tanks, simply called as “Tank Model”. In SSM (by the latest version), a new concept of “River System” is introduced. The tank model simulates the recharge and surface flow-out, then, the surface flow runs down through the river system. Because of introducing the river system, the spring system and river intakes were easily installed.

Calibration of the surface system is, usually, carried out by so-called “Pattern Matching” as shown in Figure 4.2.6. In this Study, however, because of no snowfall data it was impossible to make the



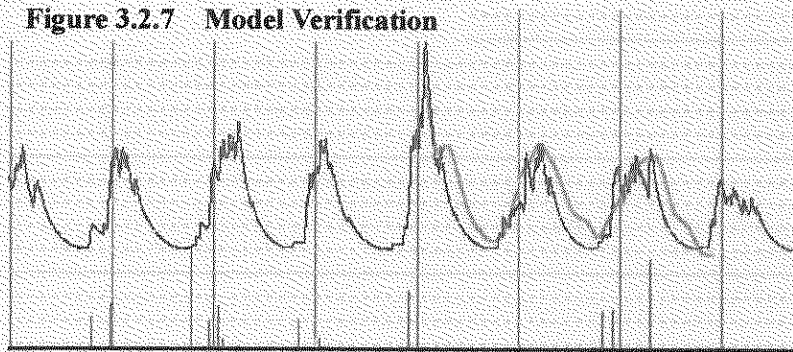
pattern matching, so that the model must be calibrated by the yearly runoff volume. In this case, the series of yearly runoff at 1996 was adopted, because the year 1996 had average yearly rainfall of recent ten (10) years. Calibration procedures are just “try and error approach”. A certain set of tank parameter such as number of orifices, runoff coefficient of each orifice, and infiltration coefficient, and run the program. Then, the output of the model and the actual record (verification data) are compared. If they are not matched, the parameters are modified and run the program. In case of the latest version of SSM (it has a spring out system), the modification of spring out elevation is also one of the quite important factors of calibration. Thus, the modification of parameters are continued until the model output becomes almost same with the verification data.

(2) Calibration of groundwater system

For the calibration of groundwater system, there is same problem: lacking of data. In Lebanon, there is no systematic groundwater monitoring system, and therefore, of long period, of each aquifer, and of enough accurate groundwater hydrograph were not available.

In this study, only three set of short period groundwater observation records, at Beirut, at South Lebanon, and at Central Bekaa, are obtained.

Figure 3.2.7 Model Verification



Three sub-basins which have groundwater data above mentioned can be calibrated directly by the verification data. Figure 4.2.7 shows the direct verification result at Beirut. In the figure, a thick line is actual observation and thin but sharp line shows the

groundwater level by the model output. Difference between the actual record and the model output was come from the lacking of snow data. The other sub-basins are, therefore, calibrated by so-called "Passive Verification". The passive verification is a kind of compromised verification method, that is, if the groundwater level of model output keeps a reasonable range of depth in a certain sub-basin for enough long period such as more than 30 years or 40 years, it is considered the groundwater model of the sub-basin was properly constructed.

In case of the groundwater system, the modification of permeability coefficient on every groundwater link is the main works. The groundwater level is going up when the permeability to the downstream is reduced, and going down when the permeability is increased. Thus, all of the permeability sets of all 99 sub-basins were calibrated, mostly by passive verification and some were by direct verification.

The results, it mean the final sets of every parameters, both surface and groundwater systems, are attached in Annex.

4.2.4 Water Balance Simulation

(1) Water balance simulation under current condition

When the model was calibrated under the current condition, the water balance simulation under the current condition is completed. SSM calculates the infiltration (recharge), evapotranspiration, surface runoff, river runoff, spring out, and current intakes under the daily rainfall for 40 years, to calculate the surface water balance. The model calculates the recharging volume, groundwater level of each sub-basin, spring out, groundwater inflow, groundwater outflow, volume of stored water, and current discharge volume by daily basis for 40 years, to calculate the groundwater balance.

Results of the water balance simulation under the current condition are simply summarized into the surface water balance sheet by yearly basis (but for recent 10 years) and for every river basin, and

attached in Annex. Further discussion on the water balance under the current condition shall be done in the following chapter.

(2) Water balance simulation under natural condition

SSM which was once verified under the current condition is to be modified to make a simulation under the natural condition, without pumping and without intake. The modification is quite simple, only the current discharge data and intake volume files are erased from the model. The model calculate again the surface water balance and also groundwater balance, in daily basis and for every sub-basin for 40 years.

Outputs of the model, under the natural condition, indicates the maximum volume of surface water and groundwater existing in the target area.

(3) Assessment of water resources potential

The water volumes exist in the area, both for surface and groundwater, are calculated through SSM simulation under the natural condition. They are just existing water volumes and they suggest the upper limit volume of the water resources but do not show the water resources development potential. In the case of surface water, the water resources potential can be calculated from the base flow of a certain river at the 10years return period of drought, and the development potential is the volume minus current utilized volume (which means already developed).

In the case of groundwater, the maximum resources volume is same with yearly recharging volume in a 10 years return period drought year, and it is huge volume in the case of Lebanon because of a plenty rainfall and a high infiltration rate of the foundation. However, a sustainable development potential, or a safety development potential, is not so much. In Lebanon, a considerable amount of recharged water is come back to the ground again as a spring, so that the concept of “net recharged water” must be introduced. Further, recharged groundwater at a certain sub-basin flow-out to the other basin to feed the neighbouring or far apart rivers from the original basin sometimes. Thus, the development potential of groundwater must carefully be assessed basin by basin but it must not beyond 1/3 of the net yearly recharge volume. In the case of coastal basins, the groundwater development potential must be less than the volume which causes the drawdown to elevation 0m to avoid the sea water intrusion. However, in the case of development of offshore submarine spring, the development potential can be the same volume with the groundwater outflow to the sea. Further details on the groundwater development potential shall be discussed in the following chapter.

(4) Water balance simulation under the development scenario

Once the SSM is constructed (and verified), it can be utilized as a decision making tools in combination with DBM. If any kind of water resources development plan was raise up, the water volume required for the plan, a kind of resources (surface water or groundwater), and the location of intake (target basin) are put into the model and run the program for another 40 years, using the existing rainfall set though. The model easily outputs the volume can be taken out actually and the effects of such intake in the case of surface water development. The model also outputs the water

volume can be pumped up and then the groundwater level if such volume of groundwater was withdrawn. Thus, the planner can know the available water volume and effects of the water resources development roughly, before conducting a Feasibility Study.

(5) Limitation of the current SSM simulation

As explained above, the SSM can simulate both surface and groundwater balances, can estimate groundwater level under current condition, natural condition, or future condition, and so forth. It is quite useful tools for decision making in water resources management. However, the current SSM constructed through the Study has serious limitation come from the lacking or shortage of several basic data and information.

At first, the lacking of snow data is almost fatal deficit for SSM simulation in Lebanon. The snow on the mountain can carry the precipitation in winter over into early summer, feeding continuously water to springs and rivers. Because of no snowfall data, the model cannot make a pattern matching for surface system, and therefore, it cannot simulate time series river runoff exactly. Then, lacking of rainfall data for enough long period in the mountainous area also severely influence to the accuracy of the simulation. Further, there was no actual observation data on some of important rivers runoff, such as the Assi, Hasbani, and upper Litani. Even though the pattern matching is impossible now, the volume matching is available so the runoff data on those rivers were desired. Lacking of systematic groundwater monitoring record was another serious deficit for the simulation. It made impossible to verify the groundwater system directory, and to separate confined aquifer from unconfined aquifer. Beside the verification data, some of important data sets were also not available: those are actual discharge volume at each sub-basin, actual intake volume at each sub-basin. These basic data sets are important to keep accuracy of the simulation.

SSM simulation in this Study must be carried out under such unfavorable condition, so that several compromising measures were taken such as volume matching and passive verification for the verification, and allocation of rainfall data from only three sets to all of other zones. Even though SSM has several limitation in this moment, it can offer many useful and significant data and information, and it is available as a tool to assist the decision making. In future, after completion to set systematic groundwater monitoring system for both unconfined and confined aquifers, and metrological observation system for both rainfall and snowfall at whole country, the SSM must be tuned up and all of simulation must be done again.

4.3 Digital Balancing Model

4.3.1 Concept of DBM

DBM, standing for Digital Balancing Model, was developed by the JICA Study Team and transferred to counterparts of MEW (Ministry of Energy and Water) with its usage technology. In order to formulate a master plan for water resources management in Lebanon, the Team conducted “the Study on Water Resources Management in the Republic of Lebanon” from 2002 to 2003. Through the course of the study, the Team collected a lot of data related to water resources management including water demand and water supply parameters. Successively, the Team entered the data into the GIS database, which is a database controlled by GIS software, in order to unify data management. At the same time, the Team developed DBM as a supplement of the GIS database system.

DBM is a part of GIS database system. Under the control of GIS software, GIS database can normally process and output the data. However, for the predictive calculation of water demand and possible water supply in the future, the standard functions are not sufficient except for the skilled user having much knowledge about GIS. For this reason, DBM is prepared to enable any ordinal user to do such processing easily by customizing necessary operations of GIS. Consequently, DBM with GIS database plays a significant role in water resources management.

DBM is defined as a tool that *“can make predictive calculations of water demand and possible water supply in the future based on GIS Database and can output them on a designated basis.”*

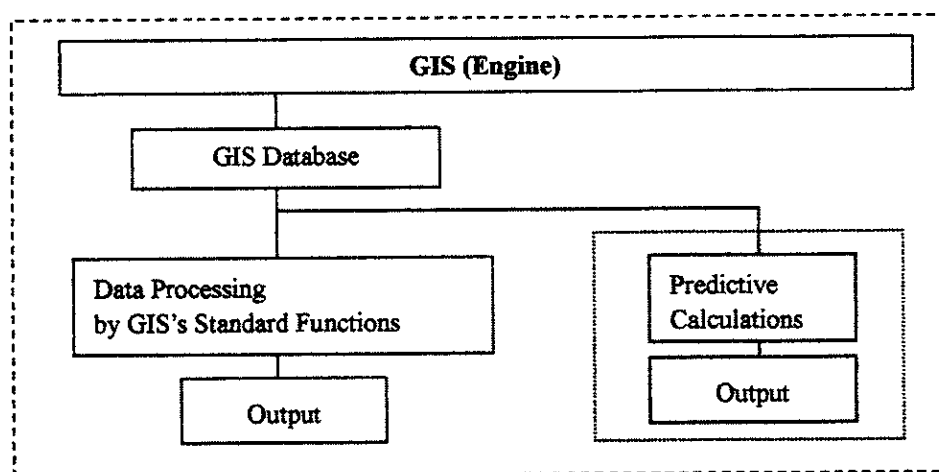


Figure 4.3-1 GIS Database System

4.3.2 Overview of DBM

As shown in Figure 4.3-2, DBM consists of four main components, (“window”) named after their functional characteristics. Full-scale structure is illustrated as DBM System Diagram in the attached Operation Manual.

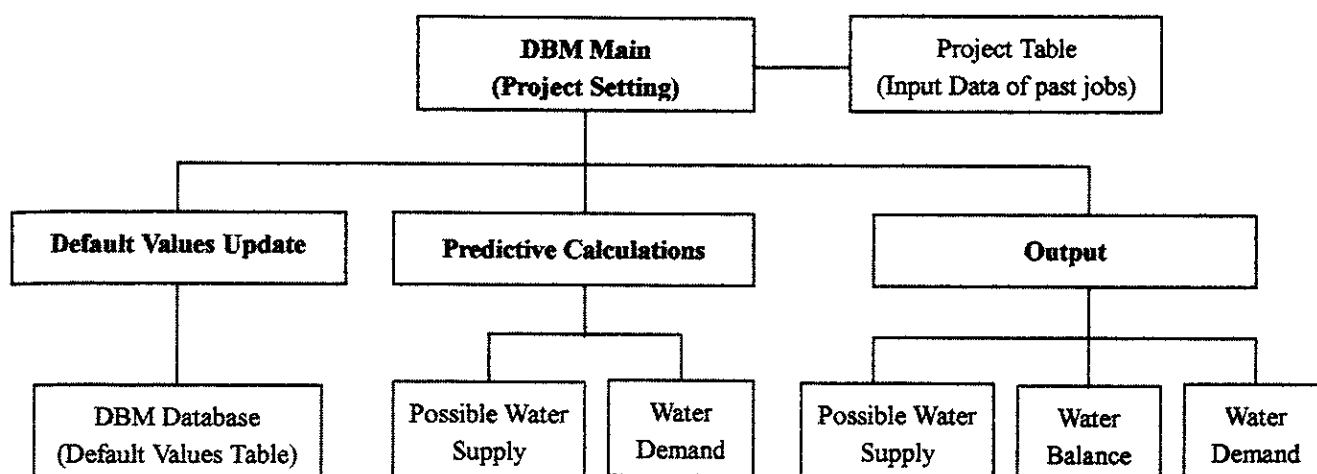


Figure 4.3-2 DBM Structure

Table 4.3-1 Main Function of DBM

Component	Description	Function
DBM Main	This component can manage project data such as input and output data.	- Control project data - Delete project data
Default Values Update	This component can update default values. But the usage is limited to an administrator.	- Change default values - Update default values
Predictive Calculations	This component can calculate water demand and supply from 2002 to 2030. The user does not need to input all parameters every operation, because DBM has default values of all parameters. If needed, the user can simply modify the default values.	- Change default values - Refer to previous input data - Calculate dam development potential - Calculate reuse of wastewater - Calculate residential water - Calculate non-residential water - Calculate tourism water - Calculate industrial water - Calculate irrigation water
Output	This component can create some excel files of input and output data, and link some tables with thematic maps. When the output on GIS maps is required, the user can draw the maps reflecting and/or overlapping the DBM results by an application of the standard functions.	- Create some excel files such as input data, possible water supply, water demand, water balance. - Link some tables with thematic maps.

Data retention forms for basic data, classified by spatial and time bases, are shown in Table 4.3-2.

Table 4.3-2 Data Retention Form

Data	Spatial Basis	Time Basis
Socio-Economic Frame - Population & Population growth rate - Establishment	Demand Area (Caza + Greater Beirut, Saida)	Annual data, varying for 2002-2030
Agricultural Frame (schemed and large scale) - Irrigate area - Cropping pattern and irrigation method	Irrigation schemes	Annual data, varying for 2002-2030
Agricultural Frame (existing small-scale) - Cropping pattern and irrigation method - Irrigate area	Demand Area (Caza + Greater Beirut, Saida)	Annual data, constant for 2002-2030
Water Resources Potential - Surface water - Groundwater	Supply Area (Watershed)	Monthly data, constant for 2002-2030

All the calculations can be output with this component. The user sets output parameters such as “Output Area”, “Output Time” and “Output Style”. DBM prepares three kinds of output styles, map, chart and table. Each style has the following characteristics.

Map: It has the most apparent effort in spatial perception, but does not present details. Mainly it is used for presentation.

Chart & Table: They present details, which map cannot express.

DBM prepares three kinds of “Output Time”, i.e. monthly, seasonal and annual. Seasonal means wet and dry seasons, defined as below.

Dry season: April to October (7 months)

Wet season: November to March (5 months)

“Output Area” includes six kinds of areas. Table 4.3-3 shows output matrix between calculations and output areas.

Table 4.3-3 Output Matrix

Output Area Predictive Calculation		Administrative area			Water Authority	Irrigation area	Watershed
		Demand area (Caza)	Mohafaza	Lebanon			
Demand	Domestic Water	○	○	○	○	-	○
	Industrial Water	○	○	○	○	-	○
	Leakage Water	○	○	○	○	-	○
	Irrigation Water	○	○	○	○	○	○
Supply	Surface water	-	-	○	○	-	○
	Groundwater	-	-	○	○	-	○
	Reuse of wastewater	-	-	○	○	-	○
Balance (between Demand & Supply)		-	-	○	○	-	○

○ : able to express

- : not able to express

4.3.3 Sample of Output

(1) Input Data Output Form

All the input data used in the predictive calculation can be output to the excel file and linked to the map's attribute data.

Table 4.3-4 List of Excel Sheet

Sheet Name	Descriptions
Project	Project information such as project name, establishing date
Supply Water	Surface water and groundwater development potential
Dam	Dam name, starting year and development potential
Wastewater Reuse	Wastewater reuse parameters
Growth Rate	Growth rate of population and industry
Residential	Population and per capita consumption
Non-Residential	Non-residential parameters
Tourism	Tourism water parameters
Industry	Industrial water parameters
Leakage	Leakage water parameters
Irrigation	Existing and proposed irrigation scheme parameters
Application	Application ratio of existing and proposed irrigation scheme
Irrigation (caza)	Caza irrigation (small scales) parameters
Application (caza)	Application ratio of Caza irrigation (small scales)

The screenshot shows a software window titled 'Input Data Output Form'. It contains a large table with columns for 'Category', 'Item', and various numerical data points. The data is organized into sections for 'Domestic', 'Industrial', and 'Leakage' classes, each with multiple sub-items and their respective values.

Figure 4.3-3 Sample of Input Data Output Form

Table 4.3-5 List of Map's Attribute Data

Item	Descriptions
Domestic	Population, non-residential class by Caza from base year to 2030.
Industrial	Industrial class, establishment by Caza from base year to 2030
Leakage	Coverage ratio of domestic water network, coverage ratio of industrial water network and leakage ratio by Caza in base year to 2030.

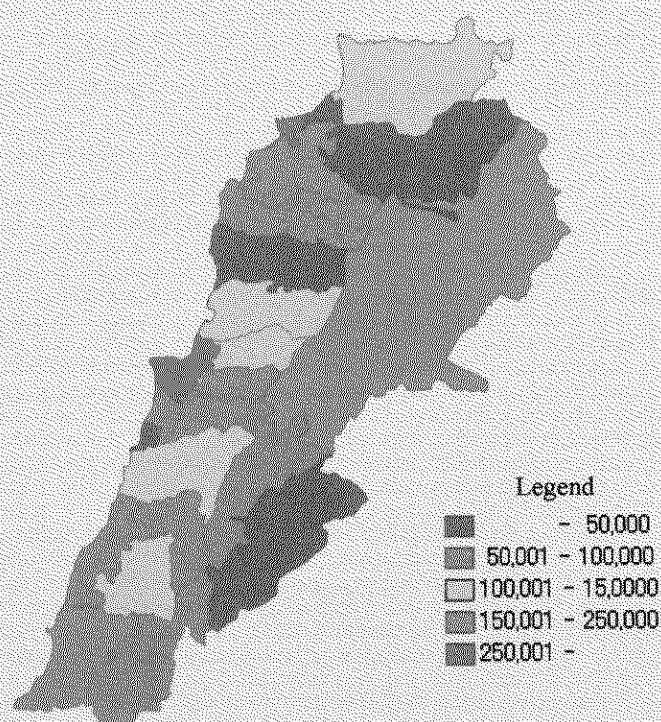


Figure 4.3-4 Population Map

(2) Possible Water Supply (Water Resources Potential and Reuse of Wastewater) Output Form

Calculation results can be output into the table & chart of the respective excel sheets in monthly/yearly basis. Besides, the results can be summarized for the whole Lebanon, supply areas and water authority areas. Stacked type bar chart is provided to show surface water development potential, groundwater development potential and reuse of wastewater. The data are linked to the map's attributed data.

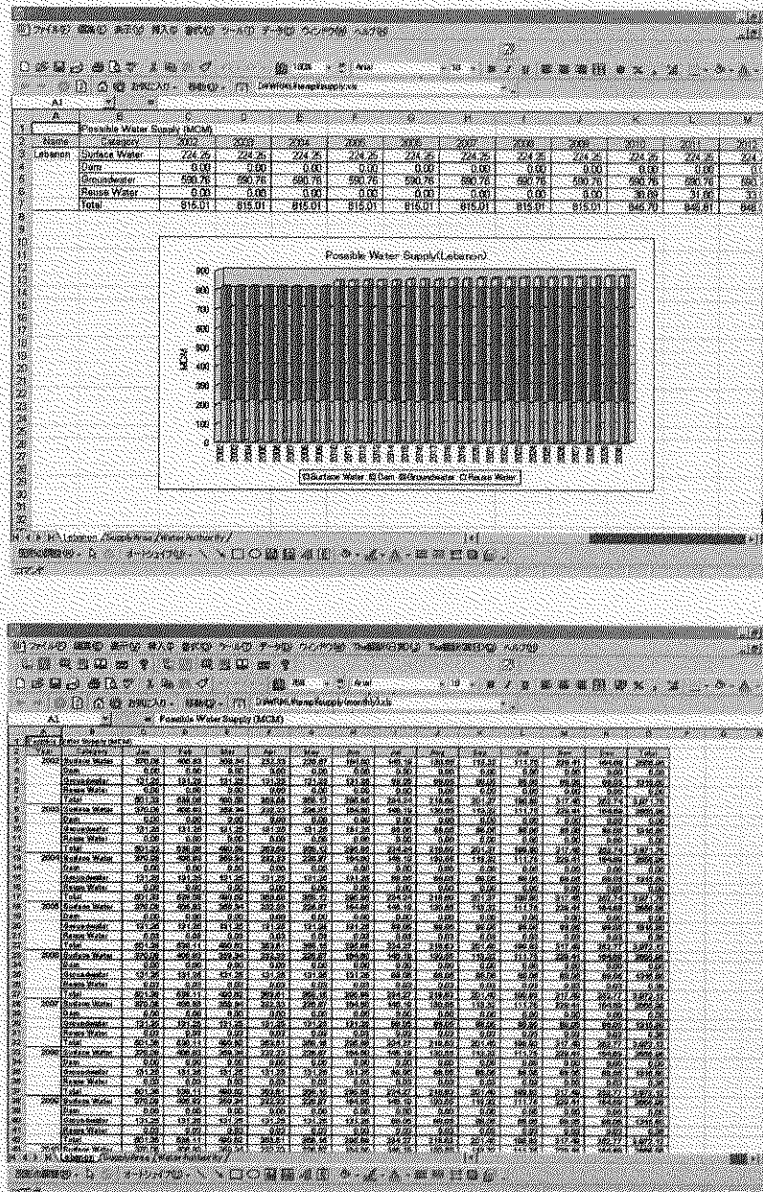


Figure 4.3-5 Sample of Possible Water Supply Water Output Form (yearly & monthly)

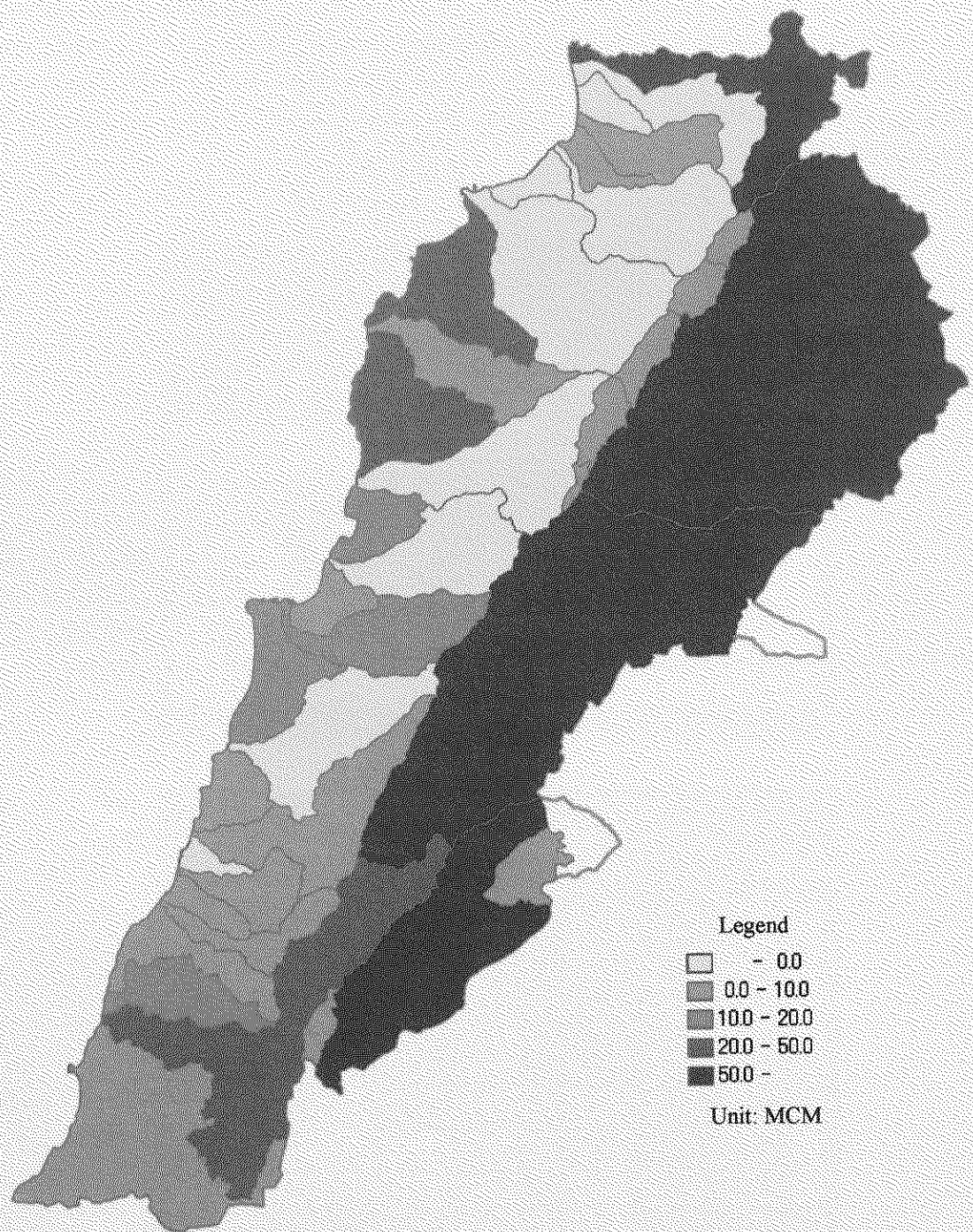


Figure 4.3-6 Sample of Supply Water Map

(3) Water Demand Output Form

Calculation results can be output into the table & charts of the respective excel sheets in the monthly/yearly basis. Beside, results can be expressed for the whole Lebanon, Mohafaza, Caza, Water Authority areas. Clustered type bar chart is provided to show the results from the different aspects. The data is linked to map's attribute data.

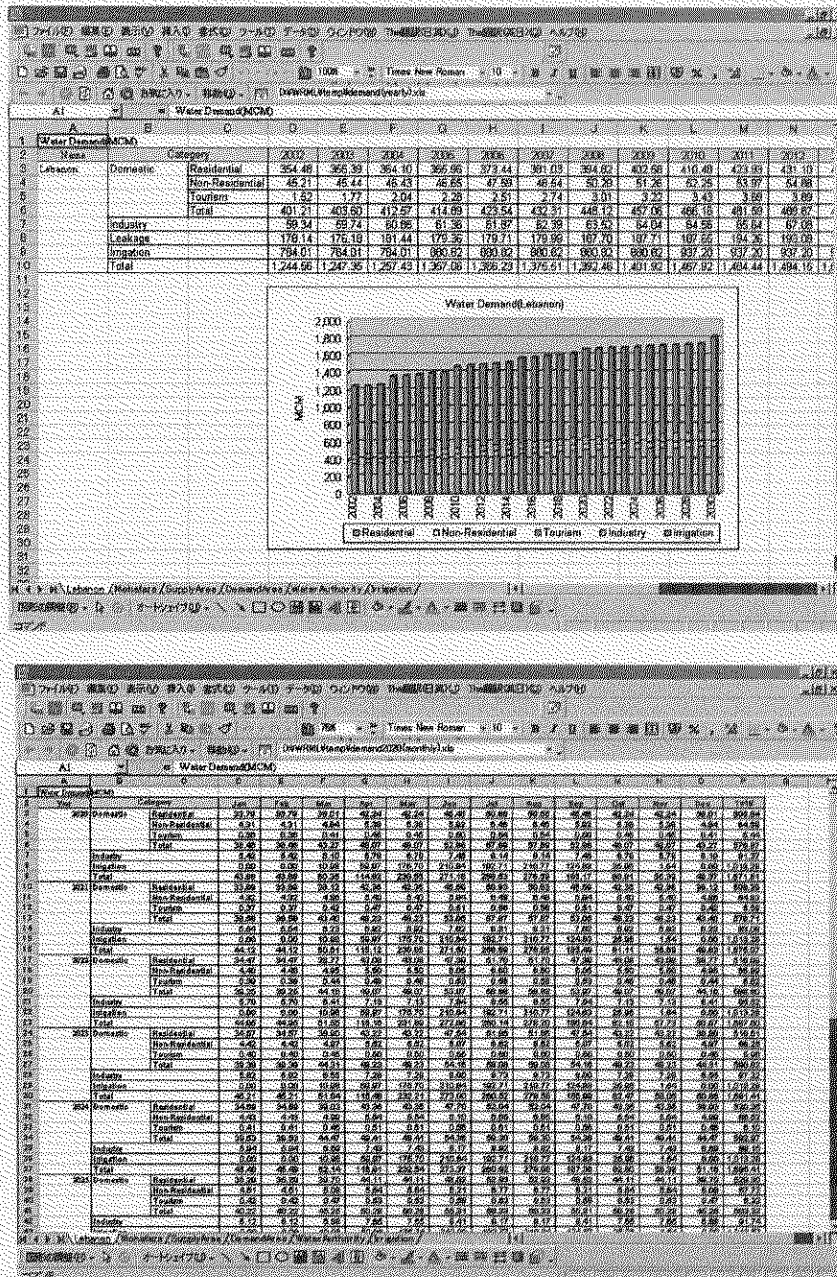


Figure 4.3-7 Sample of Water Demand Output Form (yearly & monthly)

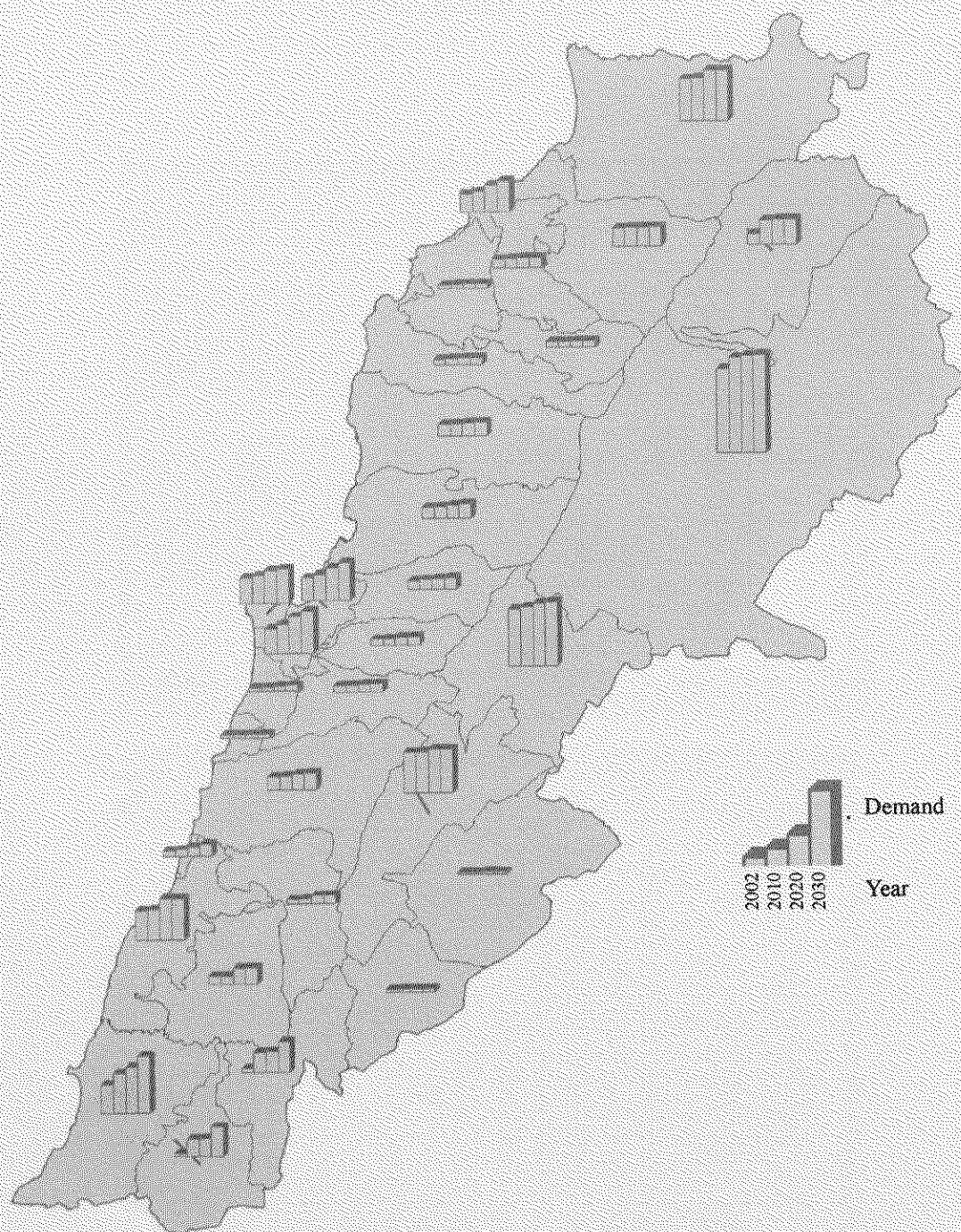


Figure 4.3-8 Sample of Total Water Demand Map

(4) Water Balance Output Form

Both calculation results of water demand and water supply can be output into an excel file. Water balance is displayed on the table and chart by showing demand and supply together. Water balance can be indicated for the whole Lebanon, water authority areas and watersheds supply area. Cluster type bar chart is applied to the graphical presentation. The data is linked to map's attribute data.

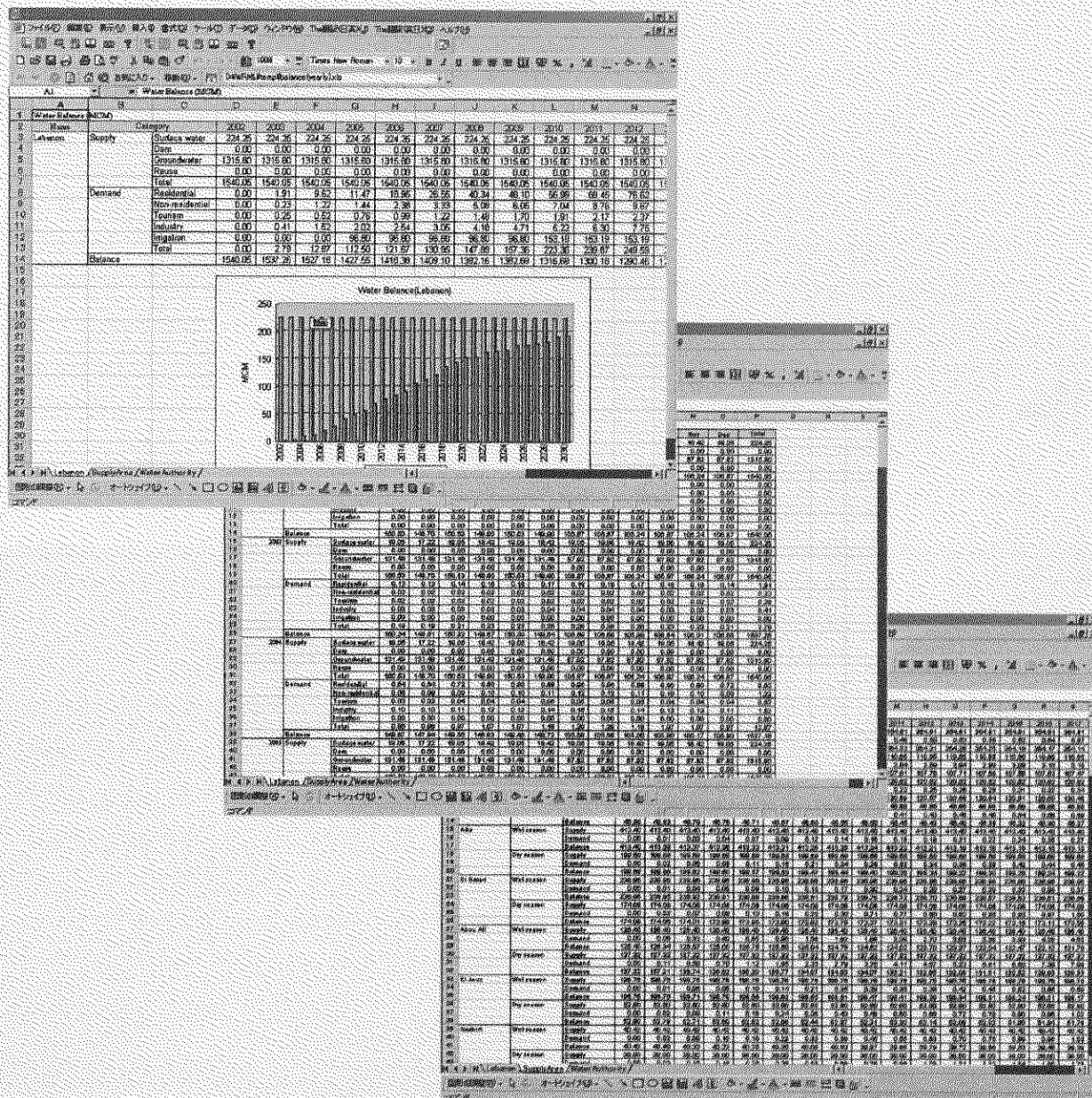


Figure 4.3-9 Sample of Water Balance Output Form (yearly, monthly & seasonal)

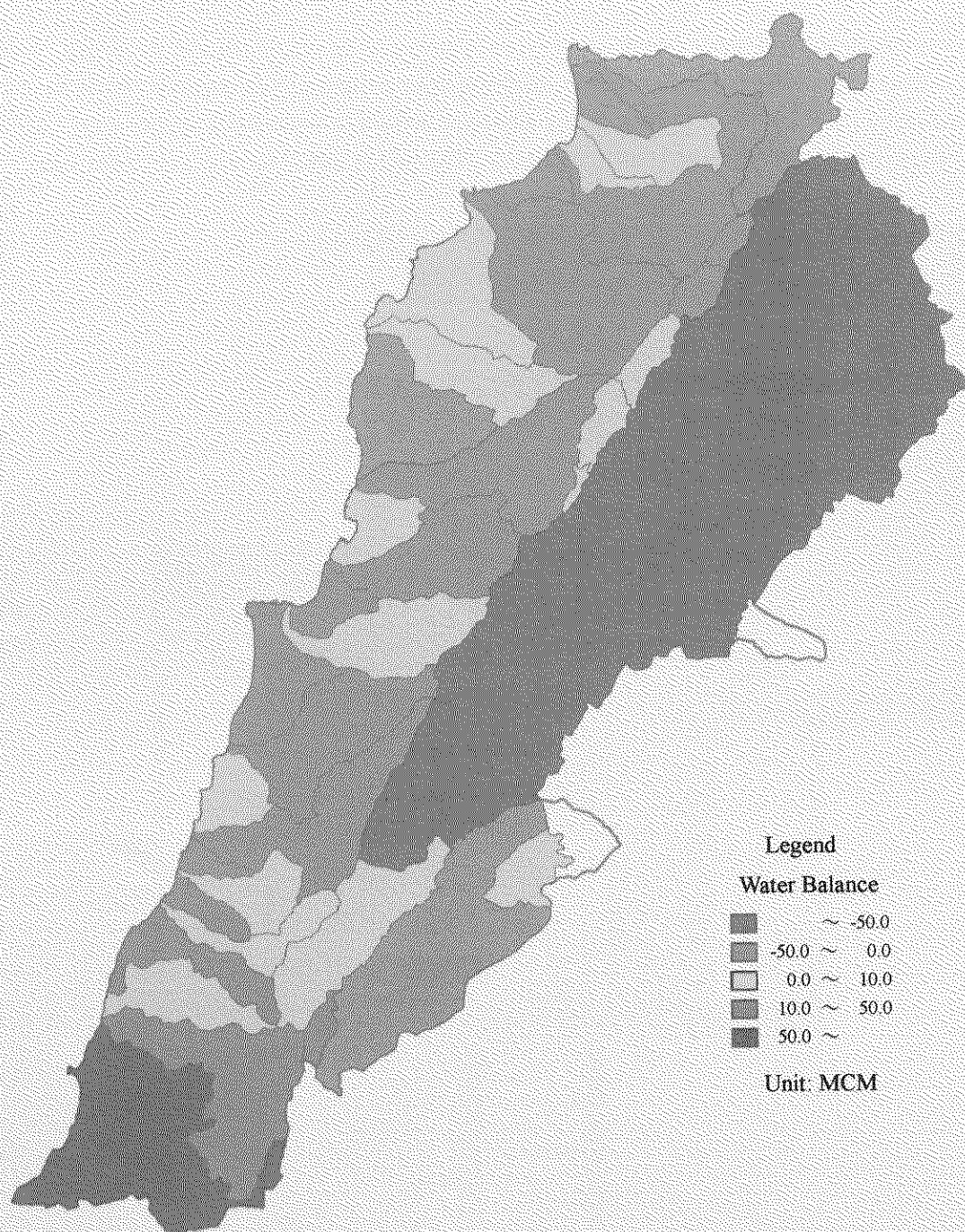


Figure 4.3-10 Sample of Water Balance Map

CHAPTER 5 WATER RESOURCES OBSERVATION AND MONITORING PLAN

The civil war, which lasted almost 17 years since 1974, has thoroughly exhausted domestic social and economic infrastructure throughout the country. Most of water-related structures and equipments had also suffered misery from the war, and meteorological and/or hydrological observation and monitoring stations were destroyed, and records were forced to come to a halt due to suspension of observation works. In addition to the fact that facilities for groundwater observation and monitoring had not been equipped all along, imperfection of such devices and records has been a great difficulty in formulating a national and regional water resources management master plan. Currently as for meteorological observation, a plan of “Meteorology Network System in Whole Lebanon” has been progressed since 1998 by the Meteorology Department located in the Beirut International Airport. However, even so, measures for lacking snowfall data is still in short. Rehabilitation and even new installation of hydrological stations have been urged by the Litani River Authority (LRA), however, accuracy of data required for formulation of water resources management master plan is not always secured due mainly to old-fashioned devices, observation method and function of data analysis. In the field of groundwater and water quality, necessity for observation and monitoring has been roused but actual enforcement has not been employed yet. Because that the consolidation of such meteorological, hydrological, hydro-geological and water quality data requires a considerably long period, hence it is urgent to take measures to cope with this situation.

5.1 Surface Water Observation and Monitoring Plan

In the past before civil war, LRA was managing 81 gauging stations in total. These stations already rehabilitated or to be restored are used as they are, however, in order to expect common accuracy of observation, all equipments will be replaced. Water level meter equipped with a water pressure sensor and data log of IC-card type will be recommendable. Appropriate devices for flood observation will be installed at appropriate locations. In addition to the plan of LRA, seven (7) stations are recommended to be newly constructed to cover the all of necessary points for hydrological observation and monitoring. The location and name of such stations are shown in Figure 5.1-1 and Table 5.1-1.

For the time being, observations of snowfall are not done in Lebanon due mainly to budgetary limitation. However, snow is one of the most important parameter to define volume and pattern of seasonal runoff yield, since during winter season considerable part of highly-elevated river basins are covered with snow and deposit of snow on the mountainous slope has a close correlation with the seasonal pattern of river runoff. In 2002, Saint Josef University has installed snowfall measurement facilities in the high mountainous areas. In Lebanon, And in addition to

these, it is recommended to install fifteen (15) snow observation stations as the first priority to cover major river basins, and sixteen (16) stations as the second priority as given in Figure 5.1-2 as well as in Table 5.1-2.

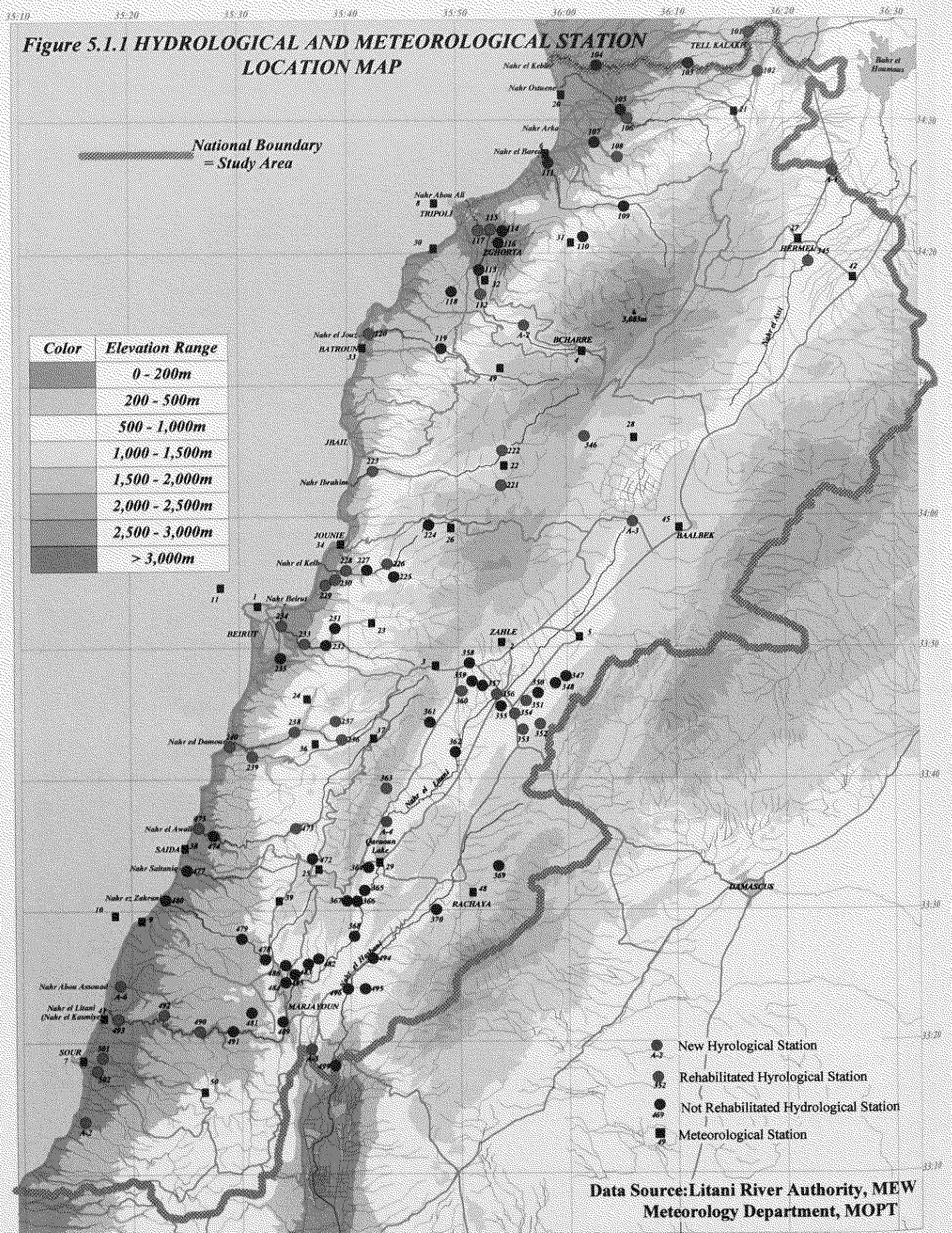
Table 5.1-2 Proposed Location of Snowfall Station

River	Sub-basin	X	Y	Z	Priority	nos
Kebir	1	200,653	278,067	1,700	1	15
Bared	14	192,362	273,217	1,700	1	
	15	187,346	275,538	1,200	1	
Abou Ali	18	182,174	262,687	2,600	1	
	19	174,578	267,206	1,500	1	
Jouz	23	168,982	250,500	1,530	1	
Ibrahim	27	171,314	239,569	1,950	1	
Kelb	31	162,959	226,786	2,200	1	
Beirut	34	151,448	214,151	1,200	1	
Damour	38	150,804	205,836	1,250	1	
Awali	42	146,076	193,069	1,700	1	
Litani Upper	55	168,758	222,508	2,100	1	
Litani Middle	59	151,400	201,815	1,300	1	
Assi	66	199,023	261,827	2,100	1	
Indiv	98	186,910	2,567,173	1,600	1	
Kebir	2	204,425	284,368	1,250	2	16
Ostueue	6	199,161	285,239	1,250	2	
Abou Ali	20	174,827	255,599	1,300	2	
Jouz	24	163,261	250,624	1,350	2	
Ibrahim	28	164,718	239,664	1,600	2	
	29	156,426	237,465	1,000	2	
Kelb	32	155,578	224,650	1,500	2	
Damour	39	141,821	201,815	900	2	
Awali	43	139,653	185,775	1,100	2	
Zahrani	49	132,593	170,364	950	2	
Litani Upper	54	198,304	217,991	1,900	2	
Assi	65	218,724	240,918	1,900	2	
Hasbani	70	160,065	165,506	2,100	2	
Chekka	81	167,324	255,474	1,400	2	
Batrouan	84	157,830	243,369	1,500	2	
Jounie	87	148,040	229,141	1,200	2	
Total			Ave.=	1,543		31

Snow gauging stations are recommendable to consist automatic depth recording system and rainfall recorder with heater and also wind velocity and direction meter.

Table 5.1-1 List of Hydrological Station to be Newly Established

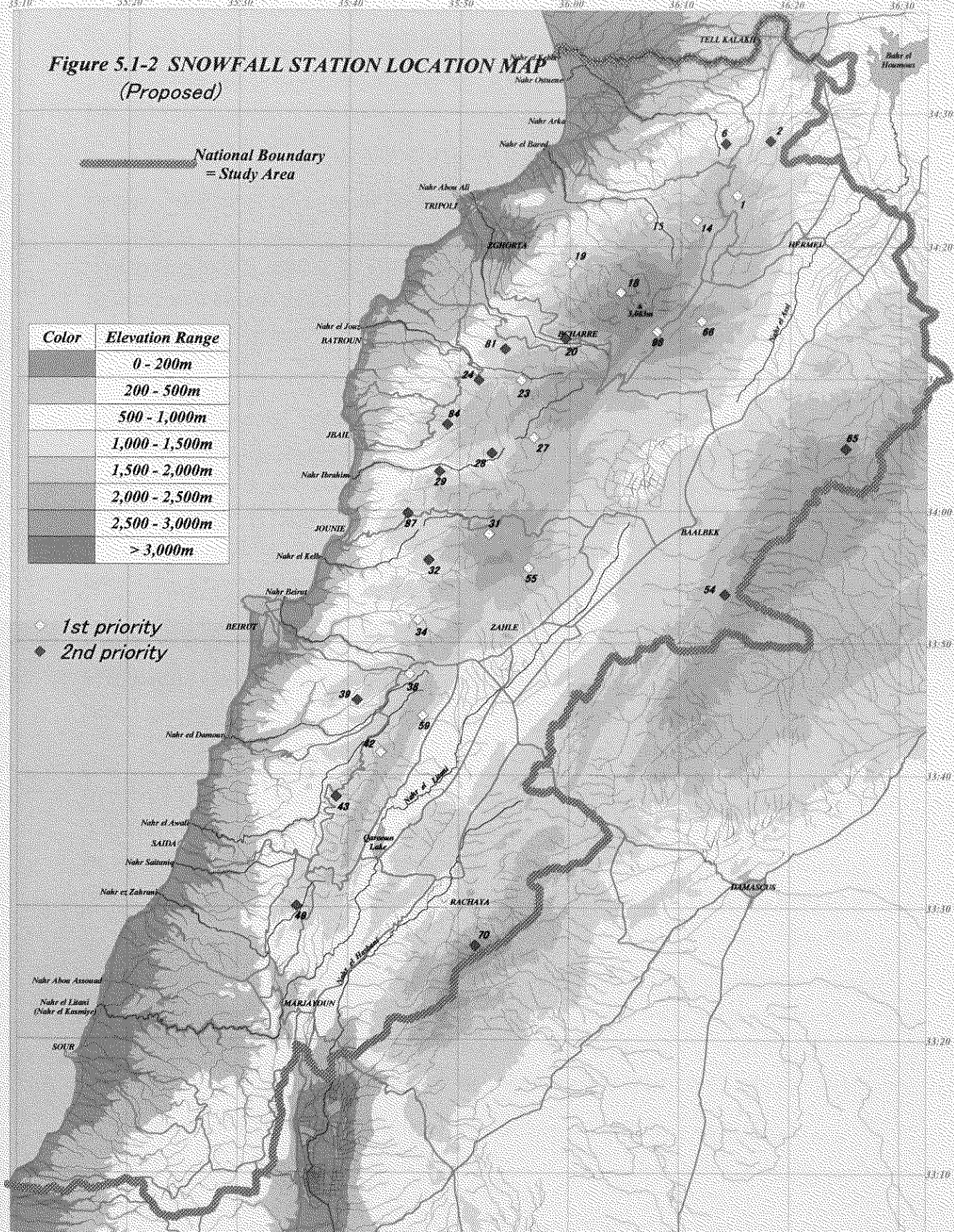
Station No.	Basin	River	Station	CA(km2)	EL(m)	Latitude	Longitude
A-1	Assi	Oronte	Border of Syria				
A-2	Abou Ali	Abou Ali	Cedar				
A-3	Litani	Litani	Near Baal Bek				
A-4	Litani	Litani	Qaraoun Dam				
A-5	Hasbani	Hasbani	Border of Israel				
A-6	Abou El A	Abou El A	Sea Mouth				
A-7	Wadi Ain e	Wadi Ain e	Sea Mouth				



National Boundary
= **Study Area**

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

- 1st priority
- 2nd priority



5.2 Groundwater Observation and Monitoring Plan

An integrated observation and monitoring plan of groundwater should include 1) time series observation of groundwater level, 2) observation of water quality, 3) monitoring of pumped volume of groundwater and 4) observation of quality of spring water..

A proposed plan of groundwater monitoring comprises the above 1) and 2). In order to expect accurate observation of groundwater level in a time series, it is necessary to drill new observation wells and to install automatic water level gauges. In addition, it is recommendable to equip small-scale pumps or potable pumps for periodical monitoring of groundwater quality. Simple shelters will also be needed to prevent equipments from destruction or robbery or to prepare a proper environment for observation and monitoring.

To achieve accurate analysis/simulation of groundwater phenomenon, observation wells are to be located at proper points. Precisely, they are recommendable to be excavated as a first step in 46 sub-basins out of 99 sub-basins divided in the SSM analysis. It is desirable certainly to install observation wells in all 99 sub-basins as a long-term plan. One well (Type-A) or two wells (Type-B) are required at one location according to hydro-geological conditions. Location of well, type, estimated geology and required depth of excavation are as shown in Table 5.2-1 and as visualized in Figure 5.2-1. Water level and quality gauge of automatic type with a micro-sensor of pressure type is recommendable to be installed, and observation is to be made at a fixed time, everyday (desirable in the morning when influence of water extraction is minimum). As for water quality, water sample is to be delivered to a laboratory for chemical and other testing once in a week or two weeks.

Observation of pumped extraction of groundwater is recommendable to be made at production wells operated under Water Authorities wherever more than 100 m³/day of groundwater is produced. Automatic discharge gauges are to be installed at those wells, and water samples are to be taken and delivered to laboratories for chemical and other analysis of water quality at least once or twice a month.

Observation of spring discharge is proposed at 160 springs, where discharge measurements were conducted under this study, and water samples are also to be delivered to laboratories for quality testing at least once a month. Notches or channels are desirable to be constructed at those springs for easy implementation of discharge measurement.

Visual concept of the groundwater observation and monitoring station is as given below;

Figure.5.2-2 Concept of Groundwater Monitoring Station

