2.10 Field Survey by Sub-contract

2.10.1 Field Survey General

(1) Survey items

In accordance with the TOR of the Study, the following five (5) items of Field Works were conducted (in August 2002 and January 2003), under the sub-contract between the Study Team and a local Consultant:

- River flow measurement,
- Spring flow measurement,
- Well inventory survey,
- Water quality analysis (1), and
- Water quality analysis (2).

In the beginning of Phase-II Study (in June 2003), the additional field works including the uppermost two items of the above list were performed, also by the sub-contract base.

(2) Procedure on sub-contract

As mentioned above, the survey items were prescribed in the Contract of the Study between JICA and the JV of Sanyu Consultants Inc. and Yachiyo Engineering Co. At first, the Study Team formulated the sub-contract form and technical specifications on the field works and sent them to JICA HQ for his approval. After obtaining the approval, the Team invited three local consultants and asked for the cost quotation on the works, according to the technical specification and contract form. After received the cost quotation from all of the consultants, the Team selected one of the consultant, who showed the lowest cost quotation. In this case, even the lowest cost quoted was higher than the scheduled cost which was the JICA's budget. Immediately after that, the Team negotiated with the consultant on discount the cost, and finally the local consultant: "Jouzy and Partners", agreed to conduct the works by the cost shown by the Team. The draft of the Contract between the Team and the local consultant was sent to JICA HQ again for his approval. JICA approved the contract (draft) on July 25, and the Contract between the Team and "Jouzy and Partners" was concluded on July 30.

At the beginning of Phase-II Study (late May 2003), the Study Team showed BQ and specifications on the additional field works to the same Contractor above mentioned and made negotiations on the cost. The Contractor did not agree the proposes cost (JICA's cost) on the field works because of quite high river discharges and spring flows caused by 50 years abnormal rainfall of the last rainy season. Finally the Study Team made the contract on the field works with the Contractor by somewhat higher contract cost than the scheduled one, and the excess cost was bone by the JV.

2.10.2 B/Q and Technical Specification

(1) B/Q of the works

Measurement of river flow shall be carried out in selected 15 rivers shown bellow:

El Kebir, Ostouene, El Bared, Abou Ali, El Jouz, Ibrahim, El Kelb, Beirut, Damoure, Awali, Sainiq, Zahrani, Lower Litani, Upper Litani and El Assi.

The measurement shall be done three times during August 2002, January and June 2003, so the work volumes is 45 times.

Measurement of spring flow shall be conducted targeting 160 springs, three times during August 2002, January and June 2003. Works volume shall be 480 times.

Well inventory survey is scheduled to prepare well inventory listing 2000 wells at selected groundwater basins.

Water quality analysis (1) is to study water quality from a view point of environment. Water samples are to be taken at 17 rivers, 17 springs, and 5 sea sites. Sampling and analysis shall be done two times during August 2002 and January 2003.

Water quality analysis (2) is conducted for hydrogeological study. Sampling number is as follows:

Samplings:	for spring (high elevation)	20 points x 1 time = 20 samples,
	for spring (middle elev.)	20 points x 2 times = 40 samples,
	for spring (low elev.)	20 points x 2 times = 40 samples.
	for spring (coastal)	10 points x 2 times = 20 samples
	for river (middle stream)	20 points x 2 times = 40 samples

All of the B/Q and the target rivers or springs on the field survey, excepting "Well Inventory Survey," are summarized as Table H-1, attached as Annex 2.10.1.

(2) Location of the works

Locations of the field works, decided through the discussion between the Engineers of the Team and the Contractor, are shown roughly in Figure 2.10-1, and the details of the survey points of every survey items are shown in appendix (as Annex 2.10.3).

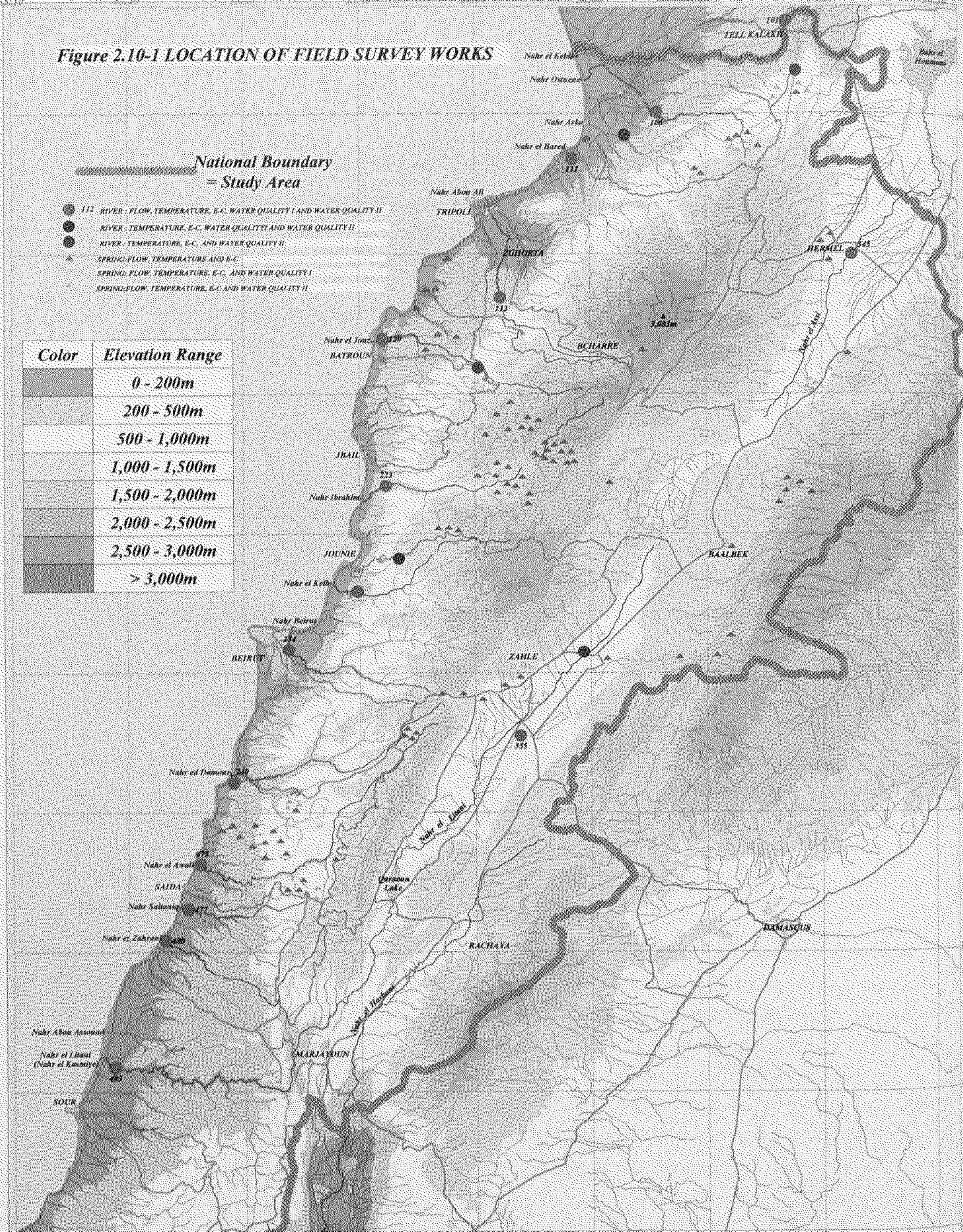
Figure 2.10-1 LOCATION OF FIELD SURVEY WORKS
National Boundary = Study Area
112 RIVER : FLOW, TEMPERATURE, E-C, WATER QUALITY I AND WATER QUALITY II
RIVER : TEMPERATURE, E-C, WATER QUALITYI AND WATER QUALITY II
RIVER : TEMPERATURE, E-C, AND WATER QUALITY II
SPRING:FLOW, TEMPERATURE AND E-C
SPRING: FLOW, TEMPERATURE, E-C, AND WATER QUALITY I
SPRING:FLOW, TEMPERATURE, E-C AND WATER QUALITY II
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
TELL KALAKH
Nahr el Kebir
Nahr Ostuene
Nahr Arka
Nahr el Bared
Nahr Abou Ali
TRIPOLI
ZGHORTA
HERMEL
Nahr el Jouz
BATROUN
BCHARRE
3,083m
Nahr el Asi
JBAIL
Nahr Ibrahim
JOUNIE
Nahr el Kelb
BAALBEK
Nahr Beirut
BEIRUT
ZAHLE
Nahr ed Damour
Nahr el Awali
SAIDA
Nahr Saitanic
Nahr ez Zahrani
Nahr el Litani
Qaraoun Lake
RACHAYA
DAMASCUS
Nahr el Hasbani
Nahr Abou Assouad
Nahr el Litani (Nahr el Kasmiye)
MARJAYOUN
SOUR
101
106
111
112
120
223
234
240
355
475
477
480
493
545

(3) Technical specification

The technical specifications on the field works mentioned above are attached in the Report as Annex 2.10.2.

2.10.3 Progress of the Survey

Immediately after the signing of the Contract, the Team and the Contractor hold technical meetings on the works schedule, details of the methodology, forms of datasheet, equipments provided by the Team, interim reporting, etc. After physical preparation for 10 days, the field works have been started at 10th August for the first field survey. The field works of the survey were completed by the end of August.

The second field survey was conducted from the end of December 2002 to the last of January 2003. The third (Additional) field survey was started by the last day of May and completed by the end of June 2003. Two interim reports on the summer-time and winter-time measurements were prepared and submitted to the Study Team at the end of September 2002 and the end of February 2003, respectively. The last report on the works of June (Snow-melting time) survey was prepared and submitted to the Study Team on 10th July 2003, just before the Study Team left Lebanon.

2.10.4 Survey Results

(1) Measurement of River Flow

Targets of the River Flow Measurement were 15 points in 14 rivers, and these 14 rivers were rather large rivers among the 17 study target rivers in Lebanon except the Hasbani River, which is located in the area where the Study Team can not enter by security reason.

The full results of measurement including the river cross sections are shown in Annex (Annex 2.10.4, 5, and 6) and the river discharges are summarized as Table 2.10-1.

As shown in the Table 2.10-1, only 9 points in 9 rivers had a river flow to be measured, and the other 6 points in 6 rivers had no flow or little flow not enough to be measured in August 2002. All of the survey points had enough river flow in January 2003, but again three points had no flow in June 2003, nevertheless other survey points had quite high river discharge in the same period.

These measurement points are not exactly same with the current gauging stations by LRA but all of the measurement results in each duration were compared with the 10 years average of monthly river flows (August) observed by LRA. As the results, the river discharge in August 2002 and January 2003 were almost same with the 10 years average, however, the measured discharge in July 2003 was quite larger than the 10 years average, although the actual measurements were only one time in each month.

Table 2.10-1 RESULTS OF RIVER DISCHARGE MEASUREMENT

Code	Name of the River	Instrument	Location: Observation Point (in Degree) x	Location: Observation Point (in Degree) y	Location: Altitude (m)	August, 2002: Discharge (m^3/s)	August, 2002: Temperature (°C)	August, 2002: Electro-conductivity (μS/cm)	January, 2003: Discharge (m^3/s)	January, 2003: Temperature (°C)	January, 2003: Electro-conductivity (μS/cm)	June, 2003: Discharge (m^3/s)	June, 2003: Temperature (°C)	June, 2003: Electro-conductivity (μS/cm)
601	NAHR EL KABIR	UC-204	34.655556	36.308889	250	1.51	25.50	396	10.69	11.40	492	2.37	22.20	474
602	NAHR OSTOUENE	UC-204	34.563889	36.093333	78	0.28	24.30	524	4.03	12.60	512	1.16	19.10	513
603	NAHR EL BARED	UC-304	34.500278	35.964167	20	0.57	26.60	522	9.76	8.50	501	10.44	16.40	340
604	NAHR ABOU ALI	UC-204	34.309167	35.861944	265	0.51	17.30	403	2.81	9.00	734	3.09	14.00	286
605	NAHR EL JAOUZ	UC-204	34.267500	35.661389	4	dry	-	-	2.70	12.60	419	0.63	26.70	320
606	NAHR IBRAHIM	UC-204	34.061389	35.651944	16	0.37	26.30	303	29.19	11.80	406	26.90	14.10	237
607	NAHR EL KELB	UC-204	33.950833	35.606111	17	dry	-	-	10.46	13.20	419	10.50	17.40	257
608	NAHR BEIRUT	UC-204	33.880833	35.531667	7	dry	-	-	4.15	14.10	479	dry	-	-
609	NAHR EL DAMOUR	UC-204	33.704722	35.448333	3	dry	-	-	5.51	13.90	464	2.69	23.80	321
610	NAHR EL AWALI	UC-204	33.588611	35.543333	12	0.51	19.20	501	49.38	12.10	462	29.38	15.80	437
611	NAHR SAINTANIQ	UC-204	33.535278	35.366111	6	dry	-	-	4.28	13.90	497	dry	-	-
612	NAHR EL ZAHRANI	UC-204	33.491389	35.344167	6	0.02	22.70	793	10.26	14.00	371	dry	-	-
613	LOWER LITANI	UC-204	33.330000	35.258611	2	0.08	23.40	742	39.67	14.20	446	2.62	23.10	473
614	UPPER LITANI	U-204	33.863611	35.988611	931	dry	-	-	4.62	10.80	669	1.03	23.20	683
615	NAHR EL ASSI	UC-204	34.391667	36.415278	598	6.01	14.70	317	6.34	13.40	343	23.24	13.60	275
Note:						6 rivers were dry.						3 rivers were dry.		

(2) Measurement of Spring Flow

Total 160 springs were measured their flow rates by several means such as a notch, flow meters (UC-304 and UC-204), or bucket. During the flow rate measurement, their field water qualities (temperature and EC) were also measured by portable water meter. Their locations (location of the measurement point) and altitudes were identifies by GPS (GPS 315, Magellan).

All of the results on spring flow measurements are shown in Annex 2.10-4, -5 and -6, and summarized as Table 2.10-2. As mentioned above, August is one of the most dry months in a year, and therefore, the most of spring flows were at very low rate. The maximum flow rate was measured at Yammoune, as as 1123.88 l/s followed by Nabaa el Safa of 861.45 l/s and Nabaa el Barouk of 620.45 l/s. However, the Yammoune spring is a complex with many small springs, and thus, the Safa Spring was the largest spring as an individual spring, among the 160 springs measured in this time. The smallest flow rate measured was 1.00 l/s at Ain el Quassis. The spring located at the highest elevation was Nabaa el Ymmoune at 1,123.9m above msl. Spring water quality was good in general, most of the springs showed 200 to 600 μ S/cm, and only one sample at the spring near the sea (Minie) showed slightly higher than 1,000 μ S/cm.

The flow rates measured in January were quite higher than the ones in August 2002, they were more than four (4) times of the latter in an average. However, the flow rates in June, at the snow-melting period were more higher than the former, around eight (8) times of the ones in August and roughly two times of the ones of January. Throughout the actual measurements, the highest spring flow was measured at Nabaa Qssem in June, as high as 12,560.4 lit/sec, followed by Nabaa Succa of 10,268.1 lit/sec and Nabaa Rachaane of 6,826.4 lit/sec. Those are not the highest spring rates in August or January, supposedly they have somewhat different spring mechanism than the other most of springs.

Table 2.10-2(1)(2)(3)

No.	CODE	SPRING NAME	VILLAGE	INSTRUMENT	Location X	Location Y	Location Z	Summer (August) Discharge	Summer (August) Temp.	Summer (August) E.C	Winter (January) Discharge	Winter (January) Temp.	Winter (January) E.C	Snow-melt (July) Discharge	Snow-melt (July) Temperature	Snow-melt (July) E.C	REMARKS
					(° N)	(° E)	(m)	(l/s)	(°C)	(μS/cm)	(l/s)	(°C)	(μS/cm)	(l/s)	(°C)	(μS/cm)	
1	101	NABAA FNAIDEQ	FNAIDEQ	UC-304	34.4800	36.2058	1325	91.40	9.70	464	911.78	8.00	413	279.66	9.00	403	
2	103	NABAA EL BANAT	FNAIDEQ	UC-304	34.4772	36.1967	1201	12.08	11.00	386	125.24	10.60	489	104.54	9.90	400	
3	104	AIN EL DEEK	AKKAR EL ATTICA	BUCKET	34.5042	36.2331	1272	8.02	9.80	404	19.96	8.90	402	45.74	9.00	343	
4	1051	NABAA EL CHOUH EL ALI	AKKAR EL ATTICA	BUCKET	34.5033	36.2325	1336	12.35	9.50	287	454.79	8.90	404	122.78	10.30	387	
5	1052	NABAA EL CHOUH EL WATI	AKKAR EL ATTICA	UC-304	34.5042	36.2328	1271	60.80	9.60	406	364.73	9.00	401	148.03	8.90	342	
6	106	NABAA EL JAOUZ	AKKAR EL ATTICA	UC-304	34.5069	36.2356	1183	38.86	10.10	384	502.71	9.10	390	584.52	10.00	342	
7	107	NABAA ECH CHEIKH JNAD	AKKAR EL ATTICA	WEIR	34.5156	36.2475	998	21.55	11.00	411	82.75	10.40	405	61.97	10.20	389	
8	108	NABAA OMAR KAYLO	AKKAR EL ATTICA	UC-304	34.5144	36.2497	1109	18.92	10.10	417	53.48	9.90	413	54.09	9.80	375	
9	109	AIN EL WATIEH	AKKAR EL ATTICA	UC-304	34.5392	36.2439	864	27.79	14.70	625	18.81	13.80	623	29.62	13.90	618	
10	110	AIN EL HOMSIYE	AKKAR EL ATTICA	BUCKET	34.5297	36.2411	748	3.24	13.40	525	20.16	13.40	601	5.63	13.50	484	
11	111	AIN AAYAT	AAYAT	BUCKET	34.5378	36.1997	660	1.40	15.40	513	19.27	15.20	759	10.26	15.10	687	
12	112	NABAA ES SAFA	BOQAIAA	UC-204	34.6217	36.3931	383	499.93	15.50	522	1,914.31	15.10	52	1,888.09	15.40	509	
13	113	TAL ET TINE	BOQAIAA	UC-204	34.6533	36.3331	281	118.50	18.10	542	300.03	17.40	560	218.30	17.70	544	
14	115	AIN EL ABIAD	QOBAIYAT	BUCKET	34.5472	36.2639	672	3.66	15.10	616	31.57	14.90	654	30.19	15.00	647	
15	116	NABAA HMADE	QOBAIYAT	50/100	34.5339	36.2736	915	18.64	13.00	527	48.32	12.40	536	64.40	12.80	540	
16	117	NABAA EL SHARQI	ANDQET	50/100	34.5422	36.3103	790	4.71	17.70	534	8.34	13.40	543	14.81	14.20	583	
17	118	NABAA EL CHARQI	ANDQET	BUCKET	34.5461	36.3042	721	11.19	14.90	486	69.16	14.50	493	96.73	14.50	486	
18	119	NABAA ECH CHEIKH	LAQLOUQ	BUCKET	34.1706	35.8758	1571	3.36	9.00	261	65.97	9.20	288	31.44	8.90	359	
19	120	AIN ES SAOUDA	TANNOURINE-HARISSA	50/100	34.1903	35.9358	1733	3.06	8.10	291	10.87	7.80	340	12.02	7.80	313	
20	122	NABAA EL MOGHRAQ	TANNOURINE-BALAA	50/100	34.1717	35.8789	1608	18.46	8.70	445	206.17	8.20	333	104.30	8.40	385	
21	123	NABAA EL KORSI	WATA HOUB	50/100	34.1922	35.9122	1519	31.77	10.00	358	70.76	9.50	295	58.79	9.80	290	
22	126	NABAA EL FOUAR	LAQLOUQ	BUCKET	34.1528	35.8928	1955	1.18	6.70	358	1.89	6.60	359	9.10	7.10	458	
23	127	EL HOUALIF	TANNOURINE-WADI EL JORD	BUCKET	34.1692	35.9158	1691	3.57	8.80	372	18.89	7.40	346	22.50	8.70	361	
24	128	NABAA EL ANBOUB	TANNOURINE-WADI EL JORD	BUCKET	34.1686	35.9189	1750	4.13	10.30	317	23.07	7.60	246	35.64	9.90	327	
25	129	AIN EL BAIDA	TANNOURINE-HARISSA	BUCKET	34.2047	35.9708	1952	1.01	9.30	392	2.65	7.90	375	5.56	8.00	347	
26	130	NABAA EL AHMAR	TANNOURINE-HARISSA	BUCKET	34.1997	35.9561	1767	1.97	9.10	399	7.62	8.60	358	10.81	7.90	360	
27	131	NABAA EL ASFAR	TANNOURINE-HARISSA	50/100	34.1992	35.9553	1746	3.15	8.10	401	6.21	7.80	398	3.91	8.40	371	
28	132	NABAA HAZRITA	TANNOURINE -WADI EL JORD	BUCKET	34.1717	35.8939	1607	1.11	9.90	348	3.49	9.50	327	4.00	8.70	321	
29	133	NABAA EL MOKHADA	TANNOURINE	BUCKET	34.1775	35.9050	1460	2.58	13.50	231	9.96	9.40	409	6.89	11.00	390	
30	134	NABAA EL JDID	TANNOURINE-HARISSA	BUCKET	34.1986	35.9589	1841	1.06	8.50	396	2.78	8.30	391	12.50	6.50	315	
31	135	NABAA DALLI	KFARHILDA	UC-204	34.2197	35.8447	623	125.29	13.50	246	1,006.67	11.40	346	674.04	13.00	389	
32	136	NABAA RACHAAINE	RACHAAINE	UC-204	34.3875	35.9306	157	210.33	11.20	281	2,711.00	13.10	375	6,826.40	10.00	205	
33	137	AIN EL KHALDIEH	KHALDIEH	UC-304	34.3706	35.9056	147	9.81	18.50	524	5.29	17.90	617	22.51	18.20	613	
34	138	AYOUN ACHACH	ACHACH	UC-304	34.4222	35.9414	220	63.76	19.60	537	27.08	18.80	557	11.17	19.30	515	
35	139	NABAA MAR SARKIS	EHDEN	UC-304	34.2892	35.9828	1510	65.63	6.40	195	57.62	7.70	201	775.86	5.80	181	Flows of 2 pipes 200mm and 150mm taking water from the spring are not included
36	140	NABAA KADISHA	BCHARRE	UC-304	34.2439	36.0367	1708	293.41	6.60	202	594.69	7.10	259	1,242.29	5.00	228	
37	141	NABAA NBAT	BCHARRE	BUCKET	34.2614	36.0233	1768	13.95	9.50	234	32.97	8.70	283	1,170.98	5.70	178	
38	142	NABAA MAR SEMAAN	BCHARRE	UC-304	34.2619	36.0094	1753	68.37	5.80	193	134.44	7.10	215	1,109.59	5.60	182	
39	143	AIN EL HADDAD	BCHARRE	UC-304	34.2614	35.9950	1545	17.33	8.90	276	29.71	8.70	284	104.88	9.50	305	
40	145	NABAA EL JOUANI	BEQAAKAFRA	BUCKET	34.2250	36.0342	1931	2.61	10.40	269	27.14	9.70	365	32.17	8.80	259	
41	146	AIN MABKHA	BAZOUN	UC-304	34.2269	35.9950	1732	5.97	7.60	303	41.60	7.80	346	99.51	6.80	240	
42	147	NABAA EL AARBIT	BEQAAKAFRA	BUCKET	34.2242	36.0047	1770	35.76	5.60	206	48.65	5.30	235	63.64	5.40	192	
43	148	AIN EL FOUAR	ES SOUAISSI	UC-304	34.5544	36.1158	148	20.26	20.00	572	23.99	19.50	533	41.03	19.60	584	
44	149	NABAA EL HADDAD	SAADINE	BUCKET	34.5917	36.0881	51	2.32	20.70	655	18.75	20.50	675	17.14	20.50	617	
45	152	NABAA EL QOLQAS	KOUAIKHAT	50/100	34.5731	36.0953	84	5.64	21.40	543	13.79	20.50	575	7.94	21.00	589	
46	164	AIN EL AFSA	TANNOURINE-HARISSA	BUCKET	34.2003	35.9467	1663	5.62	10.60	356	9.71	10.40	379	15.00	10.30	353	
47	165	ARID EL MSALLEM	TANNOURINE-HARISSA	BUCKET	34.2028	35.9592	1787	1.02	10.90	479	8.53	6.80	373	6.67	6.70	362	
48	166	NABAA EL KORSI	TANNOURINE-WADI EL JORD	BUCKET	34.1706	35.9128	1686	2.56	10.80	359	8.33	9.50	366	2.86	12.10	333	
49	168	NABAA EL CHELLAL	LAQLOUQ	BUCKET	34.1539	35.9019	1972	1.01	7.70	213	3.57	8.10	486	6.00	6.00	324	
50	169	NABAA CHAIAA	TANNOURINE -WADI EL JORD	BUCKET	34.1686	35.9214	1748	1.16	9.40	352	13.27	8.40	291	12.88	6.30	302	
51	170	NABAA EL TINE	AKKAR EL ATTICA	BUCKET	34.5275	36.2342	655	8.40	15.10	297	13.65	13.60	539	23.63	14.40	545	
52	171	AIN EL TAQIYEH	AKKAR EL ATTICA	UC-304	34.5225	36.2367	663	19.72	12.80	382	159.51	12.80	458	97.19	12.10	426	
53	172	AIN EL SET	QOBAIYAT	50/100	34.5567	36.2797	614	8.50	15.00	590	84.36	14.80	611	34.78	13.80	613	
54	173	AIN EL TINE	ANDQET	BUCKET	34.5450	36.3089	731	1.46	16.40	538	4.08	14.10	572	12.76	14.00	562	
55	174	NABAA EL HARFOUCH	BCHARRE	BUCKET	34.2619	36.0214	1773	19.89	5.50	176	12.32	7.50	201	77.82	5.50	177	
56	176	NABAA EL HAMAM	CHIR EL HMAIRIEH	50/100	34.6319	36.0969	22	47.34	21.80	678	158.44	21.40	679	162.70	21.50	689	
57	177	NABAA GHZAILI	GHZAILI	50/100	34.5933	36.1056	97	37.35	24.10	513	30.89	20.20	518	80.14	21.10	509	
58	178	NABAA ABOU SHAWKAT	KOUAIKHAT	BUCKET	34.5722	36.0975	84	17.65	21.50	493	6.13	21.30	498	26.97	21.30	487	
59	179	NABAA SIR	SIR EL DANNIYE	UC-204	34.3833	36.0283	908	485.32	8.40	227	1,169.15	9.80	315	1,479.84	7.20	179	Flow of a large number of pipes taking water from the spring is not included

No.	CODE	SPRING NAME	VILLAGE	INSTRUMENT	Location X (° N)	Location Y (° E)	Location Z (m)	Summer (August) Discharge (l/s)	Summer (August) Temp. (°C)	Summer (August) E.C (μS/cm)	Winter (January) Discharge (l/s)	Winter (January) Temp. (°C)	Winter (January) E.C (μS/cm)	Snow-melt (July) Discharge (l/s)	Snow-melt (July) Temperature (°C)	Snow-melt (July) E.C (μS/cm)	REMARKS
60	180	NABAA QSSEM	BEQAARHABOUNE	50/100	34.3725	36.0350	1094	36.27	7.20	202	281.76	9.40	303	12,560.40	6.50	172	Flow of a large number of pipes taking water from the spring is not included
61	181	NABAA SUCCAR	BEQAARHABOUNE	50/100	34.3672	36.0828	1676	195.31	5.50	179	112.23	5.50	195	10,268.08	4.30	180	
62	182	NABAA CHQEIQ	KFARBIBNIT	50/100	34.4025	36.0750	1134	15.15	11.60	435	27.50	11.40	431	55.65	11.80	439	
63	183	AIN EL BORJ	MINIEH	50/100	34.4975	35.9389	10	24.14	19.40	1007	69.21	19.90	1,141	17.57	18.50	967	
64	184	AIN EL CHARCHARA	MINIEH	BUCKET	34.4961	35.9367	4	11.76	19.60	921	15.84	19.50	1,006	177.12	18.50	884	
65	185	AIN MARKABTA	MARKABTA	50/100	34.4503	35.9661	275	9.11	19.20	404	33.15	19.00	434	23.67	19.10	391	
66	186	AIN MARMAR	OYOUN ES SAMAK	50/100	34.4414	36.0242	243	12.56	16.90	506	14.77	16.70	529	17.39	16.70	522	
67	187	AIN ES SAYED	OYOUN ES SAMAK	50/100	34.4392	36.0028	216	14.10	15.60	515	179.35	15.30	546	309.92	15.10	458	
68	188	AIN EL SAKHRA	MINIEH	50/100	34.4944	35.9336	0	4.81	21.50	865	8.39	19.10	893	4.99	19.30	953	
69	189	AIN EZ ZARQA	MINIEH	50/100	34.4944	35.9358	27	67.60	19.90	893	102.03	19.70	908	39.35	18.90	948	
70	201	NABAA EL BAROUK	BAROUK	UC-304	33.7117	35.6931	1089	820.45	10.30	260	1,339.09	10.30	268	3,235.25	10.30	262	
71	202	NABAA ES SAFA	SAFA	UC-304	33.7519	35.7003	914	681.45	11.10	268	1,539.25	10.80	355	2,484.98	11.10	280	
72	207	NABAA EL AKHOUAT	WADI BNEHLAY	UC-304	33.6872	35.5383	443	65.07	15.90	455	232.70	15.40	496	173.49	15.70	490	
73	208	AIN EL BARDEH	WADI BNEHLAY	UC-304	33.6819	35.5286	389	10.36	17.00	571	31.10	16.00	557	21.94	16.60	551	
74	211	NABAA BATER	BATER ECH CHOUF	UC-304	33.5994	35.6178	971	46.13	13.50	452	278.34	13.10	444	195.52	13.40	435	
75	212	NABAA EL AASAL	FARAYA	UC-304	34.0097	35.8383	1551	471.48	5.40	186	2,080.78	7.10	248	1,255.05	5.30	184	
76	213	NABAA EL LABAN	KFARDEBIAN	UC-304	33.9950	35.8283	1646	53.20	7.30	240	4,370.24	6.30	223	5,326.94	4.50	158	
77	214	AIN ED DELBE	FARAYA	UC-304	34.0106	35.8242	1279	26.51	8.80	329	54.83	8.90	319	51.02	7.50	237	
78	215	NABAA EL MGHARA	HRAJEL	UC-304	34.0119	35.8006	1542	12.01	11.40	491	330.69	10.60	431	19.64	9.70	374	
79	216	NABAA EL QANA	HRAJEL	UC-304	34.0422	35.8086	1580	33.38	10.00	403	205.41	8.10	299	33.52	7.90	283	
80	2171	NABAA ECH CHHARIR	MAIROUBA	BUCKET	34.0175	35.7681	1292	1.28	15.10	204	13.56	8.40	176	4.37	16.30	215	
81	2172	NABAA ES SOUANE	MAIROUBA	BUCKET	35.0150	35.7697	1308	2.64	13.30	350	13.69	11.10	459	6.37	11.70	341	
82	2181	NABAA EL SANNOUR	MAIROUBA	BUCKET+UC-304	34.0247	35.7817	1332	5.11	15.30	363	293.56	8.20	297	0.90	14.30	341	
83	2182	NABAA EL TANNOUR	MAIROUBA	BUCKET	35.0200	35.7739	1319	1.75	12.60	702	25.28	11.50	481	3.57	12.40	682	
84	219	NABAA SANNINE	BASKINTA	UC-304	33.9367	35.8419	1674	21.38	6.00	220	252.29	6.50	220	436.24	5.50	181	
85	220	NABAA JAOUZ EL NEMEL	BASKINTA	UC-304	33.9303	35.8383	1655	6.88	8.80	288	103.68	7.90	271	55.28	8.10	268	
86	223	NABAA KHALAF	QARTABA	BUCKET	34.0964	35.8506	1189	1.04	13.60	465	5.88	13.40	405	2.08	15.50	405	
87	224	RAS EN NABAA	QARTABA	50/100	34.1092	35.8564	1329	1.78	14.50	387	5.00	8.60	374	17.81	11.90	403	
88	225	NABAA ECH CHARBINE	ECH CHARBINE	50/100	34.1175	35.8589	1578	4.28	12.10	386	15.95	9.80	434	12.39	10.00	327	
89	226	NABAA EZ ZGHIR	ECH CHARBINE	BUCKET	34.1175	35.8586	1565	1.51	12.60	317	17.89	9.90	408	10.42	9.60	314	
90	227	NABAA EL KBIR	ECH CHARBINE	BUCKET	34.1206	35.8661	1585	1.62	10.80	360	20.91	9.10	390	12.35	9.00	318	
91	228	NABAA EL FOUAR	ECH CHARBINE	BUCKET	34.1211	35.8592	1621	5.22	8.60	313	47.15	8.40	339	34.03	8.00	285	
92	229	NABAA EZ ZEIN	MGHAIRI	BUCKET	34.1050	35.8736	1237	1.06	16.80	472	4.78	12.20	383	14.23	10.90	398	
93	230	NABAA BOU SALHAB	MGHAIRI	50/100	34.1050	35.8789	1195	9.26	12.60	415	69.24	12.50	406	33.04	12.40	395	
94	231	NABAA EL TOUTE	YANOUH	50/100	34.0992	35.8797	1106	2.76	12.80	631	3.70	12.10	528	10.92	12.70	555	
95	232	NABAA EL ROUAISS	AAKOURA	BUCKET	34.1097	35.9072	1300	116.25	9.00	271	1,940.34	8.80	260	3,880.00	7.60	199	
96	233	AIN EL BARBRISSE	AAKOURA	BUCKET	34.1514	35.8828	1904	2.46	9.00	313	18.61	7.60	337	19.70	7.30	333	
97	234	AIN EL BAHRA	AAKOURA	UC-304	34.1419	35.8844	1861	1.87	10.40	366	16.16	7.30	382	18.50	8.40	336	
98	235	AIN EL QASSIS	AAKOURA	BUCKET	34.1456	35.8769	1818	1.00	9.80	386	13.53	8.30	404	8.64	7.70	405	
99	236	AIN EL JAOUZ	AAKOURA	UC-304	34.1383	35.9286	1658	13.15	9.70	278	56.88	8.60	223	52.00	8.00	224	
100	237	AIN RICHMI	AAKOURA	UC-304	34.1244	35.9183	1608	7.50	9.10	259	423.39	8.70	247	31.84	8.30	219	
101	238	AIN SNITA	AAKOURA	UC-304	34.1189	35.9061	1307	7.77	11.70	536	47.49	11.10	507	23.83	11.20	418	
102	239	AIN ELIAS	AAKOURA	BUCKET	34.1256	35.8814	1500	2.14	12.50	272	80.06	9.70	311	13.08	10.90	295	
103	240	AIN EL BLATA	AAKOURA	BUCKET	34.1325	35.8786	1666	3.62	12.60	296	24.95	10.30	345	4.80	10.40	309	
104	241	AIN EL DAIAA	AAKOURA	BUCKET	34.1206	35.9044	1382	5.42	10.80	342	16.74	10.10	367	11.64	9.00	311	
105	245	AIN EL SAFRA	AFKA	UC-304	34.0703	35.8869	1145	15.71	11.10	335	20.89	10.50	35	36.02	11.10	330	
106	246	AIN EL HISSAN	AFKA	UC-304	34.0689	35.8850	1182	10.45	10.50	297	33.68	10.50	315	64.61	10.30	296	
107	247	NABAA EL MADIQ	YAHCHOUCH	UC-304	34.0842	35.7019	170	513.10	15.40	406	2,023.78	13.20	387	1,870.62	15.80	410	
108	248	NABAA EL DAYSHOUNIEH	DAYSHOUNIEH	UC-304	33.8403	35.5886	110	117.26	17.50	554	4,995.71	14.60	517	576.16	16.90	540	
109	250	TANNOUR EL WADI	ANTELIAS	UC-304	33.9119	35.5978	32	34.96	16.20	486	341.76	14.80	439	54.19	15.60	447	
110	251	FOUAR ANTELIAS	ANTELIAS	UC-304	33.9117	35.5986	30	261.68	16.00	425	2,313.33	15.10	435	1,545.26	15.30	430	
111	256	NABAA EL QAA	SAFA	UC-304	33.7492	35.7014	961	32.98	11.50	267	931.07	11.90	282	751.65	11.30	261	
112	257	NABAA ET TANNOUR	SAFA	UC-304	33.7492	35.7022	997	110.94	11.50	267	251.24	11.90	281	236.66	11.30	260	
113	258	AIN EL DAIAA	AIN ZHALTA	BUCKET	33.7431	35.7022	1082	1.10	13.50	571	8.80	13.10	509	1.66	12.50	485	
114	259	NABAA EL MOUBARAK	DEIR DOURIT	UC-304	33.6872	35.5394	465	9.03	16.00	489	17.09	15.50	513	15.32	15.90	495	
115	260	AIN ES SAOUDA	AAKOURA	BUCKET	34.1386	35.8875	1820	1.03	10.50	393	2.60	8.70	404	1.53	8.20	354	
116	261	DOUAR EL MARJEH	AAKOURA	BUCKET	34.1325	35.9872	1703	1.05	12.40	179	48.98	7.60	369	9.46	9.70	382	
117	262	NABAA EL HOUAIRI	QARTABA	BUCKET	34.1061	35.8533	1301	1.27	15.40	330	10.55	8.80	358	3.13	14.00	327	
118	263	NABAA EL WAHLI	QARTABA	BUCKET	34.1078	35.8547	1314	1.01	18.90	339	1.53	10.30	316	2.22	13.50	250	
119	305	QAA ER RIM	ZAHLE	UC-204	33.8861	35.8719	1227	129.65	8.00	191	137.15	7.70	285	6,009.07	8.70	208	Flow of pipe 50mm taking water from the spring is not included

No.	CODE	SPRING NAME	VILLAGE	INSTRUMENT	Location X	Location Y	Location Z	Summer (August) Discharge	Summer (August) Temp.	Summer (August) E.C	Winter (January) Discharge	Winter (January) Temp.	Winter (January) E.C	Snow-melt (July) Discharge	Snow-melt (July) Temperature	Snow-melt (July) E.C	REMARKS
					(° N)	(° E)	(m)	(l/s)	(°C)	(μS/cm)	(l/s)	(°C)	(μS/cm)	(l/s)	(°C)	(μS/cm)	
120	308	NABAA CHTOURA	CHTOURA	UC-204	33.8236	35.8508	929	344.45	13.50	355	360.43	13.10	408	860.96	12.50	315	
121	309	NABAA ECH CHAGHOUR	OUADI NAHLE	50/100	34.0456	36.2906	1380	10.53	15.50	303	8.62	14.30	227	11.68	14.60	259	Flow of pipe 75mm taking water from the spring is not included
122	310	NABAA EL FOUARA	OUADI NAHLE	50/100	34.0739	36.3197	1550	10.59	11.70	310	4.61	11.80	307	338.92	9.50	268	
123	311	NABAA HAQL EL TEFFAHA	OUADI NAHLE	50/100	34.0692	36.3089	1487	30.25	13.00	380	10.48	11.10	356	23.54	11.40	308	
124	312	NABAA EM MELHEM	OUADI NAHLE	50/100	34.0567	36.2969	1472	10.01	14.20	374	5.11	12.00	360	97.01	11.60	317	
125	314	NABAA ER ROUAISS	LABOUE	UC-304	34.1967	36.3525	906	251.78	14.30	324	290.81	14.40	328	529.61	12.80	265	
126	315	NABAA EL QAA	LABOUE	WEIR	34.1978	36.3525	908	416.60	17.50	324	466.75	14.40	329	418.83	12.80	268	Flows of 2 pipes 200mm and 150mm taking water from the spring are not included
127	316	NABAA MATRAFE	LABOUE	UC-304	34.1975	36.3519	903	179.02	14.20	323	168.99	14.40	328	296.55	12.80	269	
128	317	NABAA SOUAIKA	LABOUE	UC-304	34.1967	36.3528	903	24.76	14.20	324	23.56	14.40	328	110.15	12.90	269	
129	318	NABAA RAS BAALBECK	RAS BAALBECK	UC-304	34.2606	36.4172	989	18.69	17.80	477	29.14	17.40	455	34.73	17.70	447	
130	319	NABAA EL FAKEHA	FAKEHA	UC-304	34.2419	36.4069	981	84.57	17.90	367	108.75	17.80	371	96.82	17.80	368	
131	320	RAS EL AIN	BAALBECK	UC-304	33.9994	36.2164	1170	97.21	16.60	282	139.01	12.20	32	1,212.92	13.60	295	Flows of 2 pipes 200mm and 150mm taking water from the spring are not included
132	321	NABAA EL YAMMOUNEH	YAMMOUNEH	UC-304	34.1217	36.0333	1360	1,123.88	13.00	240	873.31	8.00	253	2,138.03	8.80	205	42 springs are collected into 1 canal
133	323	RAS EL MAL	HERMEL	UC-304	34.3903	36.3714	786	149.17	11.40	258	229.20	11.20	259	192.79	11.20	262	
134	324	NABAA EL RAYSEH	HERMEL	UC-304	34.3919	36.3744	759	18.36	11.70	266	29.62	11.30	236	8.38	11.80	269	
135	325	NABAA EZ ZHOUR	SAADNAYEL	50/100	33.8217	35.8750	910	7.15	18.60	576	78.67	15.10	564	69.80	16.60	507	
136	327	EHDAASHARIEH	HERMEL	UC-304	34.3914	36.3775	777	53.03	12.46	282	69.38	11.00	280	74.75	12.00	280	
137	328	NABAA EL TAQA	ZAHLE	50/100	33.8783	35.8636	1308	10.37	11.00	280	19.43	10.80	279	23.37	10.70	276	
138	329	NABAA CHAMSINE	ZAHLE	UC-204	33.7436	35.9564	887	119.43	16.70	444	481.83	14.40	425	587.89	15.50	402	
139	330	NABAA ANJAR	ANJAR	UC-204	33.7331	35.9461	881	202.52	14.90	417	671.99	14.90	450	682.73	15.40	428	
140	331	NABAA AHLA	CHAAT	UC-204	34.1339	36.2950	992	33.56	17.40	319	37.12	15.00	326	140.39	15.80	333	
141	332	NABAA OM RAAD	LABOUE	50/100	34.2100	36.3397	868	82.12	15.70	475	54.24	14.90	550	185.05	15.50	541	
142	333	NABAA GHABSHOUN	LABOUE	50/100	34.2353	36.3428	822	52.47	17.60	579	175.14	14.20	534	175.17	16.00	542	
143	334	AIN EL JAMEAA	MARJHINE	50/100	34.4036	36.2464	1727	24.28	10.80	333	73.26	9.20	322	9.65	9.80	333	
144	335	NABAA EL HAOUR	MARJHINE	50/100	34.3753	36.2294	1729	84.34	17.10	259	223.56	14.52	241	208.70	9.50	275	
145	336	OYOUN TAQTAQ	OYOUN TAQTAQ	50/100	34.3006	36.3658	761	37.76	16.90	461	24.23	14.10	561	67.77	17.20	551	
146	401	NABAA JEZZINE	JEZZINE	UC-304	33.5400	35.5869	1036	10.63	13.20	398	508.51	12.90	399	408.57	14.20	387	Flows of 1 pipes 75mm and 1 pipes 100mm taking water from the spring are not included
147	407	NABAA EL ZARQA	HIDAB	UC-304	33.5786	35.5347	630	16.90	16.90	502	78.25	16.20	440	61.92	16.20	440	
148	409	NABAA EL QOBAIAA	KFARMELKI	UC-304	33.5061	35.4750	343	3.89	17.20	731	18.67	17.10	655	12.75	16.90	659	
149	410	AIN ABOU YOUNESS	KFARMELKI	UC-304	33.5086	35.4703	317	3.83	18.00	619	8.63	16.60	610	19.79	17.40	602	
150	415	AIN EL BOUSTANE	AIN BOU SOUAR	BUCKET	33.4722	35.5186	893	3.20	14.60	534	3.02	13.80	546	6.13	14.40	482	
151	418	AIN EL BARDEH	BESRI	UC-304	33.5844	35.5456	343	25.10	17.90	628	84.40	17.30	600	88.04	17.50	611	
152	419	NABAA MERCHED	MOUKHTARA	UC-304	33.6539	35.6253	808	66.24	14.20	486	542.76	12.70	465	84.43	14.10	467	
153	420	SIN EL DOUARA	AIN BOU SOUAR	BUCKET	33.4711	35.5189	879	1.47	15.50	533	1.03	13.70	530	6.10	13.90	509	
154	421	NABAA SFINTA	WADY BERTY	BUCKET	33.5072	35.4922	353	1.16	18.00	385	6.40	17.70	400	2.27	17.60	356	
155	422	AIN BOU SOUAR	BOU SOUAR	BUCKET	33.4708	35.5200	933	4.51	13.50	474	1.01	13.70	476	6.51	13.00	475	
156	423	AIN EL DAIAA 1	KFARMELKI	BUCKET	33.5019	35.4792	412	1.02	17.90	648	2.84	17.60	653	1.66	17.80	638	
157	424	AIN EL DAIAA 2	JARJOUAA	BUCKET	33.4450	35.5208	782	1.27	16.40	610	3.25	16.30	600	9.13	16.00	553	
158	425	AIN EL HECHACHE	JARJOUAA	BUCKET	33.4431	35.5203	716	1.04	16.50	587	1.95	15.90	580	1.13	15.80	568	
159	502	NABAA BOU HALQA	BOHSAS	UC-204	34.4069	35.8156	1	290.18	18.90	615	1,274.70	18.60	609	1,323.33	18.90	601	200 l/s of the given discharge are pumped
160	504	NABAA EL AAJOUZ	CHEQA	UC-304	34.3389	35.7294	1	2.99	16.90	581	25.67	16.90	728	23.54	16.70	621	
		Total/Average						10,418.04	13.17	409.10	45,022.93	12.09	416	81,133.79	12.20	398	

(3) Water Quality Analysis (1) & (2)

Water quality analysis (1) was conducted for three major targets: for river water, for sea water, and for spring water from an environmental point of view. **Water quality analysis (2)** was conducted to check the water quality from a view point of hydrogeology. For the purpose, the water samples were taken from a) Rivers at their middle approach (20 samples), b) Springs at low elevation (20 samples), c) Springs at middle elevation (20 samples), and d) Springs at coastal zone (10 samples). Water quality analysis on spring water at high elevation was carried out only in Winter Season.

The samples taken at the sites were sent to the laboratory for biological and chemical analysis as explained above. Besides the laboratory analysis, all of the samples were measured their physical properties (temperature and EC) by portable water meter at the same time of sampling. Location of the sampling points, ant their altitude, were measured by GPS (GPS 315, Magellan).

All of the results are attached in Annex (Annex 2.10.4 and 5), and they are summarized as Table 2.10-3 and Table 2.10-4 for water quality analysis (1) and (2) respectively.

Water quality analysis (1)
The findings from the survey data are shown as follows.

1) River Water
- Total and faecal coliform were detected in all rivers.
- The figures of total and faecal coliform in winter exceed the magnitudes of 10,000 and 5,000 respectively as against the Lebanese standard (which total and faecal coliform shall not be detected) especially in Nahr Ostune, Nahr Ibrahim, Nahr El Awali, Nahr El Zahrani, Lower Litani, Nahr Sainiq and Upper Litani.
- As a seasonal change, the figures of total and faecal coliform in winter are higher compared to those of summer.
- As a regional change, the lower parts of the rivers show higher figures compared to their upper parts in electrical conductivity, BOD, chloride and coliform except Nahr El Awali.

Above results give the suggestions that water pollution has been caused by the influence of various human activities of urbanization, farming and industrialization in the downstream areas.

2) Spring Water
- Total and faecal coliform were detected for the Lebanese standard (Not detectable) in many sampling points except 5 points which were located in comparatively higher altitude than other points
- The figures of the samples of raw water (which indicate the figure of 10 in total and faecal coliform), except the sampling site No. 8, 9, 11, 15 and 16, do not comply with Lebanese standard or WHO guideline (not detectable) in the parameters of total and faecal coliform.
- The figures of electrical conductivity, chloride, total and faecal coliform do not comply with the Lebanese standard (400, 25 and not detectable, respectively) in Nabaa Es Safa, Ain El

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3) Sea Water

The figures of coliform comply with Lebanese and Japanese bathing standards, while the high values of COD do not comply with Japanese standard. The higher figures of coliform in Beirut shows that its sea has been polluted compared to those of other cities.

Water quality analysis (2)

Results of water quality (2) from hydrogeological point of view are arranged into "Piper Diagram" (or Tri-linear Diagram) and attached in Annex 2.10.7.

As shown in the diagrams, most of the water qualities are classified into Type-I, "$Ca(HCO_3)_2$ type", which is the typical water quality type in karstic region. Water qualities of river water in winter season show this type, but some samples of river water taken in summer season are classified into Type-IV, "$NaSO_4$ or $CaCl_2$ Type", which means they are mixed by sea water or somewhat polluted. Water qualities of spring water are classified into Type-I excepting the coastal springs. Samples taken from the coastal springs, both in summer and winter times, vary from Type-I to Type-IV, suggesting the mixing with sea water. Water qualities of samples taken from springs in low, middle, and high elevations both in summer and winter, show typical Type-I characteristic, especially the springs in high elevation.

(4) Well Inventory Survey

During the study period in Phase-I, total 2,000 wells were checked and arranged into the Well Inventory. The Inventory prepared through the field works is attached in Appendix (H-4) and all of the contents of the Inventory were installed in the GIS Database. Contents (items) of the Well Inventory are Code Number, Location, Elevation, Owner name, Purpose of well, Constructed year, Well depth, Well structure (if defined), Water levels (if defined), Pump type and capacity (if defined), and Pumping rate (if defined) for each well.

As shown in the location map (in Appendix H-2), all 2,000 wells are situated in northern half of Bekaa Plain. And the location map shows some confusion of natural boundary between Lebanon and Syria. There are 2000 wells only in the half of Bekaa, and it suggests the total number of wells in Lebanon shall be more than 20,000, at least ten (10) times of this figure.

Table 2.10-3 WATER QUALITY ANALYSIS (1)

River – Summer (August, 2002)

Category	Code	Name of River	Location x	Location y	(m)	Temp. (°C)	EC (µS/cm)	pH	BOD	COD	SS	DO	TN	TP	Cl	TC	FC
River	601	NAHR EL KABIR	34.655556	36.308889	250	25.50	396	8.01	2.15	11.2	10.4	7.06	0.46	0.06	28.3	420	250
	601-1	NAHR EL KABIR	34.635556	35.978611	1	28.50	1297	8.34	0.6	7.3	18.3	6.56	0.32	0.09	200.4	1,650	1,500
	602	NAHR OSTOUENE	34.563889	36.093333	78	24.30	524	8.85	1.61	5.4	1.3	5.38	0.22	0.06	21.3	580	290
	603	NAHR EL BARED	34.500278	35.954167	20	26.60	522	8.01	2.4	48.2	16.3	7.12	0.26	<0.01	12.5	4,500	2,300
	603-1	NAHR EL BARED	34.479722	35.985000	61	19.40	475	8.00	0.2	0.6	3.4	6.69	0.21	0.01	10.1	920	150
	604	NAHR ABOU ALI	34.309167	35.861944	265	17.30	403	8.26	2.24	8.4	2.2	5.56	0.17	0.02	8.8	100	30
	604-1	NAHR ABOU ALI	34.455278	35.841667	9	24.30	608	7.08	13.6	19.5	82.9	0.52	18.2	1.8	58.8	4,200	2,200
	606	NAHR IBRAHIM	34.061389	35.651944	16	26.90	303	7.85	1.9	4.2	6.2	7.16	0.12	0.02	8.8	100	25
	610	NAHR EL AWALI	33.588611	35.543333	12	19.20	501	8.12	6.54	31.9	2.3	7.24	0.95	0.06	24.8	125	20
	610-1	NAHR EL AWALI	33.588611	35.386667	1	16.90	453	7.75	0.5	7.2	6.7	7.89	0.92	0.03	20.1	110	27
	612	NAHR EL ZAHRANI	33.491389	35.344167	6	22.70	793	7.83	3.75	6.5	3.9	8.15	0.32	0.01	42.5	>200	>200
	612-1	NAHR EL ZAHRANI	33.493056	35.341389	7	24.10	755	7.82	0.7	5.1	2.4	6.52	0.27	0.02	42.6	350	120
	613	LOWER LITANI	33.330000	35.258611	2	23.40	742	7.55	3.16	8.1	4.9	9.64	0.36	0.01	45.5	150	22
	615	NAHR EL AASSI	34.391667	36.415278	596	14.70	317	8.07	0.8	1.3	1.8	9.16	0.215	<0.01	4.5	125	30
	615-1	NAHR EL AASSI	34.421389	36.456944	595	17.30	245	8.25	5.1	1.4	1.2	8.08	0.1	0.01	5.2	440	190
	616	NAHR ARQA	34.530556	36.042778	784	24.10	483	8.30	1.27	6.1	2.7	4.04	0.19	0.02	20.5	580	110
	616-1	NAHR ARQA	34.513611	36.068056	126	18.50	526	7.79	0.2	1.3	2.1	8.34	0.23	<0.01	13.7	200	70

River – Winter (January, 2003)

Code	Name of River	Location x	Location y	(m)	Temp. (°C)	EC (µS/cm)	pH	BOD	COD	SS	DO	TN	TP	Cl	TC	FC
601	NAHR EL KABIR	34.655556	36.308889	250	11.40	492	8.09	1.4	5.3	39.4	8.1	0.23	0.12	20.8	1,500	1,100
602	NAHR OSTOUENE	34.563889	36.093333	78	12.60	312	8.22	2.1	5.7	13.2	9.92	0.076	0.08	14.8	13,500	12,500
603	NAHR EL BARED	34.500278	35.954167	20	8.50	501	7.96	0.9	5.2	17.4	9.9	0.0934	0.06	12.2	5,400	3,950
604	NAHR ABOU ALI	34.309167	35.861944	265	9.00	734	8.31	1.1	7.1	3.8	10.05	0.193	0.16	11.2	3,800	3,750
605	NAHR EL JAOUZ	34.267500	35.661389	4	12.60	419	8.15	0.7	1.2	12.1	8.84	0.087	0.06	8.0	1,340	600
606	NAHR IBRAHIM	34.061389	35.651944	16	11.80	405	7.78	2.3	5.2	7.0	7.68	0.187	0.02	9.2	20,000	2,500
607	NAHR EL KELB	33.950833	35.606111	17	13.20	419	8.07	1.3	4.4	32.4	11.2	0.063	0.06	9.1	1,000	800
608	NAHR BEIRUT	33.880833	35.531667	7	14.10	479	7.9	1.9	5.2	116.2	6.64	0.653	0.12	17.3	4,500	1,800
609	NAHR EL DAMOUR	33.704722	35.449333	3	13.90	464	8.09	0.9	1.2	5.8	10.12	0.039	<0.01	14.8	1,700	300
610	NAHR EL AWALI	33.588611	35.543333	12	12.10	482	8.05	1.1	4.3	48.2	9.28	0.323	0.031	15.7	48,000	9,000
611	NAHR SAINIQ	33.535278	35.356111	6	13.90	497	8.17	1.8	3.8	22.3	10.04	0.282	0.038	17.4	63,000	23,000
612	NAHR EL ZAHRANI	33.491389	35.344167	6	14.00	371	8.15	1.4	3.2	15.7	9.12	0.281	0.042	10.4	35,000	30,000
613	LOWER LITANI	33.330000	35.258611	2	14.20	446	8.08	1.9	3.6	29.6	9.21	0.234	0.035	14.2	30,000	3,500
614	UPPER LITANI	33.863611	35.986611	931	10.80	669	7.82	2.8	10.8	44.9	7.48	0.656	0.162	29.6	12,000	5,000
615	NAHR EL AASSI	34.391667	36.415278	596	13.40	343	8.27	1.1	2.6	0.7	10.6	0.067	0.01	7.4	850	150
616	NAHR ARQA	34.530556	36.042778	76	14.70	538	8.02	0.64	5.4	6.2	8.82	0.01	0.02	15.7	1,500	1,100
617	NAHR AACHOGOUT	35.685556	33.981111	821	10.90	340	8.04	0.3	3.4	18.5	10.52	0.012	0.06	11.0	200	100

Sea – Summer (August, 2002)

Category	Code	Name of Coast	x	y	(m)	(°C)	(µS/cm)	pH	BOD	COD	SS	DO	TN	TP	Cl	TC	FC
Sea	701	TRIPOLI	34.455833	35.811389	0	28.80	-	8.12	3.2	1,130	3.2	7.68	0.25	0.11	16,256	174	24
	702	JOUNIEH	34.004722	35.644444	0	28.20	-	8.08	2.9	840	2.9	6.34	0.14	<0.01	18,325	110	80
	703	BEIRUT	33.874722	35.480833	0	28.80	-	7.92	0.5	1,190	6.5	1.96	0.69	0.14	21,999	230	150
	704	DBAYEH	33.952778	35.592500	0	29.40	-	8.12	1.2	690	1.4	3.64	0.42	0.01	19,020	140	16
	705	SAIDA	33.583333	35.387778	0	28.00	-	8.08	0.4	780	15.2	2.84	2.95	<0.01	18,670	290	30

Sea – Winter (January, 2003)

Code	(°C)	(µS/cm)	pH	BOD	COD	SS	DO	TN	TP	Cl	TC	FC
701	15.10	-	7.98	1.3	920	4.6	4.1	0.289	0.1	17,748	120	40
702	18.10	-	8.25	2.1	960	5.9	5.4	0.57	0.02	19,520	90	8
703	19.60	-	8.18	2.8	246	10.4	8.6	0.92	0.03	10,498	300	150
704	19.70	-	8.23	1.7	241	27.2	8.93	9.94	0.01	20,097	15	2
705	18.30	-	8.08	2.3	1,150	22.7	5.5	0.52	0.02	18,444	0	0

Spring – Summer (August, 2002)

Category	Code	Name of Spring	x	y	(m)	(°C)	(µS/cm)	pH	BOD	COD	NH_4	TN	TP	Cl	TC	FC
Spring	101	NABAA FNAIDEQ	34.48000	36.20583	1,325	9.70	464.00	7.29	0.4	1.8	<0.01	0.046	0.04	7.1	11	4
	112	NABAA ES SAFA	34.62167	36.39306	383	16.50	522.00	7.06	1	3.2	0.048	0.09	<0.01	14.5	370	100
	116	NABAA HMADE	34.53389	36.27361	915	13.00	527.00	7.93	0.7	1.2	0.073	0.102	<0.01	14.0	30	18
	135	NABAA DALLI	34.21972	35.94472	623	13.50	246.00	7.68	0.4	0.7	0.0244	0.139	<0.01	5.5	5	0
	140	NABAA KADISHA	34.24389	36.03667	1,708	6.60	202.00	7.9	2.1	5.8	0.0122	0.074	<0.01	2.5	22	4
	146	AIN MARKHA	34.22611	35.995	1,732	7.60	303.00	7.75	0.3	0.5	0.0368	0.105	<0.01	4	100	0
	149	AIN EL FOUAR	34.55444	36.11583	148	20.00	572.00	7.49	1.2	1.4	0.0129	0.136	0.07	26.8	610	580
	201	NABAA EL BAROUK	33.71167	35.69306	1,069	10.30	260.00	7.67	0.2	1.2	<0.01	0.01	<0.01	19	0	0
	202	NABAA ES SAFA	33.75194	35.70028	914	11.10	268.00	7.73	<0.1	0.4	0.0244	0.07	<0.01	5.3	0	0
	216	NABAA EL GANA	34.04222	35.80861	1,590	10.00	403.00	8	0.9	2.5	0.012	0.189	<0.01	4.1	160	90
	219	NABAA SANNINE	33.93667	35.84194	1,874	6.00	220.00	7.93	<0.1	0.7	0.0112	0.06	<0.01	3.3	0	0
	246	AIN EL HISSAN	34.06889	35.665	1,182	10.50	297.00	7.36	0.65	0.3	0.0244	0.09	<0.01	5.4	120	70
	248	NABAA EL DAYSHOUNIEH	33.84028	35.58861	110	17.50	554.00	7.35	<0.1	0.2	0.0424	0.1	0.74	19.4	91	21
	258	AIN EL DAIAA	33.74306	35.70222	1,082	13.50	571.00	7.28	0.7	2.2	<0.01	0.04	0.27	19.9	26	9
	305	QAA ER RIM	33.88611	35.67194	1,227	8.00	191.10	7.84	<0.1	0.9	0.0976	0.15	<0.01	4.3	0	0
	315	NABAA EL QAA	34.19778	36.3525	908	17.50	324.00	7.74	0.3	0.4	0.0241	0.132	0.01	3.3	0	0
	318	NABAA RAS BAALBECK	34.26056	36.41722	989	17.80	474.00	7.82	1.3	5.2	0.0174	0.172	0.02	14.8	370	70

Spring – Winter (January, 2003)

Code	(°C)	(µS/cm)	pH	BOD	COD	NH_4	TN	TP	Cl	TC	FC
101	8.00	413	7.64	0.2	0.8	0.1256	0.128	<0.01	6.5	13	0
112	15.10	52	7.63	0.3	0.9	0.14	0.149	0.01	11.3	200	0
116	12.40	535	7.96	0.8	1.1	0.04	0.048	<0.01	11.3	400	0
135	11.40	346	7.85	0.2	0.7	0.0248	0.0256	0.11	7.7	0	0
140	7.10	259	7.90	<0.1	0.5	<0.010	<0.010	<0.01	4.2	0	0
146	7.80	346	7.77	<0.1	<0.1	<0.010	<0.010	<0.01	4.7	0	0
149	19.50	533	7.50	1.2	1.6	0.029	0.031	0.07	25.2	900	100
201	10.30	269	7.76	<0.1	0.3	<0.01	<0.01	0.01	4.2	1	1
202	10.90	355	8.08	<0.1	0.1	0.018	0.029	0.05	5.7	75	8
216	8.10	299	7.86	0.2	2.7	0.0366	0.0412	<0.01	7.6	0	0
219	6.50	220	7.95	<0.1	0.1	0.012	0.0137	<0.01	3.8	0	0
246	10.50	315	7.80	<0.1	0.1	0.0219	0.0364	0.03	5.9	0	0
248	14.50	317	7.52	3.1	5.2	0.065	0.092	0.06	14.4	2000	270
258	13.10	506	7.47	<0.1	0.4	<0.01	0.011	0.12	14.8	31	22
305	7.70	285	8.04	0.4	1.5	0.1342	0.15	0.02	5.3	18	4
315	14.40	309	7.92	0.2	2.1	0.0464	0.049	0.03	4.8	42	5
318	17.40	455	7.97	0.2	0.8	0.0241	0.026	0.03	15.7	1320	70

Table 2.N-4 RESULTS OF WATER QUALITY ANALYSIS (2)

	Source	Zone	No.	Coordination X(°N)	Coordination Y(°E)	Elevation Z (m)	Village	Code	Name of Spring/River
1	Spring	Coastal	coast-1	34.497500	35.938889	10	MINIEH	183	AIN EL BARDEH
2			coast-2	34.466111	35.938667	4	MINIEH	184	AIN EL CHARCHARA
3			coast-3	34.484444	35.933611	0	MINIEH	188	AIN EL SAKHRA
4			coast-4	34.484444	35.935833	27	MINIEH	189	AIN EZ ZARQA
5			coast-5	34.406944	35.815556	1	BOHSAS	502	NABAA BOU HALQA
6			coast-6	34.237500	35.727500	22	CHEKA	503	NABAA EL JRADI
7			coast-7	34.230000	35.728833	1	CHEKA	504	NABAA EL AAJOUZ
8			coast-8	34.057500	35.642222	2	AAYBE	508	NABAA EL AAQAYBE
9			coast-9	34.009167	35.644444	1	MAAMELTEIN	509	NABAA MAAMELTEIN
10			coast-10	34.000000	35.648167	20	HALAT	510	NABAA EL TEFFAHA
11		Low Elev	Low-1	34.053333	36.321944	286	BOQAATA	113	TAL ET TINE
12			Low-2	34.387500	35.931944	157	RACHAANE	136	NABAA RACHAANE
13			Low-3	34.370556	33.915000	147	KHALDEH	137	AIN EL KHALDEH
14			Low-4	34.422222	35.848889	226	ACHACH	138	AYOUN ACHACH
15			Low-5	34.591667	36.094722	51	SAADINE	149	NABAA EL HADDAD
16			Low-6	34.573056	36.094722	84	KOUAKHAT	162	NABAA EL QOLQAS
17			Low-7	34.658667	36.271111	614	QOBAYAT	172	AIN EL SET
18			Low-8	34.631944	36.094722	22	CHIR EL HMAIREH	176	NABAA EL HAMAM
19			Low-9	34.593333	35.101667	97	QHZAILI	177	NABAA QHZAILI
20			Low-10	34.512222	35.094722	84	KOUAKHAT	178	NABAA ABOU SHAMKAT
21			Low-11	34.450278	35.865833	275	MARKABTA	185	AIN MARKABTA
22			Low-12	34.441389	35.818944	249	OYOUN ES SAMAK	188	AIN MARJAR
23			Low-13	33.897222	35.542222	443	WADI ENEHLAY	207	NABAA EL AKHOUAT
24			Low-14	33.881944	35.525278	388	WADI ENEHLAY	208	AIN EL BARDEH
25			Low-15	34.084167	35.711667	170	YAHCHOUCH	247	NABAA EL MADIQ
26			Low-16	33.911944	35.593056	32	ANTELIAS	250	TANNOUR EL WADI
27			Low-17	33.911667	35.593056	30	ANTELIAS	251	FOUAR ANTELIAS
28			Low-18	33.897222	35.642222	465	DEIR DOURIT	259	NABAA EL MOUBARAK
29			Low-19	33.968611	35.626944	126	ZOUK MIKAEL	264	NABAA EZ ZOUK
30			Low-20	33.894444	35.542222	249	BEBRI	418	AIN EL BARDEH
31		Middle Ele	Mid-1	34.518556	36.247500	998	AKKAR EL ATTICA	107	NABAA ECH CHEIKH JNAD
32			Mid-2	34.514444	36.248722	1109	AKKAR EL ATTICA	108	NABAA OMAR KAYLO
33			Mid-3	34.530167	36.243889	864	AKKAR EL ATTICA	109	AIN EL WATEH
34			Mid-4	34.547222	36.263889	672	QOBAIYAT	115	AIN EL ABIAD
35			Mid-5	34.542222	36.310278	790	ANDQET	117	NABAA EL SHARQI
36			Mid-6	34.546111	36.304167	721	ANDQET	118	NABAA EL CHARQI
37			Mid-7	34.289167	35.982778	1510	EHDEN	139	NABAA MAR SARKIS
38			Mid-8	34.545000	36.308889	731	ANDQET	173	AIN EL TINE
39			Mid-9	33.699444	35.617778	971	BATER ECH CHOUF	211	NABAA BATER
40			Mid-10	34.098389	35.850556	1189	QARTABA	223	NABAA KHALAF
41			Mid-11	34.117500	35.858889	1539	ECH CHARBINE	225	NABAA ECH CHARBINE
42			Mid-12	34.117500	35.858611	1665	ECH CHARBINE	228	NABAA EZ ZOHR
43			Mid-13	34.198667	36.352500	908	LABOUE	314	NABAA ER ROUAISS
44			Mid-14	34.197500	36.351944	903	LABOUE	316	NABAA MATRAFE
45			Mid-15	34.198667	36.352778	903	LABOUE	317	NABAA SOUAIKA
46			Mid-16	34.241944	36.408944	981	FAKEHA	319	NABAA EL FAKEHA
47			Mid-17	33.723056	35.940111	881	ANJAR	330	NABAA ANJAR
48			Mid-18	33.540000	35.588944	1035	JEZZINE	401	NABAA JEZZINE
49			Mid-19	33.578611	35.588889	948	MACHMOUCHE	405	NABAA EL DAOUDIYEH
50			Mid-20	33.653889	35.626278	808	MOUKHTARA	419	NABAA MERCHED
51		High Ele	High-1	34.190278	35.935833	1739	TANNOURINE-HARISSA	120	AIN ES SAOUDA
52			High-2	34.182778	35.892778	1985	LAQLOUQ	126	NABAA EL FOUAR
53			High-3	34.169167	35.915833	1881	TANNOURINE-WADI EL JORD	127	EL HOUALIF
54			High-4	34.168611	35.918889	1750	TANNOURINE-WADI EL JORD	128	NABAA EL ANBOUB
55			High-5	34.199167	35.958278	1740	TANNOURINE-HARISSA	131	NABAA EL ASFAR
56			High-6	34.198611	35.958889	1841	TANNOURINE-HARISSA	134	NABAA EL JOID
57			High-7	34.261389	36.023333	1786	BCHARRE	141	NABAA NBAT
58			High-8	34.261944	36.009444	1753	BCHARRE	142	NABAA MAR SEMAAN
59			High-9	34.261389	35.998000	1545	BCHARRE	143	AIN EL HADDAD
60			High-10	34.225000	36.034167	1931	BEQAAKAFRA	145	NABAA EL JOUANI
61			High-11	34.224167	36.004722	1770	BEQAAKAFRA	147	NABAA EL AARBIT
62			High-12	34.202778	35.958167	1787	TANNOURINE-HARISSA	165	ARID EL MSALLEM
63			High-13	34.153889	35.901944	1972	LAQLOUQ	168	NABAA EL CHELLAL
64			High-14	34.168611	35.921389	1749	TANNOURINE-WADI EL JORD	169	NABAA CHAIAA
65			High-15	34.261944	36.021389	1773	BCHARRE	174	NABAA EL HARFOUCH
66			High-16	33.995000	35.828333	1846	KFARDEBIAN	213	NABAA EL LABAN
67			High-17	34.151389	35.882778	1904	AAKOURA	233	AIN EL BARBRISSE
68			High-18	34.141944	35.884444	1861	AAKOURA	234	AIN EL BAHRA
69			High-19	34.148556	35.878944	1818	AAKOURA	235	AIN EL QASSIS
70			High-20	34.138611	35.887500	1820	AAKOURA	260	AIN ES SAOUDA
71	River	Middle Str	Riv-1	34.650833	36.308889	260		601	NAHR EL KABIR
72			Riv-2	34.635556	35.978611	0	(alternative)	601-1	NAHR EL KABIR
73			Riv-3	34.563889	36.093333	78		602	NAHR OSTOUENE
74			Riv-4	34.600278	35.964167	20		603	NAHR EL BARED
75			Riv-5	34.478722	35.965000	61	(alternative)	603-1	NAHR EL BARED
76			Riv-6	34.309167	35.661944	285		604	NAHR ABOU ALI
77			Riv-7	34.465278	35.841667	9	(alternative)	604-1	NAHR ABOU ALI
78			Riv-8	34.061389	35.651944	16		605	NAHR IBRAHIM
79			Riv-9	34.076667	35.718944	251	(alternative)	605-1	NAHR IBRAHIM
80			Riv-10	33.688611	35.543333	12		610	NAHR EL AWALI
81			Riv-11	33.688611	35.386667	1	(alternative)	610-1	NAHR EL AWALI
82			Riv-12	33.491389	35.344167	6		612	NAHR EL ZAHRANI
83			Riv-13	33.463056	35.341389	7	(alternative)	612-1	NAHR EL ZAHRANI
84			Riv-14	33.330000	35.258611	2		613	LOWER LITANI
85			Riv-15	34.381667	36.415278	598		615	NAHR EL AASSI
86			Riv-16	34.421389	36.450944	595	(alternative)	615-1	NAHR EL AASSI
87			Riv-17	34.530556	36.042778	784		616	NAHR ARQA
88			Riv-18	34.513611	36.068056	126	(alternative)	616-1	NAHR ARQA
89			Riv-19	34.618611	36.321389	365		619	NAHR CHADRA
90			Riv-20	34.222222	35.840833	626		620	NAHR EL JAOUZ

Summer (Aug. 2002)

	Physical Prop. T (°C)	EC*1	EC25°C	pH	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Fe (mg/l)
1	19.40	1,007	977	6.8	158	17.1	17.6	2.1	307.2	25.8	183.2	0.01
2	19.60	921	895	6.67	140.8	14.1	17.9	3.3	291.4	26	87.5	0.01
3	21.50	285	248	7.02	104.2	37.6	14.8	1.2	298.1	21.3	73.2	0.02
4	19.90	893	857	6.71	132.4	15.8	8.4	0.79	304.3	12.3	86.4	0.03
5	18.90	815	803	7.17	180.6	14.4	11.8	1.9	227.8	20.6	23.4	0.01
6	17.70	576	579	7.12	72.1	16.9	28.4	3.9	189.6	47.8	28.2	0.03
7	16.90	581	596	7.36	74.4	13.4	25.7	2.4	285.4	39.6	31.1	0.02
8	23.70	1,278	1,087	7.03	160.1	32.6	217.9	8.4	228.4	338	70.2	0.03
9	18.20	oa*2		7.14	147.2	165.3	1,465	15.6	233.2	2,247	345.2	0.02
10	28.00	1,424	1,187	7.22	89.6	22.2	134.6	5.8	126.8	206.7	32.1	0.03
11	18.10	542	541	7.48	68.4	21.4	10.4	1.2	220.8	15.8	20.3	0.02
12	11.20	281	330	7.67	46	6.2	3.4	0.42	118.4	3	2.3	0.01
13	18.50	524	518	7.34	100.4	14.6	12.3	1.5	266.4	18.9	18.2	0.05
14	19.90	537	513	7.22	103.9	9.7	10.1	1.2	196.2	15.6	18.3	0.02
15	20.70	855	818	7.38	64.1	25.4	25.6	0.31	281.3	34.8	29.2	0.09
16	21.40	543	505	7.59	56.1	9.8	11.2	0.37	257.6	27.2	19.1	0.10
17	16.00	590	632	7.53	97.6	20.4	9.3	0.65	292.6	14.9	16.8	0.03
18	21.80	578	628	7.05	60.8	9.2	28.4	0.56	345.2	28.9	27.3	0.02
19	24.10	513	482	7.6	46.4	13.6	20.9	0.64	213.4	28.2	16.2	0.01
20	21.60	483	455	7.13	47.2	13.6	21.6	0.59	197.3	26.7	14.1	0.02
21	19.20	404	394	7.05	76.2	4.9	7.6	0.89	178.2	11.5	16.2	0.01
22	18.90	508	619	7.36	76.1	21.8	4.2	0.72	229.6	9.3	29.3	0.01
23	15.80	455	477	7.81	88.3	4.9	7.4	0.96	202.8	11.4	24.1	0.03
24	17.00	571	684	7.32	90.1	13.8	11.4	3.2	208.7	13.1	28.1	0.02
25	16.40	405	431	7.19	55.9	9.2	4.9	0.5	215.4	7.5	13.2	0.01
26	16.20	495	505	7.47	80.1	6.2	7.8	1.19	180.2	10.3	15.6	0.03
27	16.00	425	445	7.51	78.4	8.6	7.6	1.12	171.6	10.1	24.3	0.04
28	18.00	490	512	7.41	94.2	8.9	6.9	0.92	198.5	10.4	24.2	0.04
29	21.40	1,150	1,070	7.29	178.9	13.4	42.6	3.9	172.8	44.2	102.5	0.08
30	17.90	829	629	7.2	102.4	17.1	11.4	0.92	253.2	17.1	72.8	0.03
31	11.00	411	498	7.8	58.1	10.2	4.2	0.58	200.3	6.8	6.7	0.02
32	10.10	417	605	7.74	56.2	17.1	3.1	0.62	192.6	7.6	1.4	0.02
33	14.70	625	674	7.48	79.9	24.3	10.5	1.4	282	15.8	13.1	0.02
34	15.10	616	659	7.37	96.1	18.6	12.7	1.62	298.2	19.3	16.1	0.01
35	17.70	594	638	7.52	75.2	25.3	8.5	1.1	262.4	13.2	20.2	0.02
36	14.90	496	522	7.48	80	9.2	7.4	0.08	204.5	11.3	22.1	0.03
37	6.40	195	202	7.92	42.2	8.1	1.47	0.18	87.1	2.3	1.2	0.01
38	16.40	638	588	8.1	67.2	27.3	13.2	1.7	239.1	20	16.2	0.02
39	13.50	452	502	7.47	66.4	10.9	5.8	0.39	238.3	8.6	13.8	0.01
40	13.00	485	515	7.76	70.2	4.6	3.6	0.7	183.6	8.7	64.2	0.01
41	12.10	388	444	7.35	70.2	6.6	4.7	0.42	238.2	7.3	1.2	0.01
42	12.80	317	380	7.89	48.2	16.5	2.7	0.29	198.3	4.3	2.1	0.02
43	14.30	324	350	7.7	46.4	7.7	2.3	0.5	134.4	3.3	<0.1	0.01
44	14.20	323	352	7.73	43.2	9.7	2.3	0.51	138	3.2	<0.1	0.01
45	14.20	324	354	7.7	43.8	10.3	2.4	0.53	130.4	3.3	<0.1	0.02
46	17.90	367	368	7.8	43.5	16.4	5.6	0.59	135.2	7.5	9.4	0.05
47	14.90	417	448	7.61	51.2	11.4	4.3	0.39	201.2	6.9	16.3	0.02
48	13.20	398	445	7.56	59.2	12.4	3.9	0.33	209.3	6.6	2.1	0.01
49	15.20	692	631	7.26	96.3	14.6	7.2	1.09	250.6	11.6	16.2	0.01
50	14.20	486	530	7.97	80.2	10.9	3.4	0.58	246.5	8.5	13.7	0.02
51–70	(not done in dry season)				(not done in dry season)							
71	25.50	396	340	8.01	45.2	5.8	18.1	2.2	170	28.3	13.1	0.12
72	28.50	1,297	1,054	8.34	58.8	18.4	132.6	5.2	233.2	200.4	53.1	0.03
73	24.30	524	460	8.36	68.8	11.8	13.6	1.7	210	21.3	17.2	0.03
74	28.60	522	439	8.01	76.8	17.0	8.7	0.94	216.2	12.5	45.2	0.09
75	19.40	476	481	8.00	66.3	17.8	7.1	0.84	211.8	10.1	33.1	0.02
76	17.30	403	409	8.26	56.1	7.8	5.6	0.7	169	8.8	17.3	0.11
77	24.30	908	710	7.08	124.1	7.2	36.9	3.9	319.4	35.8	59.8	0.22
78	26.30	303	268	7.83	36.8	5.8	3.2	0.6	122	8.8	14.2	0.02
79	17.50	358	360	8.21	46.8	3.7	3.8	0.76	170.6	14.8	37.3	0.42
80	19.20	501	488	8.12	73.6	4.9	15.9	1.9	163	24.8	33.6	0.02
81	16.90	463	484	7.73	1.2	12.4	12.9	1.2	175.3	20.1	37.1	0.04
82	22.70	793	719	7.83	113.6	11.7	27.0	3.3	216	42.5	35.7	0.03
83	24.10	765	686	7.82	36.6	18.9	28.9	2.5	236.4	42.6	39.2	0.03
84	23.40	742	683	7.55	108.8	4.9	29.0	3.5	214	45.5	37.5	0.01
85	14.70	317	342	8.07	44.8	5.8	3.4	0.35	140.8	4.3	<0.1	0.02
86	17.30	245	248	8.25	49.3	12.9	3.3	0.41	165.4	3.2	1.3	0.02
87	24.10	483	428	8.33	57.6	5.8	13.1	1.6	178	20.5	16.4	0.16
88	18.90	528	519	7.79	60	24.3	8.9	3.1	217.2	13.7	16.3	0.01
89	19.70	457	441	7.96	56.2	1.3	16.5	10.6	195	6.8	17.2	0.2
90	15.20	405	402	7.79	61.6	0.6	7.8	5.1	171	8.2	13.4	0.15

Winter (Jan. 2003)

	Physical Prop. T (°C)	EC*1	EC25°C	pH	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Fe (mg/l)	Code (New)
1	19.90	1,141	1,085	7.05	180.8	20.4	22.1	2	308	34.4	142.5	0.01	
2	19.50	1,006	974	7.21	185.2	10.3	21.8	2.4	292	34.7	102.3	0.01	
3	19.10	893	872	7.07	14.8	12.2	16.2	1.1	311	25.4	75.8	0.01	
4	19.70	908	875	7.07	147.2	8.2	13.6	0.96	340	23.1	78.4	0.01	
5	18.60	609	801	6.92	105.6	5.2	15.4	0.74	254	24.4	22.1	0.02	
6	16.90	467	479	7.35	80.8	5.3	12.1	1.1	201	19.1	14.2	0.01	
7	16.90	728	748	7.16	88	7.3	49.9	2.4	212	78.3	27.1	0.02	
8	17.00	718	734	–	80	5.8	49.2	2.1	211	78.9	26.3	–	
9	16.90	2,020	2,070	7.22	112.1	41.4	79.4	21.4	126.8	112.2	27.5	0.07	
10	16.80	998	1,044	7.25	84.9	8.7	86.1	5.2	208	134.2	45.1	0.02	
11	17.40	548	557	7.47	74.4	9.7	11.8	1.2	236	19.4	17.4	0.01	
12	13.10	373	420	7.62	67.9	4.2	4.5	0.39	168	8.7	5.6	0.01	
13	17.90	617	618	7.3	110.4	7.3	12.9	0.96	260	18.7	18.2	0.01	
14	18.80	557	547	7.32	104.2	5.1	9.2	0.73	208	14.8	15.4	0.01	
15	20.50	675	640	7.52	85.1	25.6	26.2	1.1	199.3	48.2	29.5	0.08	
16	20.50	575	545	7.65	60	18.5	19.8	0.62	218	31.5	17.5	0.01	
17	14.80	611	557	7.26	103.6	7.5	9	0.96	308	14.4	8.9	0.01	
18	21.40	679	632	7.47	58.9	22.1	25.3	1.8	238	40.7	23.7	0.01	
19	20.20	518	484	7.65	45.4	11.2	20.1	0.62	204	32.1	14.6	0.01	
20	21.30	490	464	7.57	51.2	9.2	20.9	0.69	209	32.6	12.1	0.01	
21	19.00	434	425	7.4	91.6	3.8	6.2	0.8	194	13.1	12.6	0.01	
22	16.70	329	546	7.43	74.4	9.5	7.8	0.78	248	12.2	24.3	0.01	
23	15.40	496	526	7.67	76.2	12.4	8.7	0.52	222	10.8	27.1	<0.01	
24	16.00	537	583	7.46	91.5	7.6	10.8	0.72	243	16.8	26.2	0.03	
25	13.20	387	433	7.61	73.8	11.5	5.6	0.49	109	8	13.9	0.02	
26	14.80	439	472	7.45	81.6	3.2	7.4	0.72	179	10.9	24.1	0.02	
27	15.10	435	465	7.42	80	4.9	7.1	0.82	184	10.4	22.6	0.02	
28	15.30	513	543	7.35	77.6	13.1	6.8	0.48	226	11.8	28.3	0.01	
29	19.00	1,050	1,010	7.61	132.8	9.6	32.7	5.3	272	88.2	78.6	0.05	
30	17.30	680	609	7.37	99.2	4.9	10.9	1.4	221	16.8	58.4	0.02	
31	10.40	405	480	7.79	80.1	20.9	5.2	0.39	204	8.5	1.2	0.01	
32	9.90	413	503	7.7	58.8	9.5	51.6	0.42	199	8.1	3.3	0.03	
33	13.60	623	690	7.38	77.8	22.3	9.9	0.86	301	16.6	12	0.04	
34	14.90	654	702	7.2	107.5	15.8	9.3	0.82	338	15.1	15.8	0.01	
35	13.40	543	604	7.71	77.8	11.5	9.4	1	273	14.8	15.8	0.01	
36	14.30	493	534	7.41	84.8	8.7	8.1	0.56	248	9.7	18.8	0.01	
37	7.70	201	260	8.18	33.6	8.3	2.2	0.42	95	3.8	1.1	0.02	
38	14.10	572	626	7.46	79.6	19.2	8.2	0.94	275	14.2	12.2	0.01	
39	13.10	444	498	7.72	84.2	8.3	5.6	0.54	199	8.4	19.2	0.08	
40	13.40	405	461	7.67	62.4	10.2	5.4	0.82	169	8	32.4	0.08	
41	9.80	434	530	7.69	57.8	11.8	3.4	0.28	216	5.2	0.8	0.03	
42	9.90	408	498	7.63	52.1	9.2	3.1	0.39	192	3.9	1.3	0.01	
43	14.40	328	356	7.79	42.9	6.2	2.6	0.41	150	4.7	2.3	0.01	
44	14.40	328	356	7.81	44.2	6.5	3.2	0.66	152	5	0.8	0.02	
45	14.40	328	358	7.78	43.9	6.2	2.7	0.45	160	4.2	0.7	0.02	
46	17.80	371	373	7.86	44.8	7.3	6.07	0.66	162	9.3	0.8	0.01	
47	14.90	430	483	7.81	69.1	7.1	3.4	0.68	205	9.5	15.1	0.02	
48	12.90	399	449	7.68	62.4	5.6	4.9	0.61	185	7.8	14.1	0.08	
49	14.30	519	555	7.24	91.6	5.7	7.8	0.64	226	11.7	17.5	0.02	
50	12.70	465	526	8.13	78.4	5.8	5.9	0.97	212	9.8	17.6	0.02	
51	7.80	340	439	7.94	59.2	8	3.7	0.29	187	5.2	13.2	0.01	
52	6.60	359	479	7.66	43.2	6.8	2.3	0.19	174	3.3	0.3	0.01	
53	7.40	346	461	7.71	59.4	8.2	3.5	0.08	184	5.4	15.3	0.09	
54	7.60	248	319	8.25	40	5.3	3.3	0.79	113	5.1	11.2	0.26	
55	7.80	398	513	8.03	41.7	3.4	2.8	0.32	129	4.9	13.2	<0.01	
56	8.30	391	497	7.8	41.7	3.4	2.9	0.39	172	4.5	0.2	<0.01	
57	8.70	283	358	7.8	41.6	4.1	3	0.35	132	4.5	1.2	0.01	
58	7.10	215	283	7.96	30.7	7.8	2.4	0.29	99	3.8	0.4	<0.01	
59	8.70	284	357	7.83	41.7	3.4	3.2	0.38	129	5.1	1.2	<0.01	
60	9.70	365	447	8.18	58	5.8	3.1	0.4	168	4.7	9.2	0.02	
61	5.30	235	328	7.89	33.8	5.8	2.3	0.29	109	3.8	1.1	<0.01	
62	5.80	373	495	8.22	61.1	4.7	4.1	0.42	178	6.4	9.2	0.03	
63	8.10	488	621	7.56	84.5	6.5	2.8	0.21	244	4.2	1.2	0.01	
64	8.40	291	389	8	58	7.8	2.8	0.24	157	4.2	10.4	0.04	
65	7.50	201	261	8.02	28.9	4.8	2.6	0.24	92	3.9	1.3	<0.01	
66	6.30	223	300	8.03	32.8	5.3	2.6	0.32	218	4.9	3.4	0.02	
67	7.60	337	437	7.8	44.8	9.7	2.9	0.38	172	4.8	0.2	0.01	
68	7.30	382	500	7.8	45.1	9.8	9.1	0.78	175	14.4	22.3	0.07	
69	8.30	404	514	7.65	49.6	17.8	3.2	0.4	203	5.1	2.2	<0.01	
70	8.70	404	508	7.8	62	9.2	3	0.29	196	4.7	7.3	<0.01	
71	11.40	492	578	8.09	51.2	17.1	13.9	1.05	187	20.8	27.2	0.08	601
72	12.60	512	591	8.22	67.2	12.7	9.8	0.87	218	14.8	20.1	0.04	602
73	8.50	501	633	7.96	69.8	8.7	8.1	1.4	189	12.2	29.4	0.05	603
74	9.00	734	915	8.31	70.4	12.2	7.3	0.72	199	11.2	28.3	0.02	604
75	12.60	419	475	8.15	67.3	8.8	5.2	0.69	209	8	19.1	0.07	605
76	11.80	406	470	7.76	68.8	12.8	5.8	0.52	175	9.2	21.2	0.24	606
77	13.20	419	488	8.07	70.2	6.3	5.9	0.42	172	9.1	22.3	0.2	607
78	14.10	479	524	7.9	85.4	1.6	11.2	0.84	179	17.3	59.2	0.18	608
79	13.90	464	510	8.09	75.2	5.3	9.2	0.83	188	14.8	40.8	0.07	609
80	12.10	462	531	8.05	78.2	8.3	10.6	1.3	192	16.7	35.4	0.44	610
81	13.90	497	546	8.17	98.1	8.8	11.6	0.99	194	17.4	37.2	0.31	611
82	14.00	371	407	8.15	65.8	9.2	6.9	0.58	173	10.4	15.4	0.15	612
83	14.20	446	487	8.09	76.8	8.7	9.8	0.87	185	14.2	31.1	0.49	613
84	10.80	669	795	7.82	107.2	16.4	19.7	0.92	197	29.8	35.4	0.12	614
85	13.40	343	382	8.27	63.4	9.8	4.1	0.79	158	7.4	2.2	0.03	615
86	14.70	538	590	8.02	64.8	17.6	10.2	0.80	216	15.7	28.2	0.02	616
87	10.90	340	403	8.04	68.2	15.1	7.2	0.79	202	11.1	22.1	0.03	617
88	14.20	491	438	8.01	75.1	14.2	9.2	0.05	183	10.8	23.4	0.18	618
89	19.70	437	441	8.02	55.1	13.7	7.8	0.63	179	9.8	21.4	0.09	619
90	15.20	401	432	7.8	89.3	12.4	9.7	0.63	198	9.7	25.2	0.9	620

Code (New)	X(°N)	Y(°E)	Z (m)
601	34.650833	36.308889	250
602	34.563889	36.093333	78
603	34.600278	35.964167	20
604	34.309167	35.661944	285
605	34.267500	35.661389	4
606	34.061389	35.651944	16
607	33.950833	35.606111	17
608	33.880833	35.531667	7
609	33.704722	35.448333	3
610	33.688611	35.543333	12
611	33.035278	35.36611	6
612	33.491389	35.344167	6
613	33.330000	35.258611	2
614	33.853611	35.98861	931
615	34.381667	36.415278	598
616	34.530556	36.042778	784
617	35.698888	33.98111	821
619	33.763611	35.90500	675
619	34.618611	36.321389	365
620	34.722222	35.840833	626

*1 (mS/cm)
*2 Over scale

CHAPTER 3

TOOLS FOR DECISION MAKING IN WATER RESOURCES MANAGEMENT

CHAPTER 3 TOOLS FOR DECISION MAKING IN WATER RESOURCES MANAGEMENT

3.1 GIS Database

3.1.1 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.

3.1.2 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.

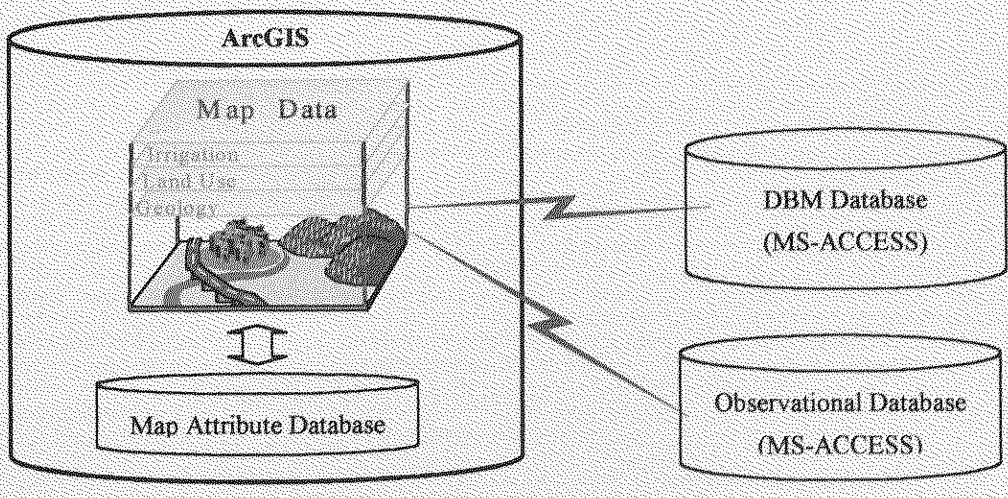


Figure 3.1-1 Image of Data Composition

Table 3.1-1 shows the list of map data.

Table 3.1-1 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	WaterSourceTransmissio n	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 3.1-1 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 3.1-2 shows the list of attribute data.

Table 3.1-2 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 atation
	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

3.2 Hydrogeological Circulation Model

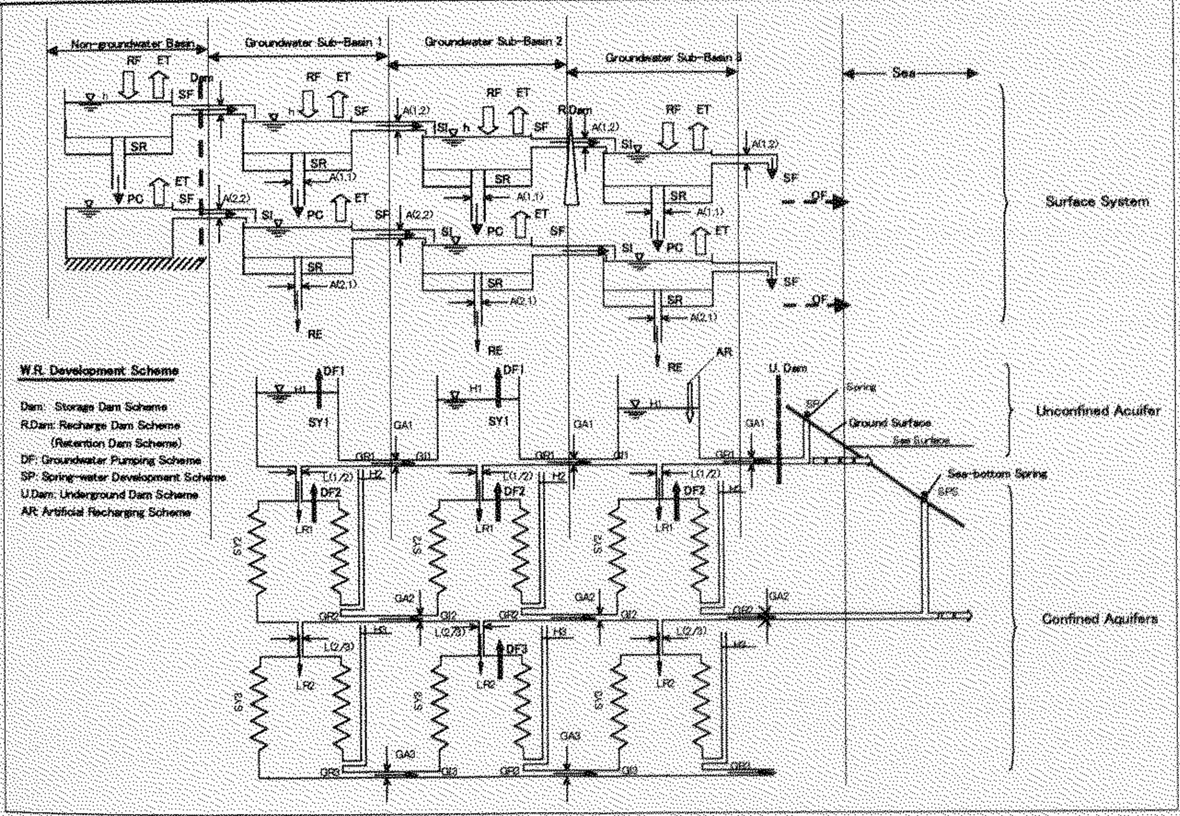
In the Study, a water balance simulation model named Synthetic Storage Model (SSM) developed in Japan was adopted for the model of water balance simulation study. It is a kind of "Hydrogeological Circulation Model" directly based on the natural hydrogeological circulation. In this chapter, only the concept 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».

3.2.1 Concept of Hydrogeological Circulation Model

(1) Concept of the model

The concept of hydrogeological circulation is summarized as Figure 3.2.1.

Figure 3.2-1 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-transpirated 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.

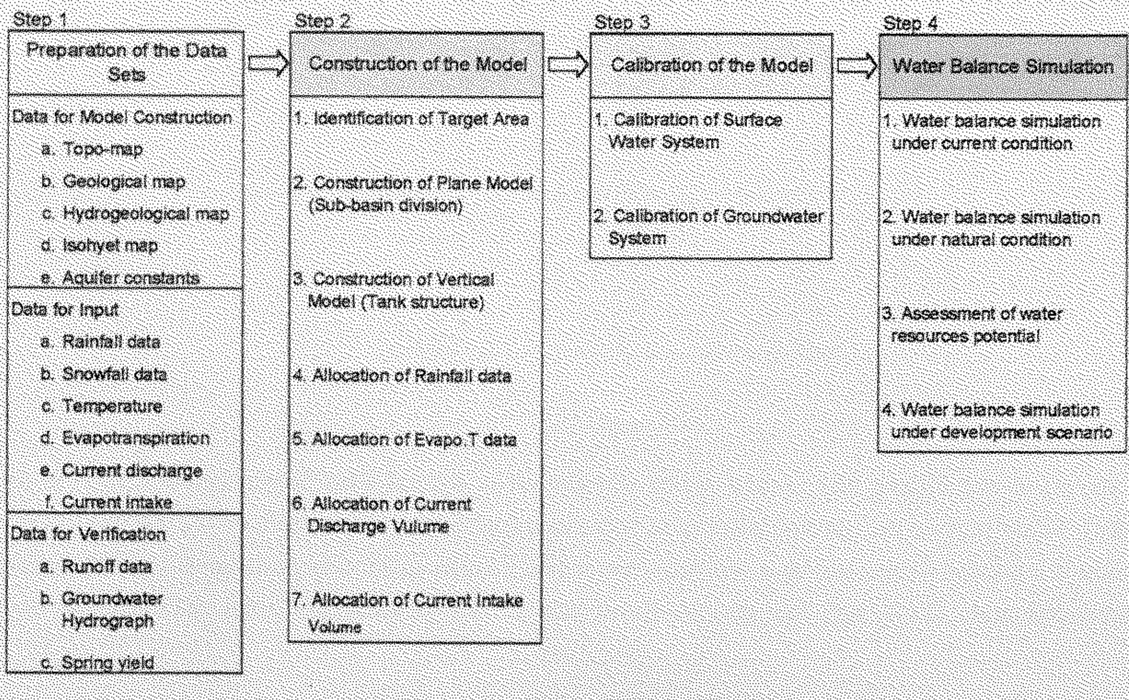
Normally through the second tanks, or directly from the uppermost tanks, some portion of the precipitation infiltrates into saturated zone, as a recharging of groundwater (RE). The groundwater system is divided into two categories: unconfined aquifer system of the uppermost raw, and confined aquifer 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 leakance (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 3.2.2.

Figure 3.2.2 FLOW OF SSM SIMULATION STUDY



3.2.2 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 3.2.3.

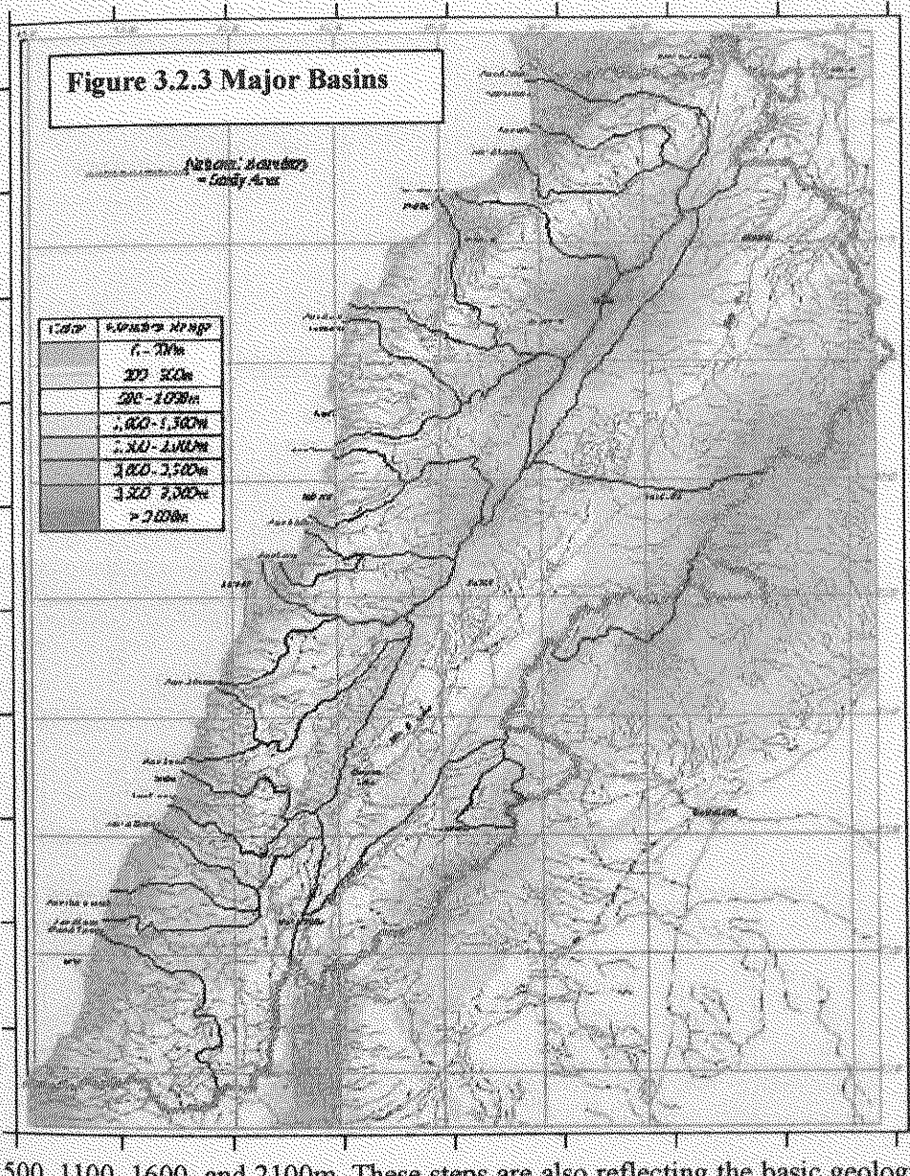
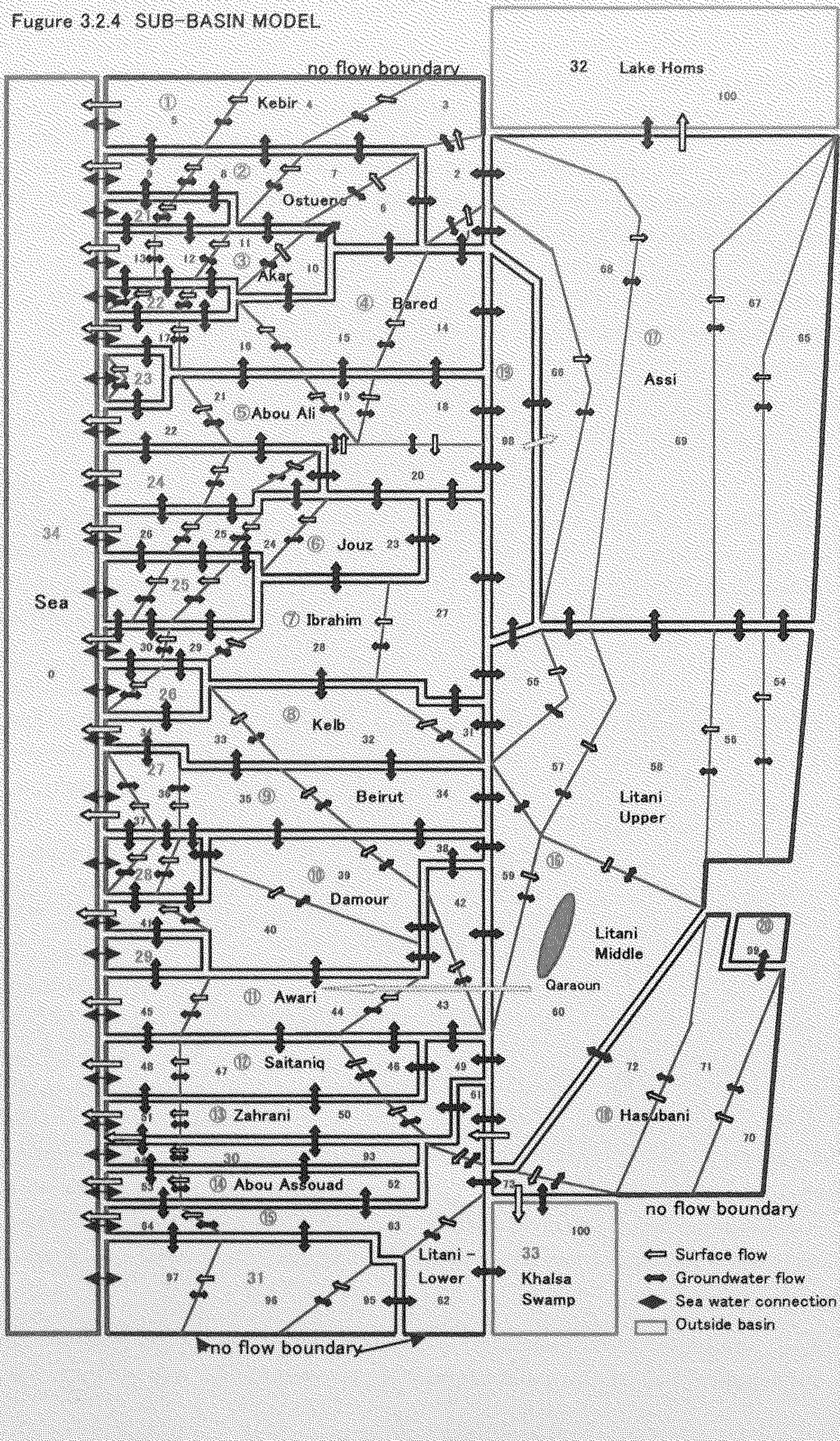


Figure 3.2.3 Major Basins

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 3.2.4.

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

Fugure 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.

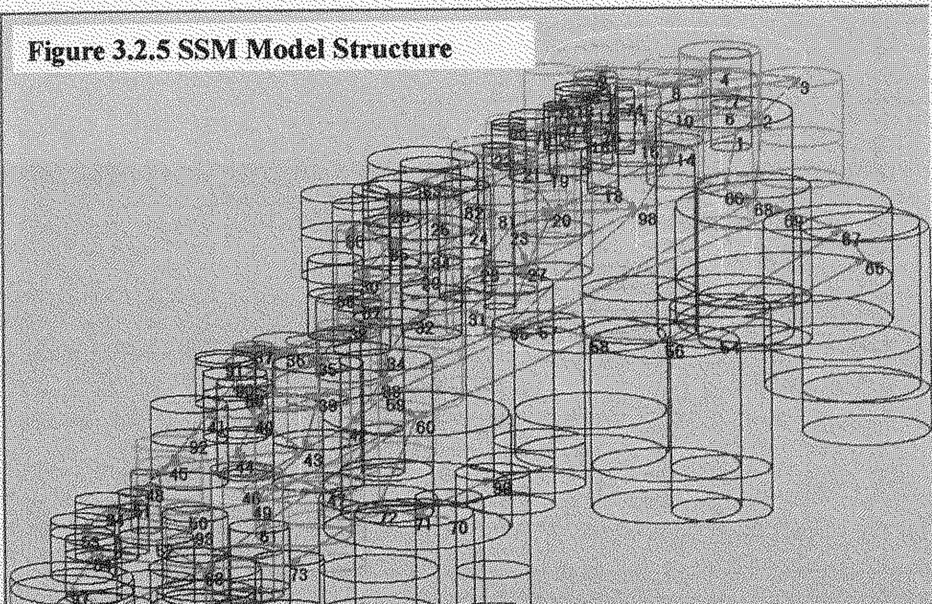


Figure 3.2.5 SSM Model Structure

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 3.2.5.

3.2.3 Calibration of the Model

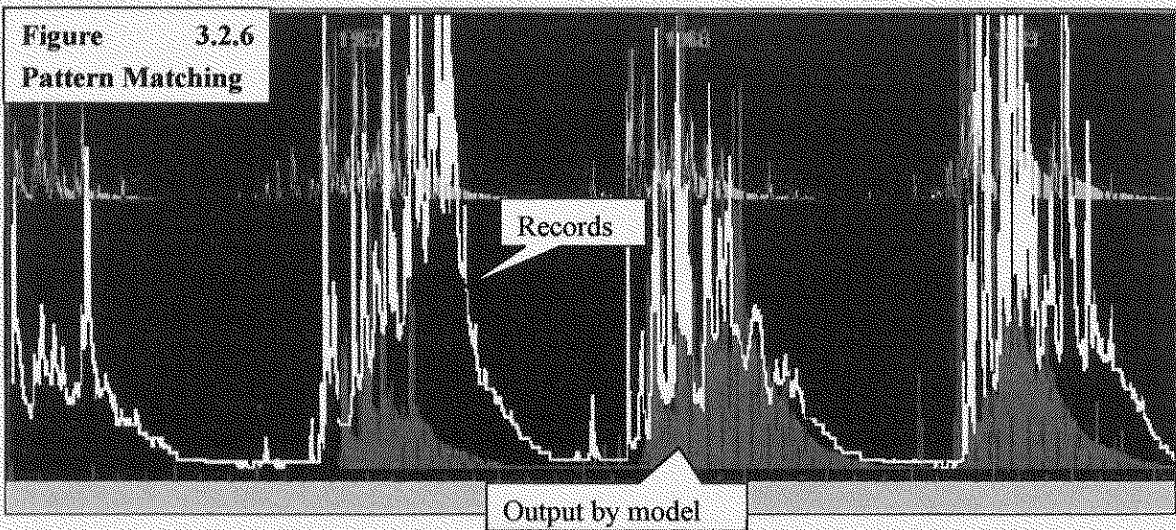
After construction of the model, it must be verified by actual records, the surface structure by river runoff records and the groundwater structure by groundwater hydrograph. The both structures are calibrated modifying their parameters a little by little until the output of the model matches to the 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 3.2.6. In this Study, however, because of no snowfall data it was impossible to make the

Figure 3.2.6 Pattern Matching



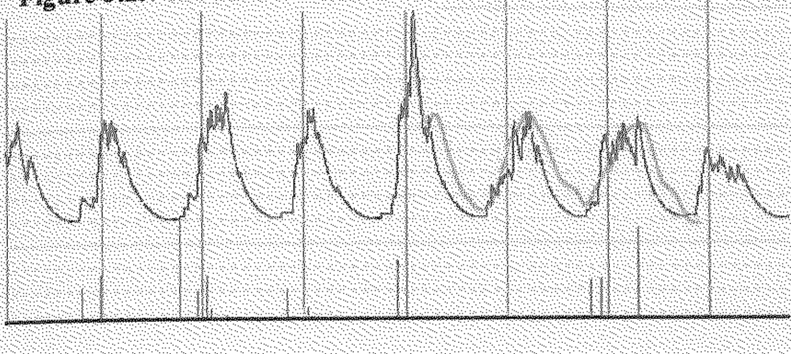
pattern matching, so that the model must be calibrated by the yearly runoff volume. In this case, the series of yearly runoff at 1996 was adopted, because the year 1996 had average yearly rainfall of recent ten (10) years. Calibration procedures are just "try and error approach". A certain set of tank 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 3.2.7 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.

3.2.4 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. Further discussion on the water balance under the natural condition shall be done in the following chapter (Chapter 4.1).

(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.