Figure 3.4.3.1 Distribution of Existing Production Wells

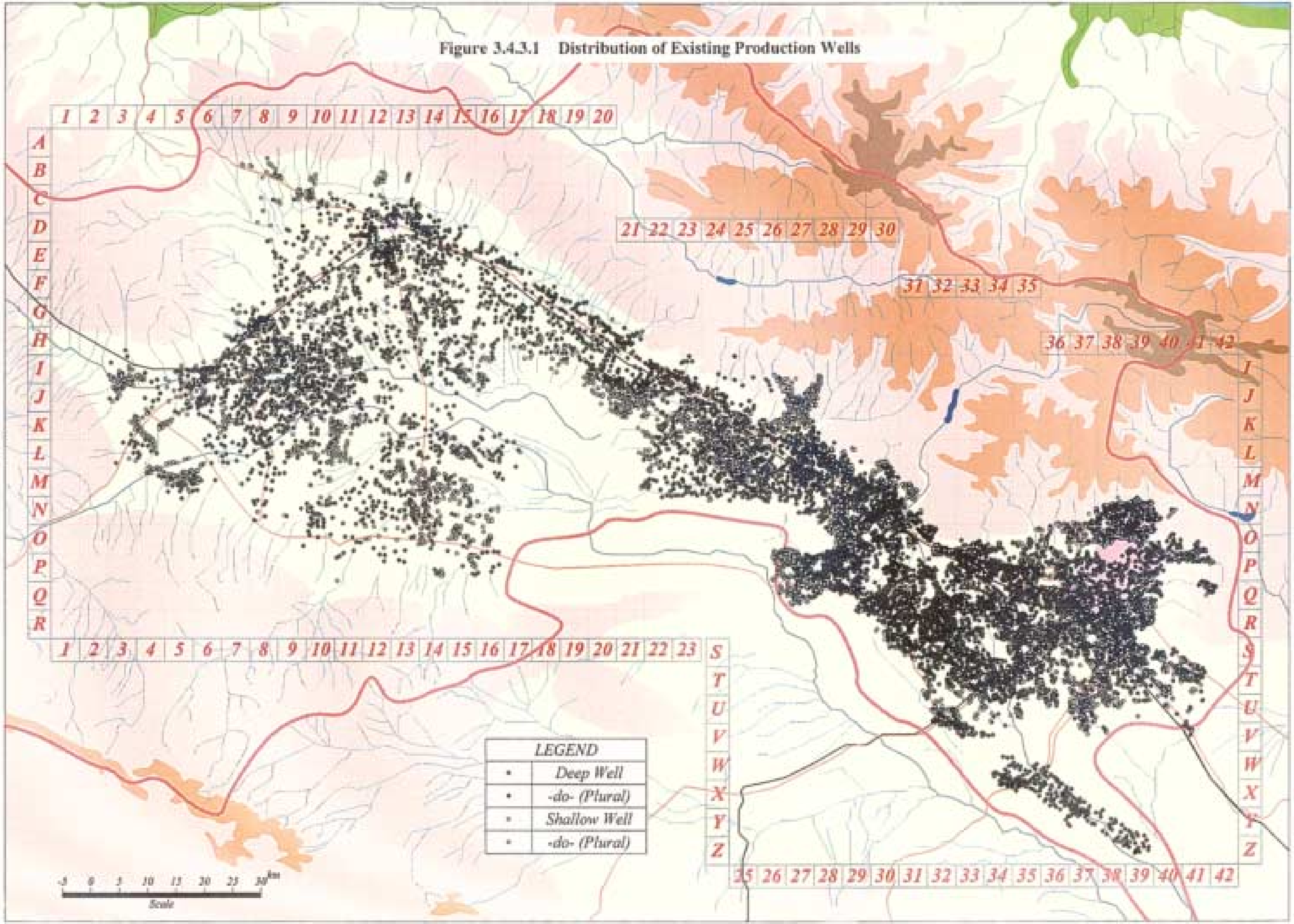
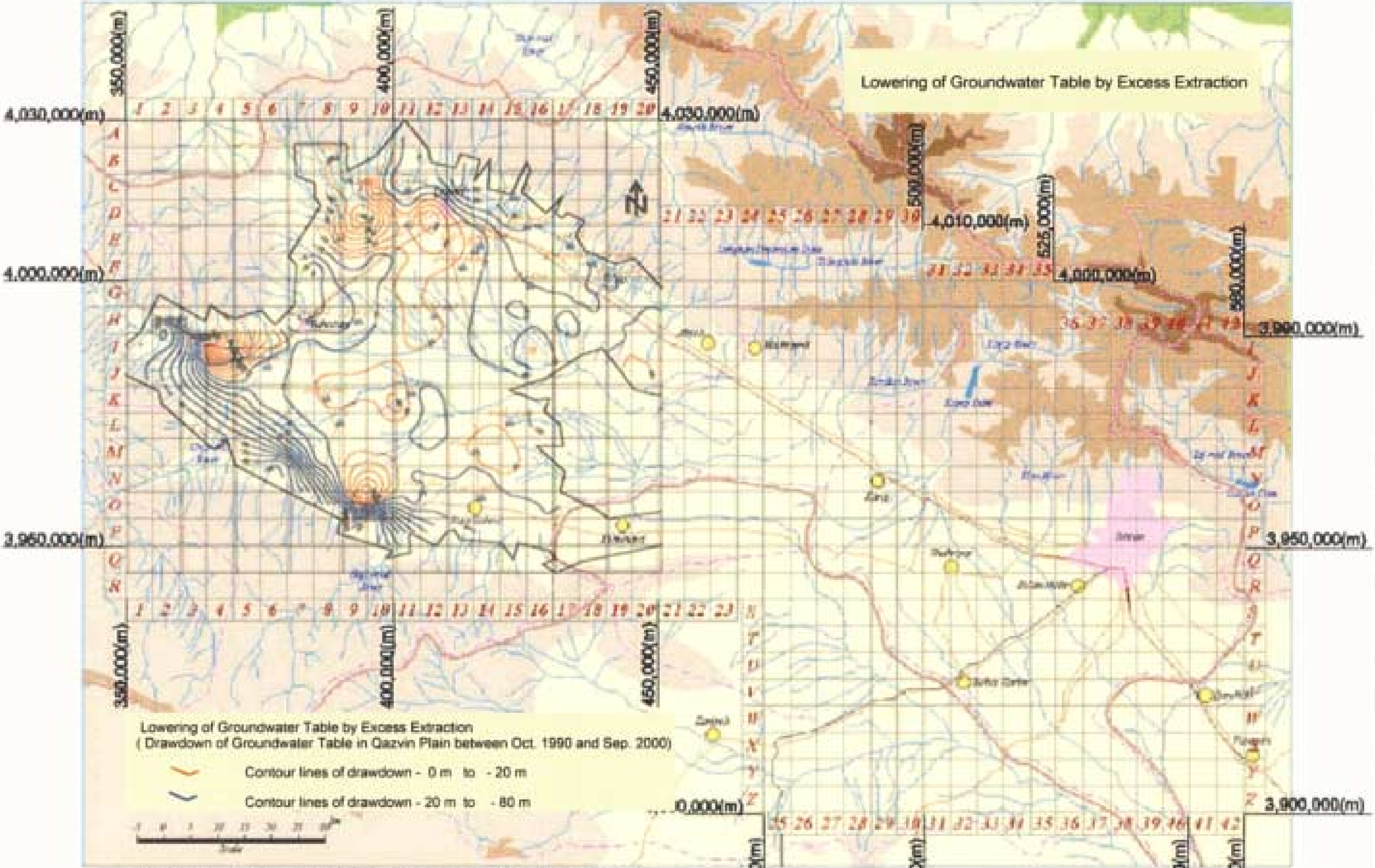
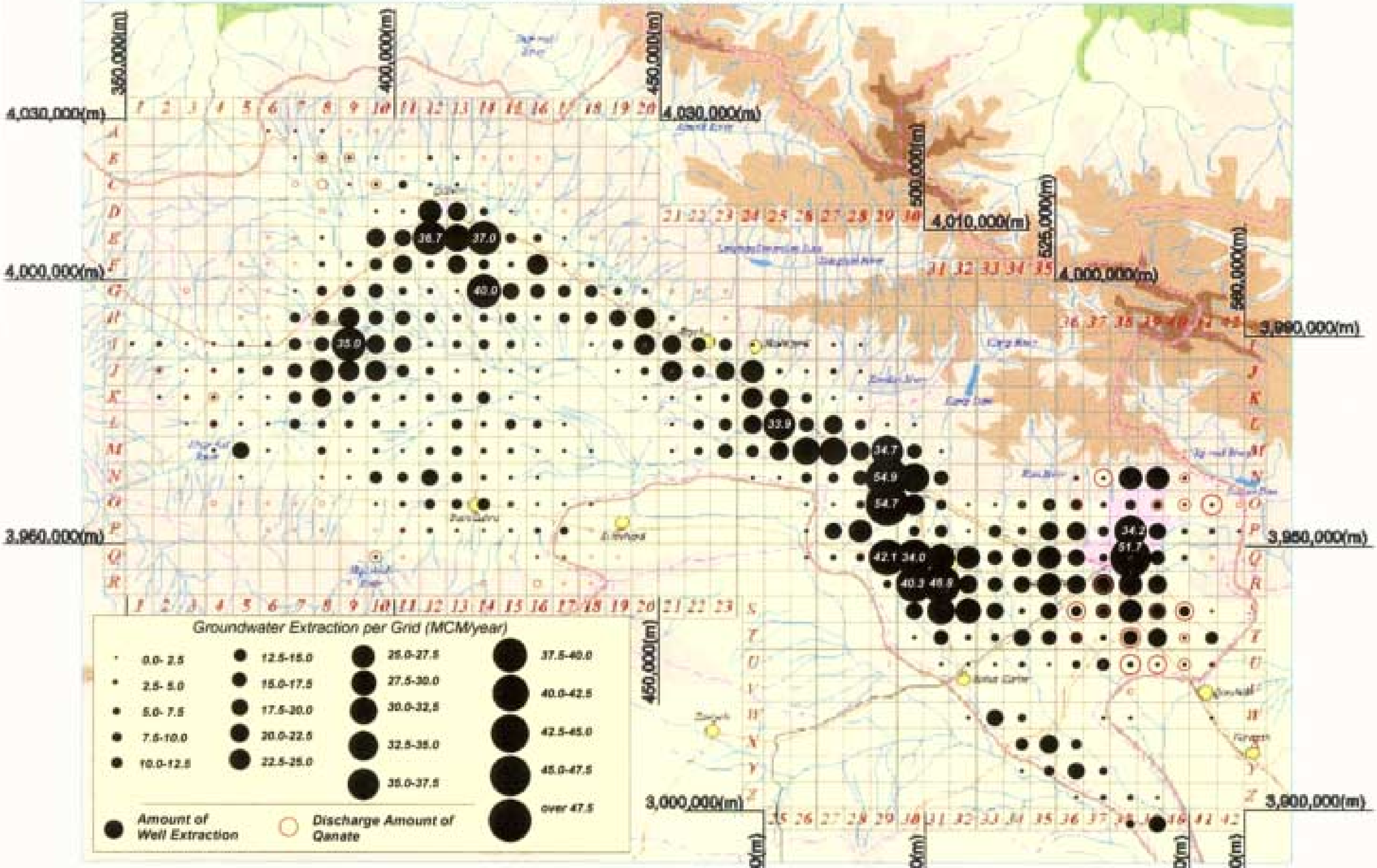


Figure 3.4.4.1 Lowering of Groundwater Table by Excess Extraction



Note: This map is compiled from "Different water surface betwenn Oct. 1990 and 2000 in Qazvin Plain" drawn by TRWB Qazvin office

Figure 3.4.4.2 Extracted Groundwater Volume



*1 Note: The extacted amount and location are plotted on the basis of TRWB's reseach. "Statistical Reports of Groundwater Recsources(1993/95)". However, qanates records at Karaj and Hashtgred are not included in the map.

Table 3.4.5.1 Summary of Groundwater Recharge

Summary of Estimation of Groundwater Recharge(1/3)
(a) Groundwater Recharge from Precipitation

Items	Qazvin south	Qazvin north	Hashtgred	Karaj	Tehran	Tehran City	Total
	(MCM/year)						
Annual Amount of Recharge	12	19	4	4	9	0	48

Summary of Estimation of Groundwater Recharge(2/3)
(b) Groundwater Recharge from Rivers

Sub-basins (outside groundwater basin) *	Area (Km2)	Qazvin south	Qazvin north	Hashtgred	Karaj	Tehran	Tehran City	Total
		(MCM/year)						
Sub-basin1	518.6	16						16
Sub-basin2	969.8	26						26
Sub-basin3	340.4	10						10
Sub-basin4	4,418.5	121						121
Sub-basin5	1,672.5	45						45
Sub-basin6	669.9	7	10					17
Sub-basin7	569.1		84					84
Sub-basin8	311.4		40					40
Sub-basin9	317.0		33					33
Sub-basin10	155.9		5	46				51
Sub-basin11	419.6			29	67			96
Sub-basin12	1,020.0				43			43
Sub-basin13	318.7					9		9
Sub-basin14	121.6					0	0	0
Sub-basin15	265.9					0	0	0
Sub-basin16	274.3				5	4		9
Sub-basin17	168.5	1		3	2			5
Total	21,711.1	226	172	77	117	12	0	605

Note: Location of sub-basin is shown in a figure given in above sub-section of "Area Precipitation"

Summary of Estimation of Groundwater Recharge(3/3)
(C) Return Flow from Wells and City Water Supply

Items*	Qazvin south	Qazvin north	Hasht-gred	Karaj	Tehran	Tehran City	Total
			(MCM/year)				
Irrigation (qazvin, canals + well)	80						80
Irrigation (qazvin, wells, year)	71	76	10				157
Irrigation (qazvin, wells, season)	6	34					40
Irrigation (west, wells, year)			24	62	107	1	194
Total	156	110	35	62	107	1	471

Note: Extent of irrigation area is referred in a figure of "Coverage Type on Groundwater Recharge"

Table 3.4.5.2 Groundwater Balance (1994/1995 and 1999/2000)

Groundwater Balance (Estimated Period: 1374: 1994/95)

Region	In (+)							Out(-)					Balance	
	Ground-water inflow	Groundwater recharge: from rivers	Groundwater recharge: return flow from irrigation	Groundwater recharge: direct from precipitation	Groundwater recharge: return from city water supply	Groundwater recharge: artificial recharge	In(+) total	Well Extraction	Qanat Discharge	Ground water outflow	Evaporation from salt marsh	Out(-) total		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		(9)	(10)	(11)	(12)	(13)
Tehran City	207	0	1	0	435		643	230	147	267		644	-1	
Tehran	491	12	107	9			619	486	125	19		631	-12	
Karaj	93	117	62	4	52		328	328		0		328	-1	
Hashtgred	88	77	35	4			203	183		0	22	205	-2	
Qazvin (north)	141	172	156	12	18	31	529	472	31	0	10	513	15	
Qazvin (south)	420	226	110	19			776	621	38	12	27	699	77	
Total	1,439	605	471	48	504	31	3,097	2,321	341	299	60	3,021	77	77

Groundwater Balance (Estimated Period: 1379: 1999/2000)

Sub-areas	In (+)							Out(-)					Balance	
	Ground-water inflow	Groundwater recharge: from rivers	Groundwater recharge: return flow from irrigation	Groundwater recharge: direct from precipitation	Groundwater recharge: return from city water supply	Groundwater recharge: artificial recharge	In(+) total	Well Extraction *1	Qanat Discharge	Ground water outflow	Evaporation from salt marsh	Out(-) total		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		(9)	(10)	(11)	(12)	(13)
Tehran City	207	0	1	0	435		643	230	147	266		643	-1	
Tehran	490	12	107	9			619	500	125	19		645	-26	
Karaj	93	117	62	4	52		328	452		0		452	-125	
Hashtgred	88	77	35	4			203	228		0	22	250	-47	
Qazvin (north)	141	172	156	12	18	31	529	776	31	0	10	817	-288	
Qazvin (south)	420	226	110	19			776	971	38	12	27	1,049	-273	
Total	1,438	605	471	48	504	31	3,097	3,158	341	298	60	3,857	-760	-760

(1), (9), (10):Refer to sub-section "Groundwater Runoff", these amounts were calculated on the basis of groundwater table record. taken Oct/1994.

(2):Refer to sub-section "Groundwater Recharge", G. Recharge from river was estimated from the surface runoff data, potential-evaporation and channels length and width and infiltration potential.
Study Area.

(4):Refer to sub-section "Groundwater Recharge", G. recharge from precipitation was estimated with "Area Rainfall" and "Infiltration Coefficient" settled in existing studies.

(6):Amount of "Artificial Recharge" was the average of performance data in last 10 years.

(7):Totaled with (1) to (6), as amount of "In (+)" items in groundwater balance (or budget),

(8):G. Extraction was estimated based on well inventory surveys copmleted in 1996 and partly 1993, details refer to sub-section "Groundwater Extraction"

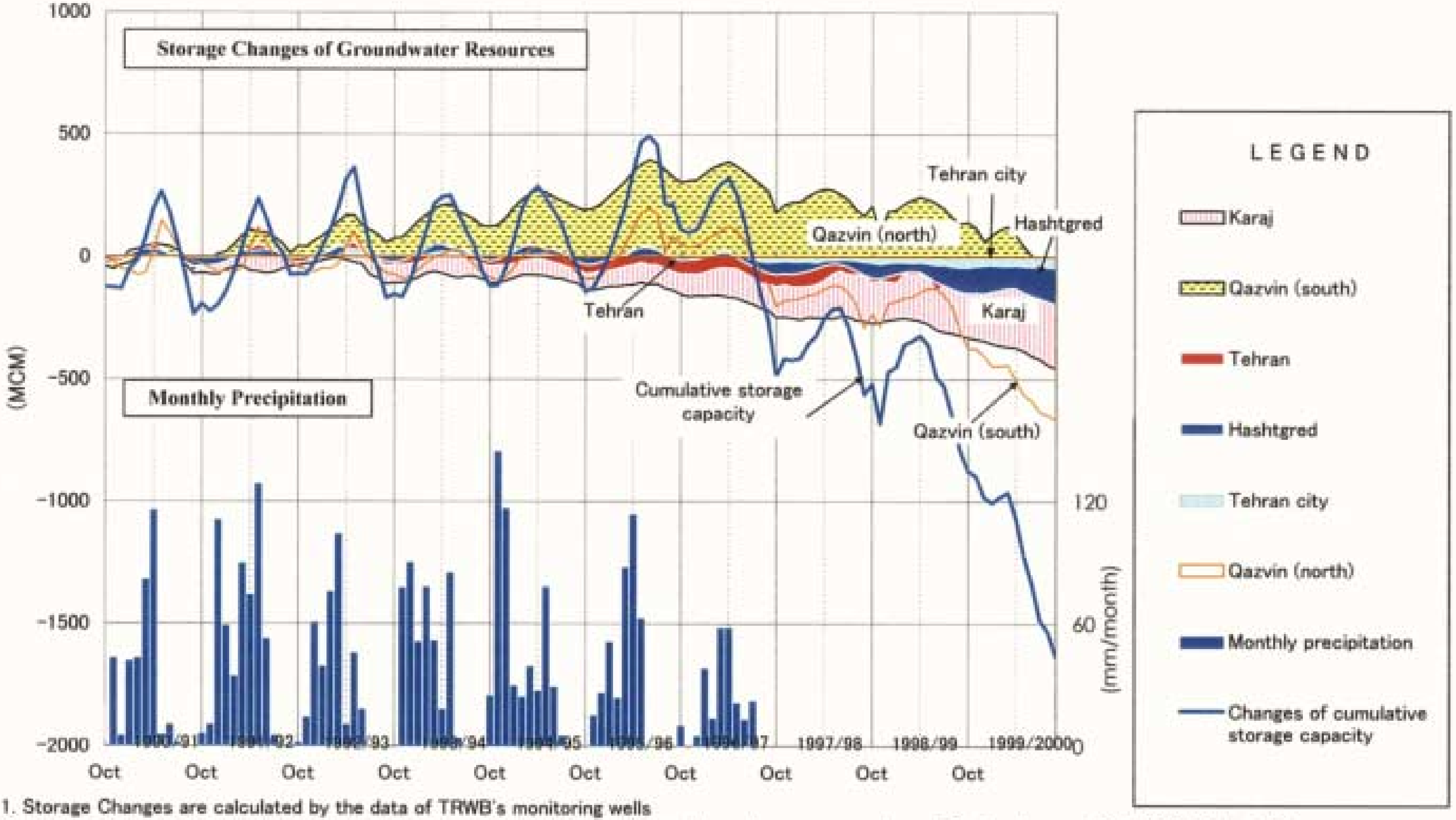
(11):Totaled with (1) to (6), as amount of "Out (-)" items in groundwater balance (or budget)

(12):Out (11) minus "In (7)", this just means a calculating result of the difference for respective "Sub-Areas", and this value were not considered "amount of in/out flow" passing through neighbouring "Sub-Areas"

(13):Out (11) minus In (7), this figure was given as an indication of "Storage Changes" of groundwater at 1994/95 and 1999/2000.

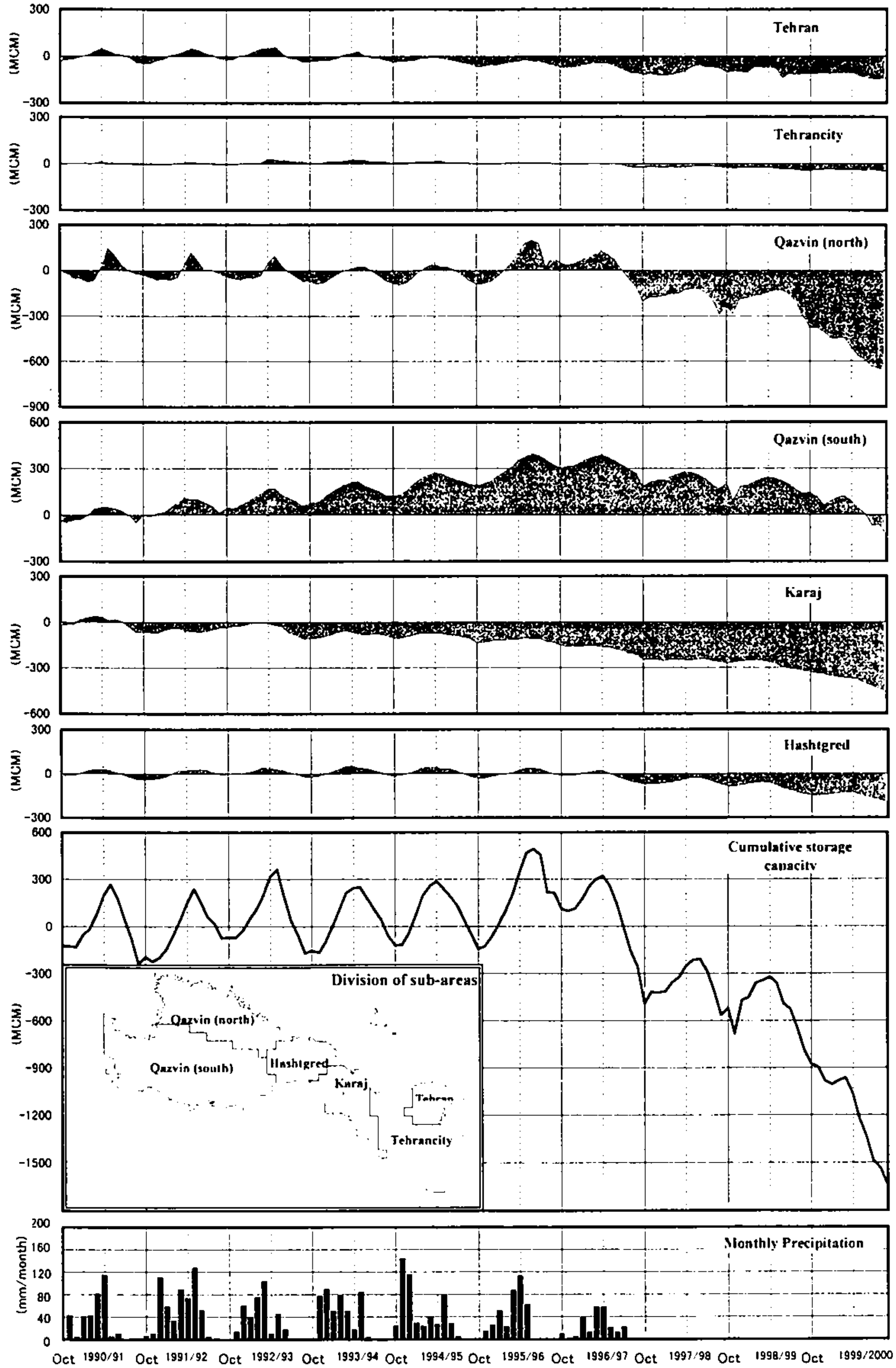
*1: Amount of well extraction in 1999/2000 exceeds the facility capacity of production wells based on "Statial Report of gropundwater Resources1376(1996/1997), therefor the re-evaluation must be requred later on.

Figure 3.4.5.1 Storage Change of Groundwater Resources (,Oct./1990 - Sep./2000), sheet 1/2



Note : 1. Storage Changes are calculated by the data of TRWB's monitoring wells
2. Storage Changes shows a disparity between calculated values of every months and an average volume of first water year (Oct/1990 - Sep/1991)

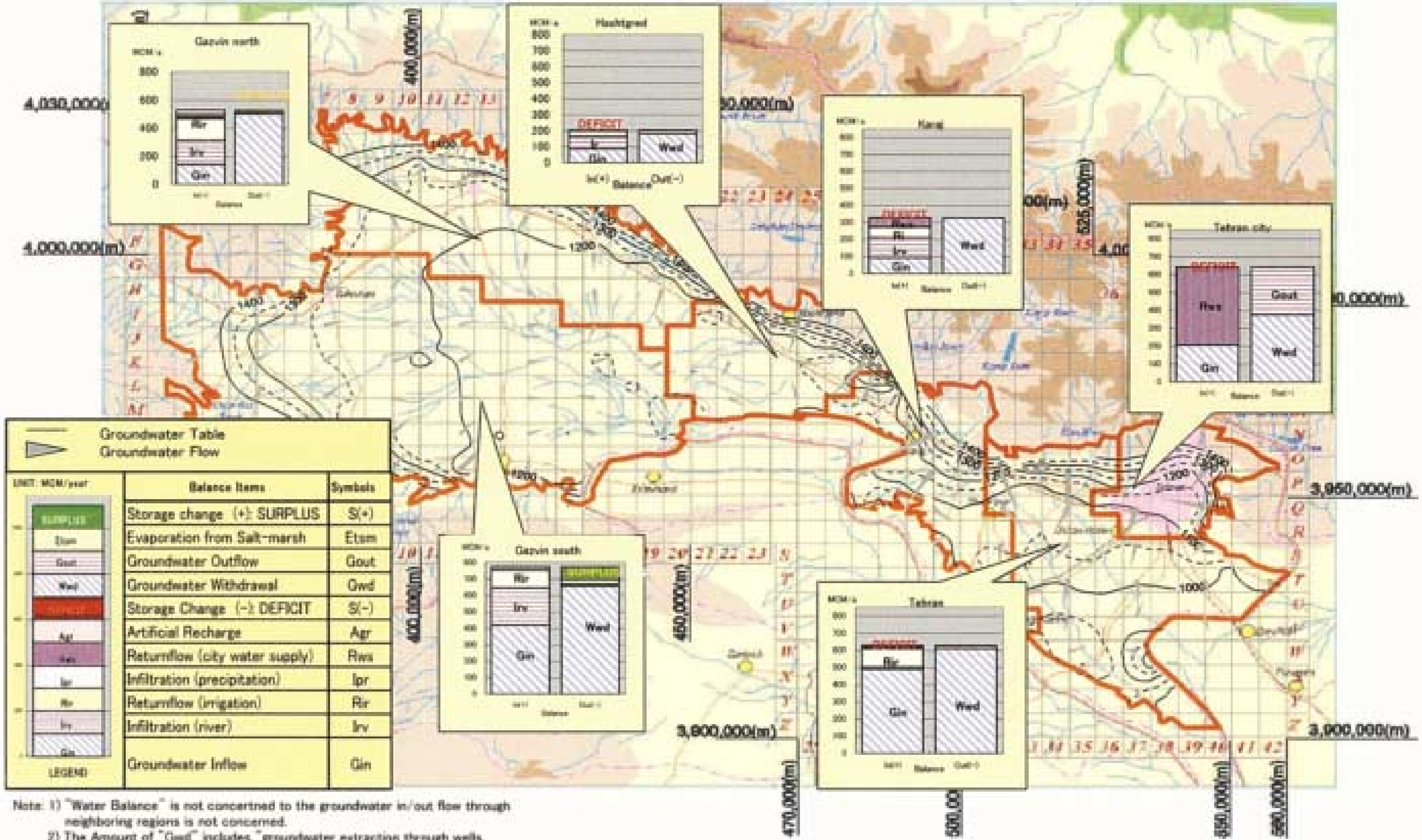
Figure 3.4.5.2 Storage Change of Groundwater Resources (Oct./1990 - Sep./2001), sheet 2/2



Note : 1. Storage Changes are calculated by the data of TRWB's monitoring wells
2. Storage Changes shows a disparity between calculated values of every months and an average volume of first water year (Oct/1990 - Sep/1991)

Storage Changes of Groundwater Resources (Oct/1990 - Sep/2000)

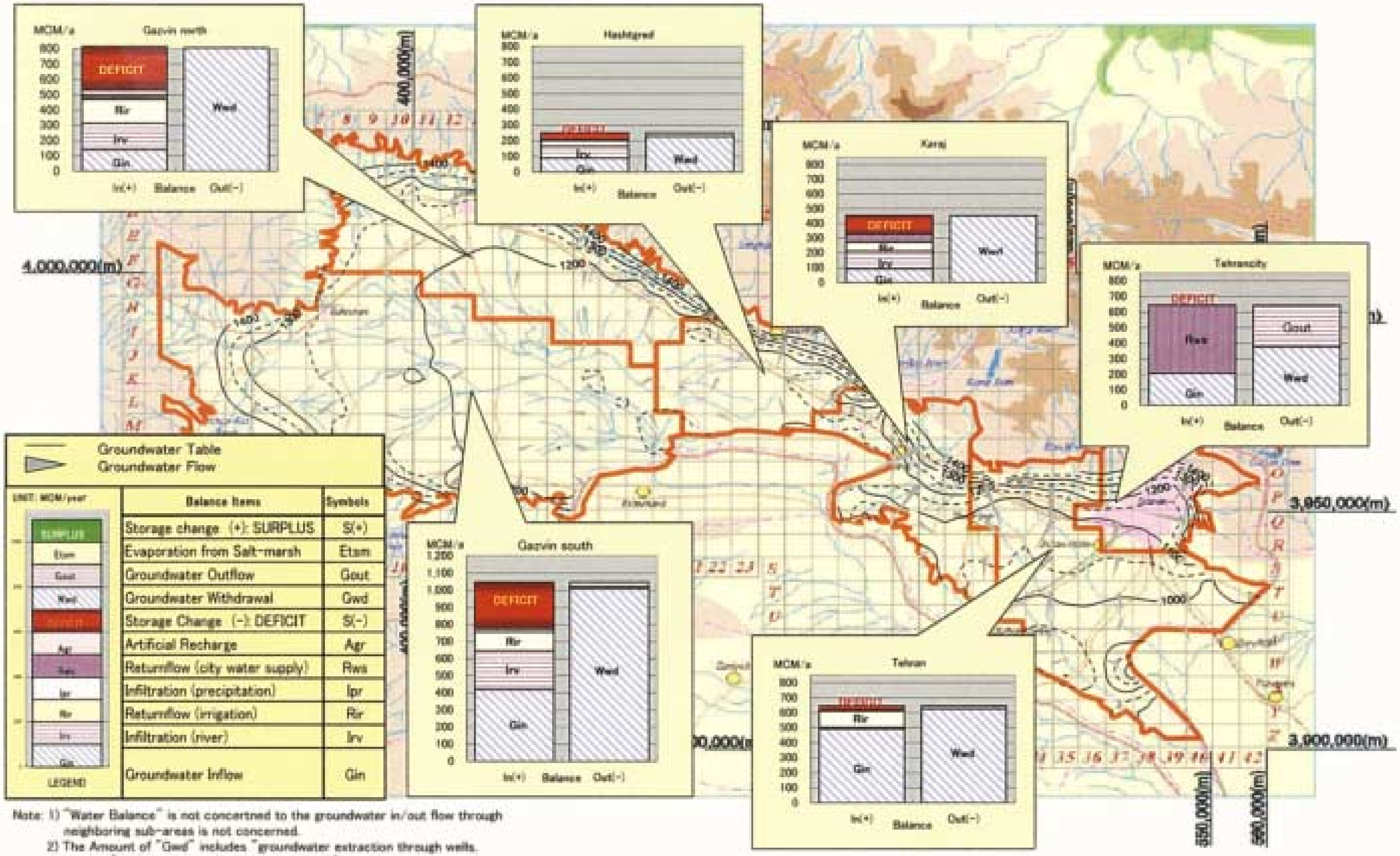
Figure 3.4.5.3 Groundwater Balance (1994/1995 Current Condition)



Note: 1) "Water Balance" is not concertned to the groundwater in/out flow through neighboring regions is not concerned.
2) The Amount of "Gwd" includes "groundwater extraction through wells, qanates" and seepage to drainages and rivers".

Groundwater Balance (1994/95)

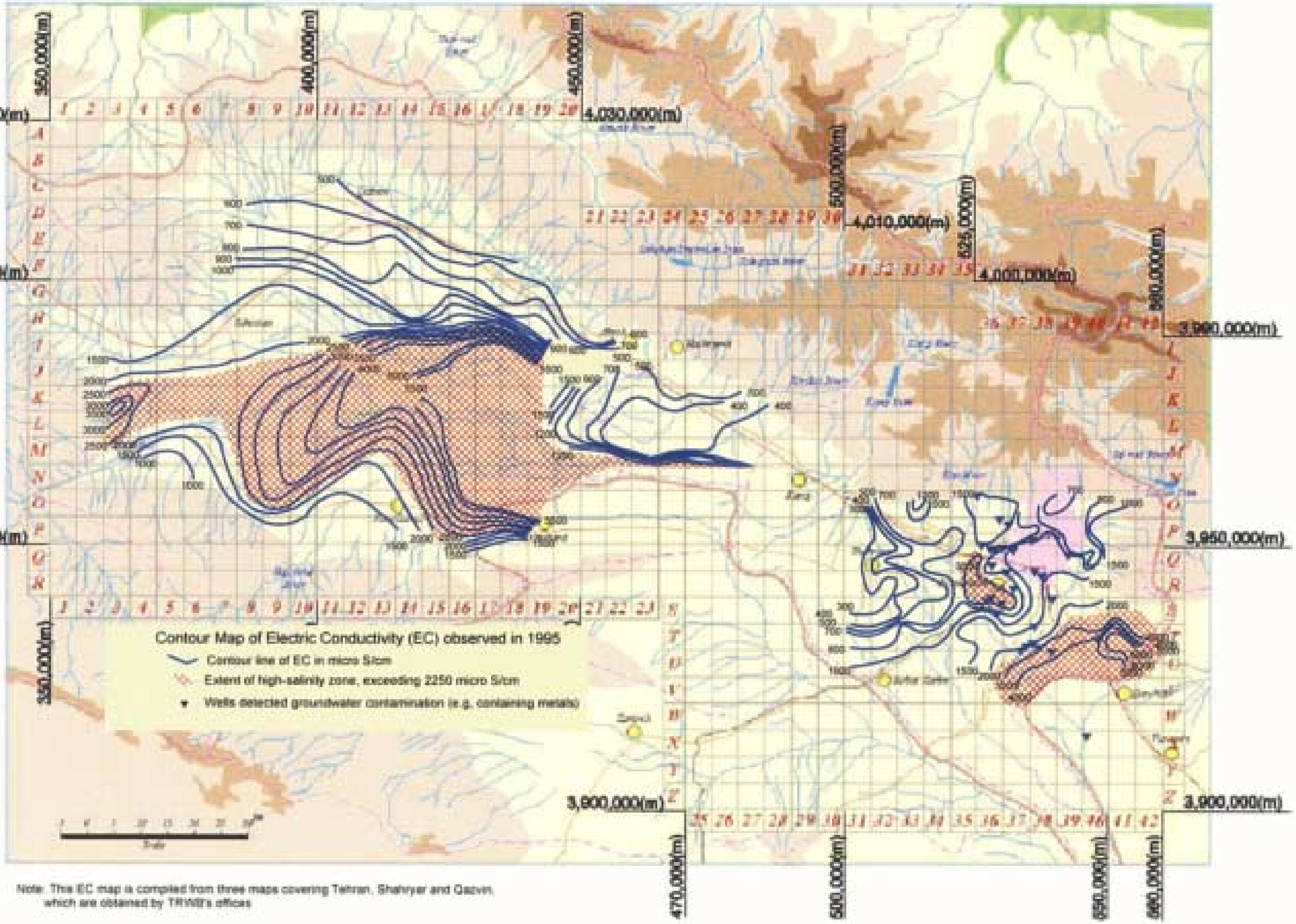
Figure 3.4.5.4 Groundwater Balance (1999/2000 Current Condition)



Note: 1) "Water Balance" is not concertned to the groundwater in/out flow through neighboring sub-areas is not concerned.
2) The Amount of "Gwd" includes "groundwater extraction through wells, qanates" and seepage to drainages and rivers".

Groundwater Balance (1999/2000)

Figure 3.4.6.1 Contour Map of Electric Conductivity (EC) Observed in 1995



Note: This EC map is compiled from three maps covering Tehran, Shahryar and Qazvin, which are obtained by TRWB's offices

CHAPTER 4.

PROPOSED WATER DEMAND

CHAPTER 4 PROPOSED WATER DEMAND

4.1 Proposed Domestic and Industrial Water Demand

4.1.1 Population Projection

In the Master Plan, the population projection in future for urban and rural area was made based on the population in 1996 and the population growth rate in the past 10 years which is different in each urban and rural area. This projected population was reviewed in 2000 under discussion of T.R.W.B and other agencies concerned. The final projected population was summarized by Jamab Consultant on November 2000 and shown in the final Master Plan. The population projection result in the final Master Plan is shown in the following table.

Population Projection

	1996	2001	2006	2011	2021
1. Tehran City					
Urban Area	**6,758,800**	**7,492,300**	**8,286,700**	**9,137,100**	**10,725,300**
2. Tehran Region					
(1) Urban Area					
Eslam Shahr	265,400	299,100	338,600	380,800	464,600
Qarchak	142,700	159,300	179,300	200,600	242,900
New Cities	0	301,700	346,700	400,200	480,600
Sub-Total	**408,100**	**760,100**	**864,600**	**981,600**	**1,188,100**
Rural Area	**312,900**	**251,900**	**226,900**	**202,500**	**231,700**
Total	**721,000**	**1,012,000**	**1,091,500**	**1,184,100**	**1,419,800**
3. Karaji Region					
Qods	138,300	157,300	179,100	202,500	248,900
Robat Karim	36,500	41,100	47,600	54,600	68,500
Hasan abad	11,200	15,300	19,500	24,000	32,900
Akbarabad	85,100	105,700	129,100	155,200	210,400
Shahriyar	40,100	46,200	53,200	60,700	75,600
Karaj Bozor	941,000	1,045,900	1,173,000	1,308,900	1,578,800
Mahdasht	29,000	32,100	35,600	39,400	46,900
Malard	88,100	106,700	128,100	152,300	210,800
New Cities	0	296,600	346,600	400,200	539,200
Sub-Total	**1,369,300**	**1,846,900**	**2,111,800**	**2,397,800**	**3,012,000**
Rural Area	**312,900**	**251,800**	**227,000**	**202,500**	**231,600**
Total	**1,682,200**	**2,098,700**	**2,338,800**	**2,600,300**	**3,243,600**
4. Hashtgerd Region					
Hashtgerd	32,800	38,000	43,800	50,100	62,500
Nazarabad	69,000	79,900	92,300	105,600	132,000
New Hashtgerd	0	65,800	217,500	319,300	523,900
Sub-Total	**101,800**	**183,700**	**353,600**	**475,000**	**718,400**
Rural Area	**112,100**	**104,000**	**104,200**	**104,900**	**102,600**
Total	**213,900**	**287,700**	**457,800**	**579,900**	**821,000**
5. Qazvin Region					
Abyek	32,800	36,600	41,900	47,700	59,000
Alvand	60,800	69,600	79,400	90,000	110,900
Qazvin	291,100	325,100	366,500	410,900	498,800
Eqbalieh	31,500	38,400	46,000	54,200	70,300
Buin	10,000	11,500	13,400	15,300	19,200

	1996	2001	2006	2011	2021
Danesfahan	8,100	9,500	11,000	12,700	16,100
Shal	14,100	14,500	14,900	15,200	19,000
Esfarvarin	11,900	13,700	15,700	17,800	22,100
Takestan	54,200	61,800	70,600	79,900	98,500
New Cities					
Sub-Total	**514,500**	**580,700**	**659,400**	**743,700**	**913,900**
Rural Area	**297,900**	**273,900**	**267,900**	**262,800**	**241,700**
Total	**812,400**	**854,600**	**927,300**	**1,006,500**	**1,155,600**
Gross Total					
Urban Area	**9,152,500**	**10,863,700**	**12,276,100**	**13,735,200**	**16,557,700**
Rural Area	**1,035,800**	**881,600**	**826,000**	**772,700**	**807,600**
Gross Total	**10,188,300**	**11,745,300**	**13,102,100**	**14,507,900**	**17,365,300**

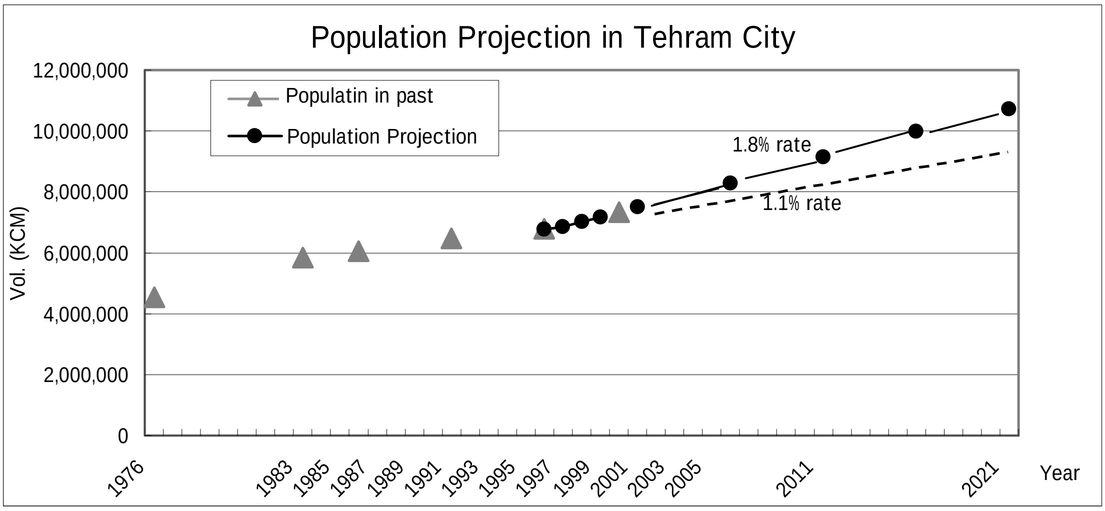
(Source: the Master Plan)

(1) Population in Tehran City

Tehran population in 2021 is estimated at about 10.7 million, which is 1.6 times of the population of 6.8 million in 1996. This population projection is made by applying the population growth rate of 1.8% per annum, though the actual rate in the past 10 years shows 1.1%. Accordingly the projected population in Tehran city is seemed to be estimated with a pretty allowance taking into account the large expansion of urbanization and population explosion in Tehran capital area in future.

Since the increasing population in Tehran city gives large influence to the future urban water demand it will be necessary to review carefully Tehran population with the three to five years interval, otherwise the proper water management to supply the urban water to Tehran could not be carried out.

The result of population projection in Tehran city prepared in the Master Plan is shown in the following table.



(Source: Census Data and the Master Plan)

(2) Population in Tehran Region

Urban population in Tehran region including Eslam Shahr, Qarchak and new city in the western area anjoing with Tehran city will largely increase to 1.2 million in 2021, which is about 3 times for the population of 410,000 in 1996. This abnormal population increment is seemed to be caused by a large urbanization of Tehran city.

However, the rural population in 2021 will decrease to 230,000 from 310,000 in 1996 due to conversion of farm land to urban area by urbanization.

(3) Population in Karaj Region

Urban population in Karaj region will increase to 3.0 million in 2021, which is 2.2 times of the population of 1.37 million in 1996. Population in Karaj Bozorg which is the center of Karaj region and a large satellite town of Tehran city will increase to 1.6 million in 2021 from the population of 940,000 in 1996 by the overflow of Tehran population. In addition the new cities with a large population of 350,000 in 2006 and 540,000 in 2021 are under construction to absorb the over population in Tehran city. The rural population will decrease to 230,000 in 2021 from 310,000 in 1996 due to large urbanization of Karaj region.

(4) Population in Hashtgerd Region

Hashtgerd region was consisting of agricultural area in the past without any urban area, but has been developed in resent years as the new residencial area for Tehran city and new industrial area to set up new factories by government designation.

Urban population in 1996 is only 100,000 but will increase largely to 720,000 in 2021, while rural population will decrease to 100,000 in 2021 from 112,000 in 1996. Namely the old agricultural area will be changed to new residencial and industrial area with a large population.

(5) Population in Qazvin Region

Qazvin region holds a large farm area of 350,000ha and forms the agricultural production area to supply various foods to Tehran capital area. The urban population is 510,000 in 1996, which will increase to 910,000 but the population growth rate in Qazvin region is small as compared with that in Karaj and Hoshtgerd because Qazvin will be developed as the agricultural production base in the capital area. The rural population will decrease a little from 298,000 in 1996 to 242,000 in 2021.

4.1.2 Domestic Water Consumption Per Capita

The domestic water consumption per capita (l.cd) in 1996 is explained in 2.4.2 “Present Urban Water Supply”. In the Master Plan, the future domestic water consumption per capita is estimated as shown in the following table taking into account the saving of water uses and water losses in future.

Per Capita Domestic Water Consumption in 1996 and Future

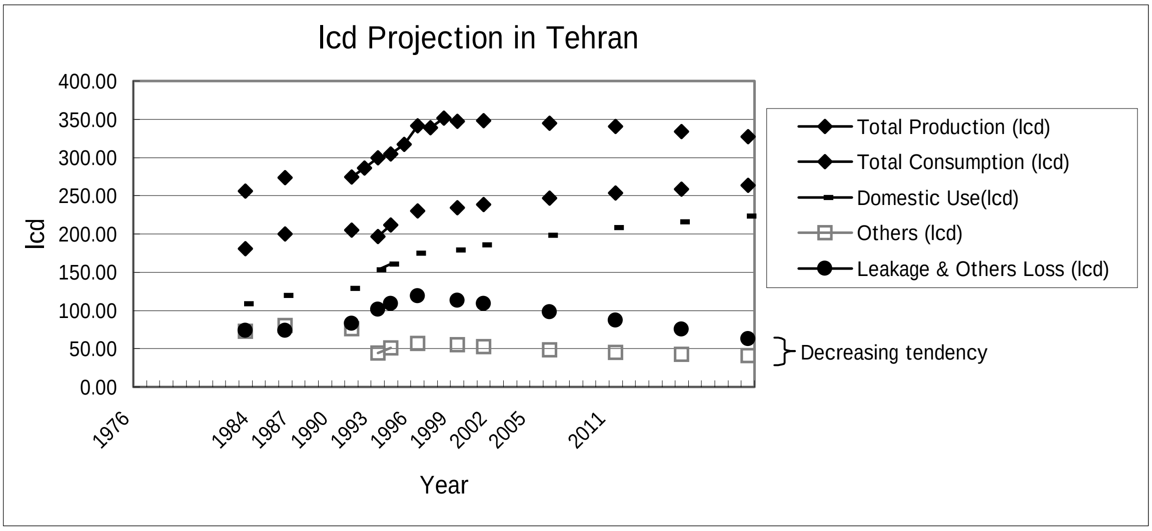
Water Demand	Per Capita Demand (lcd)				
	1996	2001	2006	2011	2021
1. Tehran City					
Urban Area	353	332	337	324	315
2. Tehran Region					
(1) Urban Area					
Eslam Shahr	291	287	285	280	274
Qarchak	286	280	278	275	274
New Cities	0	247	240	232	214
(2) Rural Water	187	166	166	166	166
3. Karaji Region					
(1) Qods	280	279	277	276	274
Robat Karim	270	272	273	274	274
Hasan abad	259	263	265	270	274
Akbarabad	268	269	270	272	274
Shahriyar	271	272	273	274	274
Karaj Bozor	268	269	270	272	274
Mahdasht	300	295	290	285	274
Malard	268	269	270	272	262
New Cities		247	240	232	214
(2) Rural Water	187	166	166	166	166
4. Hashtgerd Region					
(1) Hashtgerd	245	250	255	262	274
Nazarabad	249	255	260	265	274
New Hashtgerd		197	238	243	247
(2) Rural Water	118	139	139	139	139
5. Qazvin Region					
(1) Abyek	231	245	252	260	274
Alvand	144	247	250	253	259
Qazvin	262	265	266	270	274
Eqbalieh	148	247	251	256	205
Buin	316	260	263	267	273
Danesfahan	275	234	238	242	247
Shal	213	185	211	238	244
Esfarvarin	230	238	241	244	250
Takestan	247	248	251	254	274
(2) Rural Water	103	130	130	130	130

(Source: the Master Plan)

(1) Tehran City

The domestic water consumption per capita in Tehran city was 353 lcd in 1996 but is decreased to 337 lcd in 2006 and 315 lcd in 2021 taking into account the minimization of per capita consumption of 300 λ and saving of water losses from the present 35% to 15% in future.

The study to decrease the per capita water consumption of Tehran city in future has been made by Tehran W.S.C and its result is shown in the following figure;



(Source: Tehran Water & Sewerage Company Technical Bureau Data Base and Estimation)

(2) Other City

The other cities also have a large water leakage losses through the water pipeline and intend to save the losses up to 15% in future. The per capita water consumption of the other cities showing in the above table is proposed in the Master Plan taking into account the increasing actual domestic consumption in future and the decreasing consumption by saving the water losses.

4.1.3 Annual Projected Water Demand for Domestic and Industrial Uses

The annual projected water demand in future for domestic uses is estimated based on the projected population and the per capita water consumption mentioned in the above 4.1.1 and 4.1.2, while the industrial projected water demand is estimated based on the future scale of industrial area. Those estimation results are summarized as shown in the following table based on the Master Plan.

(1) Urban Water Demand in Tehran City

The urban water demand in Tehran city is 910MCM in 2001, which will increase to a large value of 1,230MCM in 2021. Tehran city has the large surface water sources of about 640MCM being supplied by Karaj, Latian and Lar dams and groundwater sources of about 300MCM in city but has suffered from water shortage problem in the dry year with the less surface water. The future increasing water demand will be never covered with the present water sources and water facility.

(2) Urban Water Demand in Other Cities

Urban water demand in other cities in the Study Area is 328.6MCM in 2001, which also will increase remarkably to 558.3MCM in 2021, about two times of the present demand. Especially the urban area of Tehran and Karaj region will require a large water demand of 108MCM and 289MCM in 2021 respectively.

It is expected that all urban water demand in the other cities in the Study Area except some demand for Karaj Bozorg shall be provided by the groundwater sources because of no available surface water to cover the demand at all in the area.

It is large and important issuers accordingly to confirm the sustainable availability of groundwater to meet the water demand.

(3) Rural Water Demand

Rural Water demand in the Study Area will decrease to 45MCM in 2021 from 49MCM in 2001, due to decreasing of the rural population, the rural water demand is sufficiently supplied by ground water because villages using the rural domestic water are scattering in the vast agricultural area and their extracting groundwater volume is small.

(4) Industrial Water Demand

Industrial water demand in the Study Area is 305MCM in 2001, which will increase largely to 485MCM in 2021. The industrial water in Tehran region increases to 73MCM in 2021 which is not so large amount as compared with the present demand of 54MCM in 2001 because new factories will be not provided in the Tehran region. On the other hand, the industrial water in Karaj, Hashtgerd and Qazvin regions will increase fairly as follows.

Unit: MCM

	Karaj	Hashtgerd	Qazvin	Total
Present (2001)	219	10	21	250
Future (2021)	294	43	75	412

Those industrial demand also shall be supplied by groundwater due to no available surface water. Accordingly the increasing groundwater use for the industry also will bring about a large issues because the groundwater sources are limited every places in the region.

(5) Total Domestic and Industrial Water Demand

Domestic and industrial water demand in the Study Area will reach a huge amount of 2,321MCM in 2021 as compared with the present amount of 1,570MCM in 2001. The incremental amount is 731MCM, which is rather diffult to provide newly by the existing water sources.

Annual Domestic and Industrial Water Demand in Future

Area	1996	2001	2006	2011	2021
1. Tehran City					
Total (urban)	**870.0**	**907.9**	**1,019.3**	**1,080.6**	**1,233.1**
2. Tehran Region					
(1) Urban Water					
Eslamshar	28.2	31.3	35.2	38.9	46.5
Qarchak	14.9	16.3	18.2	20.1	24.3
New Cities	-	27.2	30.4	33.9	37.5
Sub-total	**43.1**	**74.8**	**83.8**	**92.9**	**108.3**
(2) Rural Water	21.4	15.3	13.8	12.3	14.0
(3) Industrial Water	49.8	54.3	59.2	64.2	73.4
Total	**114.3**	**144.4**	**156.8**	**169.4**	**195.7**
3. Karaj Region					
(1) Urban Water					
Qods	14.1	16.0	18.1	20.4	24.9
Robat Karim	3.6	4.1	4.7	5.5	6.9
Hasanabad	1.1	1.5	1.9	2.4	3.3
Akbarabad	8.3	10.4	12.7	15.4	21.0
Shahriyar	4.0	4.6	5.3	6.1	7.6
Karaj Bozorg	92.0	102.7	115.6	129.9	157.9
Mahdasht	3.2	3.5	3.8	4.1	4.7
Malard	8.6	10.5	12.6	15.1	20.2
New Cities	-	26.7	30.4	33.9	42.1
Sub-total	**134.9**	**180.0**	**205.1**	**232.8**	**288.6**
(2) Rural Water	21.4	15.3	13.8	12.3	14.0
(3) Industrial Water	199.1	219.1	236.7	256.9	293.5
Total	**355.4**	**414.4**	**455.6**	**502.0**	**596.1**
4. Hashtgerd Region					
(1) Urban Water					
Hashtgerd	2.9	3.5	4.1	4.8	6.3
Nazarabad	6.3	7.4	8.8	10.2	13.2
New Hashtgerd	-	5.9	20.2	30.1	49.1
Sub-total	**9.2**	**16.8**	**33.1**	**45.1**	**68.6**
(2) Rural Water	4.8	5.3	5.3	5.3	5.2
(3) Industrial Water	0.2	10.0	18.9	27.0	43.0
Total	**14.2**	**32.1**	**57.3**	**77.4**	**116.8**
5. Qazvin Region					
(1) Urban Water					
Abyek	2.8	3.3	3.9	4.5	5.9
Alvand	3.2	6.3	7.2	8.3	10.5
Qazvin	27.8	31.4	35.6	40.5	49.9
Eqbalish	1.7	3.5	4.2	5.0	5.3
Buin	1.2	1.1	1.3	1.5	1.9
Danesfahan	0.8	0.8	1.0	1.1	1.5
Shal	1.1	1.0	1.1	1.3	1.7
Esfarvarin	1.0	1.2	1.4	1.6	2.0
Takestan	4.8	5.6	6.6	7.6	9.9
New Cities	-	2.8	3.1	3.3	4.2
Sub-total	**44.4**	**57.0**	**65.4**	**74.7**	**92.8**
(2) Rural Water	11.2	13.0	12.7	12.5	11.5
(3) Industrial Water	4.5	21.3	37.2	50.7	74.8
Total	**60.1**	**91.3**	**115.3**	**137.9**	**179.1**
6. Grand Total					
Urban Water	**1,101.6**	**1,236.5**	**1,406.7**	**1,526.1**	**1,791.4**
Rural Water	**58.8**	**48.9**	**45.6**	**42.4**	**44.7**
Industrial Water	**253.6**	**304.7**	**352.0**	**398.8**	**484.7**
Total	**1,414.0**	**1,590.1**	**1,804.3**	**1,967.3**	**2,320.8**

4.2 Proposed Irrigation Water Demand

4.2.1 Unit Irrigation Requirement

The present unit irrigation requirement per hectare shows relatively the high value as mentioned in 2.5.2. (1) " Unit Irrigation Requirement". Accordingly, the future unit irrigation requirement in all regions is proposed at the average value of 11,000 m^3/ha, which is about 5 to 10 % lower than the present value. It will be possible to minimize the unit irrigation requirement in future taking into account the introduction of proper and effective irrigation method on farm level, sufficient training of irrigation practice for water users group, rehabilitation works of deteriorated canal structure, rational management for water distribution and diversion in canal system, reasonable and equitable water allocation in service area, etc.

4.2.2 Proposed Available Irrigation Water

It is rather difficult to define the proposed irrigation area and water demand in the future from 2001 to 2021 because available irrigation water to be allocated from the water sources such rivers, reservoir and groundwater is not stable and its amount may decrease in the regions of Tehran, Karaj and Hashtgerd caused by the increasing domestic and industrial water supply with the first priority.

In the Master Plan, the proposed irrigation area and water demand is very roughly estimated based on the assumption for available surplus water after allocation of the domestic and industrial uses. The following various water amount, however is not estimated properly and reasonably in the Master Plan.

- Variation of water allocation of Karaj reservoir to the water supply in Tehran city and Karaj irrigation area.
- New available surface water to be developed by Taleghan dam project and its allocation amount for Tehran water supply and Qazvin irrigation.
- New available surface water to be developed by Almout water diversion project.
- Existing available surface water in mountain stream in each region of Tehran, Karaj, Hashtgerd and Qazvin and irrigation water amount at each region to be allocated by their water sources.
- Availability of reuse water from sewerage treatment plant in Tehran city to irrigation area in Tehran and Karaj region.
- Availability of groundwater in Karaj and Hashtgerd, which will be decreased in future due to in deficient recharging water.

JICA Study Team has studied carefully the issues as mentioned in 5.4 "Water Allocation Scenario" and estimated approximately the proposed available irrigation water demand and its water sources as shown in the following table.

Available Irrigation Water by Water Sources in Future

Unit : MCM

Region	2001			2006			2011			2021		
	S.W.	G.W.	Total	S.W.	G.W.	Total	S.W.	G.W.	Total	S.W.	G.W.	Total
Tehran	170	540	710	170	540	710	220	500	720	420	450	870
Karaj	135	430	565	215	305	520	215	265	480	265	175	440
Hashtgerd	60	290	350	60	260	320	60	240	300	60	200	260
Qazvin	385	1,070	1,455	355	1,100	1,455	500	1,130	1,650	590	1,150	1,740
Total	**750**	**2,330**	**3,080**	**800**	**2,205**	**3,005**	**995**	**2,135**	**3,130**	**1,335**	**1,975**	**3,310**

Note: S.W. is surface water. G.W. is groundwater. Surface water at Karaj in 2021 and at Tehran

- Surface water in Tehran region in and 2011 and 2021 will increase by getting new reuse water from Tehran sewerage treatment plant, although groundwater use will decrease.
- Karaj surface water in 2011 and 2021 also gets in 2011 and 2021 also gets the reuse water from Tehran sewerage treatment plant, so that the surface water amount largely increases as compared with that in 2006.
- Available irrigation water in Karaj region in 2021 will decrease due to conversion of farm land to urban and industrial area, and decreasing of groundwater sources which also are converted to urban and industrial uses in future.

Available irrigation water in Hashtgerd region in 2021 will also decrease a little with the same reason as mentioned in Karaj region.

Available surface irrigation water in Qazvin region in 2021 will increase by the Taleghan reservoir and Almout water diversion project. Groundwater in Qazvin region also will increase will be used sustainable because of increment of surface water to be recharged in groundwater.

4.2.3 Proposed Irrigation Area

The proposed irrigation area is estimated based on the above unit irrigation requirement of 11,000 m^3/ha and available irrigation water. The estimated area is shown as follows.

Proposed Irrigation Area in Future

Region	Unit Re. (m^3/ha)	Available Irrigation Water (MCM)				Proposed Irrigation Area (1000 ha)			
		2001	2006	2011	2021	2001	2006	2011	2021
Tehran	11,000	710	710	720	870	64.5	64.5	65.5	79.1
Karaj	11,000	565	520	480	440	51.4	47.3	43.6	40.0
Hashtgerd	11,000	350	320	300	260	31.8	29.1	27.3	23.6
Qazvin	11,000	455	1,455	1,630	1,740	132.3	132.3	148.2	158.2
Total	**11,000**	**3,080**	**3,005**	**3,130**	**3,310**	**280.0**	**273.2**	**284.6**	**300.9**

Irrigation area in Tehran region will slightly increase to 79,100 ha in 2021 from 64,500 ha in 2001. Irrigation area in Karaj and Hashtgerd regions will fairly decrease from 2001 to 2021. That in Qazvin will increase from 132,300 ha in 2001 to 158,200 ha in 2021.

The variation of irrigated agricultural area toward 2021 is illustrated in the attached figure.

4.3 Proposed Total Water Demand by Water Sources

The proposed total water demand for domestic, industrial and agricultural uses and available water by surface and ground water sources are summarized in the attached figure.

Proposed Total Water demand by Water Sources

Region & Water Source	1996	2001	2006	2011	2021	Content of Water Sources
1. Tehran City						
(1) Urban Water Supply						
Surface Water	640	640	680	810	980	Lar, Latian, Karaj & Taleghan Dam
Ground Water	230	270	340	270	250	Tehran City
Total	**870**	**910**	**1,020**	**1,080**	**1,230**	
2. Tehran Region						
(1) Surface Water						
Agricultural Use	100.0	170.0	170.0	220.0	420.0	Tributary in Tehran, Reuse
Sub-total	**100.0**	**170.0**	**170.0**	**220.0**	**420.0**	**- do -**
(2) Groundwater						- do -
Domestic Use	86.0	90.0	100.0	110.0	120.0	
Industrial Use	50.0	60.0	60.0	60.0	70.0	
Agricultural Use	365.0	540.0	540.0	500.0	450.0	
Sub-total	**501.0**	**690.0**	**700.0**	**670.0**	**640.0**	
Total	**601.0**	**860.0**	**870.0**	**890.0**	**1,060**	
3. Karaj Region						
(1) Surface Water						
Agricultural Use	110.0	135.0	215.0	215.0	265.0	Karaj & Taleghan Dam, Reuse
Sub-total	**110.0**	**135.0**	**215.0**	**215.0**	**265.0**	
(2) Groundwater						
Domestic Use	156.0	195.0	220.0	245.0	300.0	Karaj region
Industrial Use	199.0	220.0	240.0	255.0	300.0	- do -
Agricultural Use	335.0	430.0	305.0	265.0	175.0	- do -
Sub-total	**690.0**	**845.0**	**765.0**	**765.0**	**775.0**	
Total	**800.0**	**980.0**	**980.0**	**980.0**	**1,040.0**	
4. Hashtgerd Region						
(1) Surface Water						
Agricultural Use	30	60	60	60	60	Kordan Weir
Sub-total	**30**	**60**	**60**	**60**	**60**	
(2) Groundwater						
Domestic Use	14	20	40	50	75	Hashtgerd region
Industrial Use	0	10	20	30	45	- do -
Agricultural Use	219	290	260	240	200	- do -
Sub-total	**233**	**320**	**320**	**320**	**320**	
Total	**380**	**380**	**380**	**380**	**380**	
5. Qazvin Region						
(1) Surface Water						
Agricultural Use	300	385	355	500	590	Taleghan, Almont & Tributary
Sub-total	**300**	**385**	**355**	**500**	**590**	
(2) Groundwater						
Domestic Use	55	70	80	90	105	Qazvin region
Industrial Use	5	20	35	50	75	- do -
Agricultural Use	1,149	1,070	1,100	1,130	1,150	- do -
Sub-total	**1,209**	**1,160**	**1,215**	**1,270**	**1,330**	
Total	**1,509**	**1,545**	**1,570**	**1,770**	**1,920**	
6. Grand Total						
Surface Water	1,180	1,390	1,480	1,805	2,315	
Ground Water	2,863	3,285	3,340	3,295	3,315	
Total	**4,043**	**4,675**	**4,820**	**5,100**	**5,630**	

- Total water demand in the Study Area will increase to 5,630MCM at 2021 from 4,675MCM in 2001. The increment of about 1,000MCM is mainly covered with the surface water consisting of the Taleghan and Almout water of 500MCM, reuse water of 350MCM and some water by Lar dam and tributaries in Tehran and Qazvin region.
- The supply from groundwater source is general decreased due to insufficient recharging water in the region of Tehran, Karaj and Hashtgerd but that by Qazvin region will increase slightly due to increasing recharge water by the Taleghan, Almout and Kharud river.
- The domestic and industrial water by groundwater sources will increase considerably toward 2021 but agricultural water decrease as shown in the following table. Namely the groundwater used for agriculture is converted to the domestic and industrial uses.

Variation of Groundwater Use in 2001 and 2021

Unit: MCM

Region	Domestic/Industrial Use		Agricultural Use		Total	
	2001	2021	2001	2021	2001	2021
1. Tehran City	270	250	-	-	270	250
2. Tehran Region	150	190	540	450	690	640
3. Karaj region	415	600	430	175	845	775
4. Hashtgerd Region	30	120	290	200	320	320
5. Qazvin Region	90	180	1,070	1,150	1,160	1,330
Total	**955**	**1,330**	**2,330**	**1,975**	**3,285**	**3,315**

CHAPTER 5.

WATER OPERATION AND ALLOCATION

CHAPTER 5 WATER OPERATION AND ALLOCATION

5.1 Surface Water Operation

5.1.1 Basic Concept of Water Operation

Monthly distribution of precipitation is moderate over the Study Area with about 65% of annual precipitation concentrated in winter season from October to March and 35% in spring and summer season from April to September. Precipitation during the peak winter season commonly becomes snowfall especially in high elevated mountainous regions, and deposited there without drained. A freshet of snow-water usually occurs from the late March and continues until July with the peak monthly runoff in May followed by April and June. About 75% of annual runoff concentrates during spring-summer season from April to September.

On the other hand in the beneficiary plains, irrigation has been practiced consuming considerable amount of surface water and groundwater. Currently approximately 216,000 ha of farmland are under irrigation in Qazvin, Hashtgerd, Karaj and Tehran plains of which 115,800 ha belong to Qazvin plain. Wheat and barley are the main winter crops planted in April on about 45% of irrigated cropland. Fruit trees are also planted in the areas occupying 26% of the total cropped area. Summer crops such as garden crops, vegetable, industrial crops and feed crops, are planted and irrigated after harvest of winter crops.

Current consumption of irrigation water is estimated at 2,600 MCM annually, of which about 94% is consumed in spring-summer season. Because of low temperature, no crop is planted during the peak winter season from December to March consuming no water for irrigation. Consumption of irrigation water during winter season is only 6% of annual total.

This pattern of irrigation practice almost coincides with the seasonal pattern of river runoff in the Study Area, with a delay of one month for irrigation. In the early period of irrigation, surface water is the major source of water as long as such a source is available. Groundwater is, on the contrary, the major source during the latter half of irrigation period when river discharges decrease.

In the northern Qazvin plain, irrigation water has been conveyed transbasin from the Taleghan river diverted at the existing Sangban diversion dam. According to the recent statistics, monthly pattern of water diversion also closely coincide with the pattern of river runoff as shown in Figure 5.1.1.1 of the Supporting Report.

Aside from irrigation water use, demand of water for domestic and industrial purposes has been increasing due to rapid growth of population in recent years. This tendency of population growth is projected to continue in future requiring a vast volume of water to be supplied from additional source of water. Monthly pattern of water requirement for these uses is almost constant throughout a year, with a slight peak during summer season from July to September and a depression in winter from January to March. Domestic and industrial water supply has a priority over other uses however volume of water required usually exceeds available flow in rivers in dry season from August to February, and therefore river flow has to be regulated by a reservoir if supply of water depends on surface water resources.

At a Storage Reservoir

In consideration of seasonal pattern of rainfall as well as available runoff flowing into the river from where water is diverted for various uses, stored water in the reservoir has a significant importance to ensure supply of water for human beings and for dry season crops under vegetative and reproductive stages and under initial irrigation stage for wet season crops. In houses, factories and irrigated service areas under such situations, it must be intolerable and irresistible that the water supply from the reservoir be interrupted. It is, therefore, inevitably necessary that the reservoir is so operated as to ensure its storage by this time. In planning a rational operation of the reservoir against more complicated requirement of water for domestic, industrial, irrigation and others, an objective standard must be necessarily required to be established.

During dry season, operation of reservoir is undertaken in a way that two purposes confronting each other can be adjusted. The first objective is to promote water release effectively in response to demand of water in the service area. However, as a result, promotion of water release accelerates consumption of available storage in the reservoir. Secondly, some countermeasures for unforeseen drought is needed. In preparation for present and future drought, release of water is rather restricted intending preservation and restoration of storage.

During wet season when inflow into the reservoir largely exceeds water demand under the normal condition, the reservoir should be so operated that i) as much water release as possible be allotted for power generation, ii) as small amount of water as possible be wasted through spillage, and iii) reservoir be finally recovered to the full storage level as frequent as possible at the end of wet season. Accordingly even during wet season, a role of reservoir operation is constructed by means of establishing various modes of allowable release with respect to available storage, aiming at the most effective utilization of the limited water resources for multiple purposes of water supply, irrigation, hydro-electric power generation and other water supplies.

Apart from the above concept of reservoir operation, the following assumption is to be employed to simplify the problem.

- During the recovery period of reservoir storage, from March to May or June, the reservoir is so operated as to allot allowable release for various purposes in response to demand of water.

- During the consumptive period of storage from June to March, the reservoir is so operated as to release monthly amount of water corresponding to the past achievement, and additional usable storage is evaluated as the remaining storage at the end of consumptive period minus a certain volume of storage to be carried over for unforeseen drought.

An ideal pattern of operation of the reservoir is to restore its storage toward the full storage at the end of June using runoff during recovery period from March to June, and to utilize the storage during consumptive period from July to next February in response to the request from downstream water users. In view of flood control, reservoir water level is also ideal to be the lowest at the end of February when flood runoff begins to flow into the reservoir. However, ideal pattern of reservoir operation can not be achieved because of fluctuation of inflows into the reservoir and due to the fact that annual volume of inflow is absolutely insufficient against the demand of water. In order to secure storage of water in the reservoir for future use, it is necessary to restrict the use of storage especially during consumptive period and even during recovery period by means of establishing a "Lower Rule Curve" for operation.

At a Diversion Dam

Function of diversion dam is to divert water within the limitation of requirement from the service area or capacity of the facility. In case of the existing Sangban diversion dam on Taleghan river and the proposed Almout diversion dam, it is essential to divert as much available water as possible within the limitation of the capacity of diversion facility because that such excess water can be used as the source of water for recharge of groundwater that may be expected to be over-extracted whenever surface water is too short.

5.1.2 Operation of Karaj Reservoir

(1) Past Operation

On the basis of the records of Karaj dam operation collected from TRWB, some important parameters to evaluate existing operation of the reservoir, such as (1) total storage at the end of month, (2) long-term view of operation, (3) outflow for water supply and (4) irrigation, and (5) total outflow are analyzed and plotted as given in Figures 5.1.2.1 and 5.1.2.2. Even though no specific rule for operation of the reservoir is established, however as a whole, Karaj dam had been operated well until the late 1980s. Operation has been disordered ever since, and this is due to change of monthly pattern of water release from the reservoir.

Total volume of outflow from the reservoir has been maintained at almost same order, 430 MCM more or less. Allocation of Karaj water has however shifted rapidly from agricultural use to domestic purposes. Water use for domestic purpose including industrial use has been increasing due to growing population in Tehran City, while agricultural water use has decreased as is seen in Figure 5.1.2.3. Accordingly, seasonal pattern of water release from the reservoir has changed gradually providing major reasons for disturbance of reservoir operation. Following table shows annual change of volume of water released from Karaj dam and allocated to water supply and agricultural purposes.

Change of Allocation of Karaj Dam Outflow

Average Outflow	Water Supply（MCM）	Irrigation（MCM）
1970～1979	206.4	267.2
1980～1989	294.7	156.1
1990～1998	322.9	92.3
Whole Period（1970～1998）	269.3	151.2

Secondly, about 60 MCM of storage is needed to be kept as a carry-over capacity at the end of consumption season or end of February, in preparation for unforeseen drought during succeeding flood season. Unexpected inflow occurred in November and December in 1994 and 1995 may be the major reason why unusual volume of water was released in the same season after then. It is required as early as possible to recover the 60 MCM of capacity at the end of February.

Rapidly increasing demand for water supply in the Tehran capital area due to growing population and socio-economy has been satisfied quantitatively with difficulty by means of conversion of allocation of Karaj dam water from irrigation to water supply, however, this measure also has a limitation as is clear from the above table. Meanwhile, reliance of agricultural water on groundwater resources has been accelerated more and more showing a considerable reduction of groundwater levels especially along the southern-most reaches of the groundwater sub-basins. It seems that groundwater resources in this area will be exhausted in near future if this degree of decreasing tendency would continue.

(2) Future Operation without Rule

In the project target year of 2016, operation of Karaj dam is so planed to allocate 270 MCM of annual water to domestic and Industrial supply in Tehran City and 165 MCM for irrigation use in Karaj district. Monthly pattern of water demand programmed is as follows:

Future Water Demand at Karaj Dam

Unit: MCM

Use	Mhr	Abn	Azr	Dey	Bhm	Esf	Far	Ord	Kho	Tir	Mor	Sha	Year
Water Supply	24.0	22.0	20.5	19.7	19.3	20.3	19.6	20.5	25.0	26.6	26.7	26.0	270.0
Irrigation	10.0	7.4	5.9	4.4	4.3	2.8	5.0	31.2	34.6	26.0	18.4	14.9	165.0
Total	**34.0**	**29.4**	**26.3**	**24.1**	**23.5**	**23.1**	**24.6**	**51.8**	**59.6**	**52.6**	**45.1**	**40.9**	**435.0**

It is unavoidable that the dam may face relatively frequent short of water since the average annual inflow into the reservoir, 436 MCM, is insufficient equivalent almost to the demand of water, 435 MCM. Actually, simulated results of reservoir operation without giving any specific rule show that shortage of water would occur once in 2 years, as is seen in Figure 5.1.2.4. More serious is that the shortage of water will be distributed unevenly, more shortage in water supply sector and less shortage in irrigation.

Average Shortage of Water at Karaj Dam (Future Operation w/o Rule)

Unit: MCM

Use	Mhr	Abn	Azr	Dey	Bhm	Esf	Far	Ord	Kho	Tir	Mor	Sha	Year
Water Supply	2.6	2.0	2.4	3.1	2.2	0.7	0.0	0.0	0.0	0.0	0.5	2.3	15.7
Irrigation	2.0	2.1	2.2	1.7	1.6	0.7	0.0	0.0	0.0	0.2	1.8	2.2	14.5
Total	**4.6**	**4.0**	**4.6**	**4.8**	**3.8**	**1.4**	**0.0**	**0.0**	**0.0**	**0.2**	**2.3**	**4.5**	**30.2**

Even when the priority of water use is given to water supply sector, reservoir water is released for irrigation as far as water is available, if the reservoir is operated without adopting a rule for operation. Unrestricted use of reservoir water for irrigation promotes consumption of reservoir water and exerts a influence on water use for domestic purpose in the next time step. In order to avoid this situation, it is necessary to establish a specific rule of reservoir operation, so called the “Lower Operation Rule Curve”.

If the reservoir is operated only for water supply purpose, inflow into and the capacity of the reservoir are adequate and there would be no shortage of water as shown in Figure 5.1.2.5. An envelop curve is drawn and shifted lower to prepare the lower operation rule curve meaning that, if more water is kept in the reservoir than the volume given along the curve, short of water would not occur since water supply sector has a first priority of water allocation. The Lower Operation Curve is given as below:

Lower Rule Curve for Future Operation of Karaj Dam

Unit: MCM, in terms of effective storage

Item	Mhr	Abn	Azr	Dey	Bhm	Esf	Far	Ord	Kho	Tir	Mor	Sha
Lower Rule Curve	43.0	30.0	20.0	10.0	2.0	0.0	20.0	70.0	95.0	90.0	76.0	60.0

(3) Future Operation with Rule

Simulated result of reservoir operation with the lower rule curve is shown in Figure 5.1.2.6 and summarized as follows:

Average Shortage of Water at Karaj Dam (Future Operation w/o Rule)

Unit: MCM

Use	Mhr	Abn	Azr	Dey	Bhm	Esf	Far	Ord	Kho	Tir	Mor	Sha	Year
Water Supply	0.0	0.0	0.2	0.1	0.3	0.5	0.2	0.0	0.1	0.0	0.0	0.1	1.5
Irrigation	2.5	1.9	1.3	1.0	1.0	0.4	0.2	2.6	5.4	4.4	4.4	4.9	29.8
Total	**2.5**	**1.9**	**1.5**	**1.1**	**1.3**	**0.8**	**0.4**	**2.6**	**5.4**	**4.4**	**4.4**	**5.0**	**31.2**

5.1.3 Operation of Existing Taleghan Diversion Dam

According to the original plan of Taleghan water diversion, about 250 MCM/year of water was planned to be diverted to Qazvin area. Actual achievement of water diversion is, however, about 200 MCM meaning that there still remains excess water in Taleghan river for additional water diversion. In addition, it is reported that 30 MCM of the total diversion is lost from superannuated irrigation facilities and 30 MCM is used for recharge of groundwater aquifer. Monthly variation of water diversion shows the same pattern depending on the irrigation water requirement in the Qazvin plain. During the winter period from January to March, no diversion except those for groundwater recharge was achieved in almost all years. There remains considerable amount of water flowing in Taleghan river during this period, and it is recommendable to divert as much water as possible for the purpose of recharging groundwater aquifer.

On the basis of the records provided by the Qazvin Water Board on the water actually diverted from the Taleghan river and distributed to the Qazvin north irrigation system, operation study was made at the existing Sangban diversion dam in order to confirm the possible amount of water that can be diverted under given conditions. Following table summarizes monthly volumes of water diverted from the Taleghan river and distributed to the Qazvin plain. The maximum annual volume of 262 MCM was recorded in 1993/94, and the monthly pattern of water diversion recorded in 1993/94 was therefore employed in the study to evaluate possible amount of water diversion for irrigation. Daily computation was made for the duration of 21 years on the basis of daily discharges of the Taleghan river collected at Galinak.

Distribution of Taleghan Water in Qazvin Plain

Unit: MCM

	1985/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Mehr	7.00	7.00	5.99	10.01	5.99	5.00	5.99	7.10	**6.10**	11.30	9.90	6.50	6.30	9.30
Aban	7.00	8.99	3.99	10.99	7.98	7.00	7.00	8.89	**5.80**	6.30	9.70	7.70	9.30	9.80
Azar	7.98	5.99	2.00	7.00	3.01	7.00	3.99	4.69	**2.90**	0.00	4.90	7.10	8.60	10.20
Dey	3.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**7.80**	11.40	2.50	0.00	4.90	5.80
Bah.	3.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**13.80**	22.30	3.60	0.00	0.00	0.00
Esf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**6.40**	22.70	5.20	6.50	0.60	12.00
Far.	11.01	3.99	9.00	3.99	9.99	3.00	0.70	5.70	**35.30**	24.00	4.20	17.00	20.20	24.90
Ord.	27.05	40.98	38.03	50.89	40.98	45.00	20.01	42.90	**66.30**	52.50	33.10	53.10	50.80	41.10
Kho.	42.05	42.85	53.84	40.98	39.10	39.00	30.29	31.40	**69.30**	58.90	66.60	51.10	57.50	24.20
Tir	19.36	19.36	30.97	17.42	13.56	14.52	24.21	22.90	**29.60**	28.70	31.10	21.00	35.50	10.70
Mor.	12.00	13.98	23.01	8.01	6.99	6.99	16.31	11.00	**11.90**	14.50	10.30	8.40	15.00	4.50
Sha.	6.99	8.01	9.99	5.01	5.01	5.01	11.60	6.40	**6.90**	8.70	7.40	5.70	9.20	3.00
Annual	147.44	151.15	176.82	154.30	132.61	132.52	120.10	140.98	**262.10**	261.30	188.50	184.10	217.90	155.50

Note: Data after 1993 are those estimated by Qazvin Water Board.

When Priority is Given to Water Supply to Western Capital Area

To meet immediate need of water supply in Tehran City, original plan of the pipeline between Ziaran and Karaj intended to divert a part of Taleghan water for the use in Tehran City through existing Karaj – Tehran pipeline. This plan is however impossible to be executed because that existing Karaj – Tehran pipeline has been occupied fully to convey water from Karaj dam to Tehran City. JICA Study therefore proposes, as a tentative plan around the year 2006, to use this water to compensate shortage in agriculture in Karaj area. Even so, computation was made on the assumption that the Taleghan water conveyed through Ziaran – Karaj pipeline is finally allocated to Tehran City.

When the priority of water allocation is given to water to Karaj area, about 120 MCM minimum or 140 MCM on average of water will be transferred from Taleghan to Karaj through a water conduction pipeline now under construction, while about 120 MCM minimum or 170 MCM on average will be conveyed from Taleghan to Qazvin, under the Scenario-1 of short-term development plan at the year 2006 as shown in Figure 5.1.3.1. Considering the importance of water supply that can not be suspended, the minimum guarantee would be about 120 MCM that are stable and safety even in critical dry year which would occur once in 10 years. About 170 MCM of water on average distributed to Qazvin plain, that is the recent demand of water on Taleghan water diversion, is almost same amount as compared with the existing achievement (173 MCM as an average in recent 14 years). The minimum amount of water in a critical dry year will be about 120 MCM. Summary of computation is given in Table 5.1.3.1 of the Supporting Report.

When Priority is Given to Irrigation Water in Qazvin Plain

When the priority is given to irrigation water supply of Qazvin plain, Qazvin plain will receive 200 MCM minimum or 240 MCM on average of Taleghan water, while 40 MCM minimum or 120 MCM on average will be allocated to water supply sector in the western capital area, as shown in Figure 5.1.3.2. This plan will, however, invite serious water shortage problems in the domestic and industrial sectors in the capital area since there will be almost no water for diversion during the period from June to September in dry years such as 1989, 1990 and 1991, and therefore not recommendable. Summary of computation is given in Table 5.1.3.2 of Supporting Report.

5.1.4 Operation of Taleghan Storage Dam

The Taleghan storage dam construction was just commenced at the middle of 2001 and is expected to be completed by the year 2006.

(1) Future Operation without Rule

According to the Master Plan in the project target year of 2016, operation of Taleghan storage dam is so planed to allocate 310 MCM of annual water to domestic and industrial supply in Tehran City and 140 MCM for irrigation use in the Qazvin plain. Monthly pattern of water demand programmed is as follows:

Future Water Demand at Taleghan Storage Dam

Unit: MCM

Use	Mhr	Abn	Azr	Dey	Bhm	Esf	Far	Ord	Kho	Tir	Mor	Sha	Year
Water Supply	27.6	24.3	21.4	20.7	20.2	21.4	22.0	25.1	29.2	33.6	33.1	31.5	310.0
Irrigation	22.7	1.8	0.0	0.0	0.0	0.0	15.4	27.2	22.5	17.8	18.3	14.2	140.0
Total	50.3	26.1	21.4	20.7	20.2	21.4	37.4	52.3	51.7	51.4	51.4	45.8	450.0

It is unavoidable that the dam may face relatively frequent short of water since the average annual inflow into the reservoir, some 490 MCM, is not sufficient to meet the demand of water, 450 MCM. Actually, simulated results of reservoir operation without giving any specific rule show that shortage of water would occur once in 3 years, as is seen in Figure 5.1.4.1. More serious is that the shortage of water will be distributed unevenly, more shortage in water supply sector and less shortage in irrigation. This situation is the same as the operation of Karaj dam. In this connection, it is noted here that reservoir losses and precipitation on the water surface are both neglected in the computation, because that the study is only of preliminary level.

Average Shortage of Water at Taleghan Storage Dam (Future Operation w/o Rule)

Unit: MCM

Use	Mhr	Abn	Azr	Dey	Bhm	Esf	Far	Ord	Kho	Tir	Mor	Sha	Year
Water Supply	2.1	2.6	2.0	2.2	1.9	1.2	0.0	0.0	0.0	0.2	0.9	1.1	13.9
Irrigation	4.0	0.4	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.8	0.8	6.7
Total	**6.1**	**3.0**	**2.0**	**2.2**	**1.9**	**1.2**	**0.3**	**0.0**	**0.0**	**0.6**	**1.7**	**1.9**	**20.6**

Even when the priority of water use is given to water supply sector, reservoir water is released for irrigation as far as water is available, if the reservoir is operated without adopting a rule for operation. Unrestricted use of reservoir water for irrigation promotes consumption of reservoir water and exerts a influence on water use for domestic purpose in the next time step. In order to avoid this situation, it is necessary to establish a specific rule of reservoir operation, so called the “Lower Operation Rule Curve”.

Same procedures were taken as the evaluation of operation of Karaj dam to prepare the lower rule curve as shown in Figure 5.1.4.2. The Lower Operation Curve is given as below:

Lower Rule Curve for Future Operation of Taleghan Storage Dam

Unit: MCM, in terms of effective storage

Item	Mhr	Abn	Azr	Dey	Bhm	Esf	Far	Ord	Kho	Tir	Mor	Sha
Lower Rule Curve	82	62	45	27	8	0	45	110	150	135	120	102

(2) Future Operation with Rule

Simulated result of reservoir operation with the lower rule curve is shown in Figure 5.1.4.3 and summarized as follows:

Average Shortage of Water at Taleghan Storage Dam (Future Operation w/o Rule)

(Unit: MCM)

Use	Mhr	Abn	Azr	Dey	Bhm	Esf	Far	Ord	Kho	Tir	Mor	Sha	Year
Water Supply	0.1	0.0	0.0	0.0	0.0	0.0	0.8	0.6	1.1	0.2	1.0	1.1	5.0
Irrigation	4.8	0.0	0.0	0.0	0.0	0.0	1.0	1.8	2.4	2.2	3.6	3.1	18.8
Total	4.9	0.0	0.0	0.0	0.0	0.0	1.8	2.4	3.5	2.4	4.6	4.2	23.7

In this concern, it is anticipated to allocate 150 MCM of Taleghan water to domestic and industrial uses in the capital Tehran area and 300 MCM to Qazvin irrigation during the period of the Medium-term Development Plan up to 2011. Operation of Taleghan storage dam during this period may be more flexible since agriculture is more water-tolerable than domestic and industrial sectors, and therefore evaluation of operation rule during this period is neglected.

5.1.5 Operation of Almout Water Diversion

Even if the proposed demands of some 450 MCM during the period of medium-term development plan from 2011 to 2021, consisting of 150 MCM for domestic and industrial purposes in the western area of the capital Tehran and 300 MCM for irrigation in Qazvin plain, are met by the construction of the storage dam on Taleghan river, increasing water demand in the Tehran capital area would exceed such a demand in near future. A long-term development plan defined as the Scenario-3 at the target year of 2021 will provide the development plan of transbasin water diversion from Almout river.

In order to evaluate hydrological possibility of water diversion, following four (4) cases of alternative location and alignment of proposed Almout diversion dam and Almout to Taleghan diversion tunnel as well as Taleghan to Qazvin diversion tunnel are compared as is seen in Figure 5.1.5.1. Such alternative cases are summarized as follows:

Catchment Areas at Alternative Locations of Proposed Dams (sq.km)

Alternative Plan	Almout Dam	Taleghan Dam	Total
Alt-B	330	-	330
Alt-C-1	587	-	587
Alt-C-2	587	358	945
Alt-D	721	391	1,112

It is noted here that only residual catchment downstream of the proposed Taleghan dam is counted in the above table. Engineering and physical differences of plans B, C and D are given in detail in Chapter 8 of this report. In order to evaluate the possible amount of water to be diverted from Almout and residual flow of Taleghan river downstream of the proposed Taleghan dam, following procedures were simply adopted:

- Evaluation of runoff from the basin,
- Consideration of downstream release for irrigation and river maintenance, and
- Water balance simulation for alternative cases.

<u>Evaluation of Basin Runoff for Water Diversion</u>

Daily records of river flow are available at Galinak on the Taleghan river, Baghkalyeh on Almout and Siahdasht on Shah-rud river. According to the recorded river flows at these stations, considerable differences in specific runoff yield are found between Siahdasht and other two stations, Galinak and Baghkalyeh, probably due to difference in altitude of the catchment. Detailed figures are shown in the following table.

Comparison of Specific Runoff Yield

		(1) Galinak on Taleghan	(2) Baghkalyeh on Almout	(3) Siahdasht on Shah-rud	(4) Siahdasht (adjusted)	(4)-(1)-(2)
Catchment (sq.km)		775	678	2,445	2,445	992
River Runoff (MCM)	Average	440.3	324.5	808.3	913.3	148.5
	Maximum	1,144.8	805.7	2,677.7	2,677.7	727.2
	Minimum	261.2	186.4	403.8	435.7	-79.0
Specific Yield (mm)	Average	568.1	478.6		373.5	
	Maximum	1,477.1	1,188.3		1,095.2	
	Minimum	337.1	275.0		178.2	

Note: Runoff at Siahdasht is adjusted by actual amount of Taleghan diversion.

The above figures show that over-estimation will be resulted if the specific runoff yields observed at Galinak and Baghkalyeh are extended to estimate possible inflows at the proposed sites of dam construction located downstream of these two stations. In order to avoid this dangerousness, following equations were applied for estimation:

Estimation of Inflow at Proposed Dam-sites

Alternative Plan	Basin	C.A. (sq.km)	Equation of Inflow
Alt-C-1	Almout	587	QB*587/678
Alt-C-2	Almout	587	QB*587/678
	Taleghan	358	0.1217QG
Alt-D	Almout	721	1.02QB
	Taleghan	391	0.1329QG

In the above table, QB and QG denote daily discharges observed at Baghkalyeh on Almout river and Galinak on Taleghan river respectively. Drainage area of 587 sq.km for alternatives C-1 and C-2 includes 475 sq.km of the area for the main stream of Almout river and 112 sq.km for the tributary of Andah-rud from where water is also diverted. Since the proposed site of diversion dam construction on Almout river at Dozdaksar for cases C-1 and C-2 is located closely to the hydrological station at Baghkalyeh occupying nearly 90% of the catchment area at the station, available flow at the proposed dam-site is estimated simply in proportion to the magnitude of catchment area. On the other hand, available flow of Taleghan river downstream of the Taleghan storage dam is estimated as follows:

- Residual catchment area of Almout river downstream of Baghkalyeh and of Taleghan river downstream of Galinak up to Siahdasht on Shah-rud is 992 sq.km including 322 sq.km for Almout river and 670 sq.km for Taleghan river.
- Average annual flow from the above residual catchment= 913.3-324.5-440.3=148.5 MCM.

- Residual catchment at the proposed site of water diversion near Ameshk is 358 sq.km.
- Thus, Available flow of Taleghan river near Ameshk = 148.5MCM x 358/992 x 1/440.3MCM x QG = 0.1217QG
- Available flow of Almout river at the confluence with Taleghan river = QB + 148.5MCM x (721 – 678)/992 x 1/324.5MCM x QB = 1.02QB.
- Available flow of Taleghan river at the confluence = 148.5MCM x 391/992 x 1/440.3MCM x QG = 0.1329QG .

However, above assumption can not be applied for the estimation of available flow of Almout river at the sites located far from the gauging station because that the amount of precipitation has a close correlation with the altitude of catchment. Such relations between altitudes and amounts of precipitation are given in the Master Plan report, and available runoff of Almout river at Khooban estimated by the Master Plan based on this relation, 150 MCM/annum, is quite acceptable.

Consideration of Downstream Release for Irrigation and River Maintenance

It is learnt that there extend about 2,000 ha of paddy field along the Almout river, located downstream of the proposed dam-site. It is required for the project to release necessary amount of water for paddy irrigation, and such amount of water is extracted from existing flow prior to water diversion. Estimation of irrigation water to be extracted is as under:

Cropping Calendar and Irrigation Water Requirement

	Far	Ord	Kho	Tir	Mor	Sha	Meh	**Total**
	May	Jun	Jul	Aug	Sep	Oct		
Cropping Calendar		**Land Soaking**		**Growing Period**				
Unit Irrigation Requirement (mm)		150	300	250	250	150	100	**1,200**
Irrigation Demand for 2,000ha		3.0	6.0	5.0	5.0	3.0	2.0	**24.0**
Diversion Water Requirement		3.6	7.2	6.0	6.0	3.6	2.4	**28.8**

(Demand: MCM)

It is also necessary to release some of existing flow downstream for the purpose of river course maintenance as well as for environmental conservation. There is no definite guideline to estimate the amount of water for this use, and therefore 10% of existing flow, commonly adopted in water resources planning in this country, was applied. Extraction of river water separately for both river maintenance/environmental uses and irrigation seems to be over-duty, and therefore supplemental amount of water for irrigation only when irrigation demand exceeds amount of water released for river maintenance and environmental uses is considered.

Water Balance Simulation for Alternative Cases

In all cases of computation, runoff from Taleghan river upstream of the proposed storage dam/reservoir was neglected for conservative purpose. Possible amount of water diversion varies depending on given capacity of diversion tunnel and canal, and so varieties of diversion capacity were put into computation:

Tunnel capacities given in computation:	15m^3/sec, 17.5m^3/sec, 20m^3/sec, 22.5m^3/sec, 25m^3/sec, 27.5m^3/sec, 30m^3/sec, 32.5m^3/sec and 35m^3/sec
Pump or siphon capacities given in computation:	1.0m^3/sec, 2.0m^3/sec, 3.0m^3/sec, 4.0m^3/sec, 5.0m^3/sec, 6.0m^3/sec, 7.0m^3/sec, 8.0m^3/sec, 9.0m^3/sec and 10. 0m^3/sec

Computations were made based on daily discharge record of Taleghan river at Galinak and Almout river at Baghkalyeh collected from TRWB for the 21 years period from 1975 to 1998 (data contain some missing period). Possible amount of water diversion inevitably varies from case to case, and the alternative plan C-1 was finally selected through field investigations made for promised sites of diversion dam construction and alignment of diversion tunnel in consideration of engineering feasibility from topographical, geological and structural points of view accompanied with a view from construction cost as well as water cost. Details of such consideration are described in Chapter 8 of this report. Tables 5.3.8 to 5.3.10 summarize results of hydrological computation made for the alternative plan C-1.

5.2 Groundwater Operation Study

5.2.1 BasicConcept of Groundwater Operation

When the groundwater management in Tehran – Qazvin Plain is to be expected, following requirements is to be examined. These are all be solved and achieved with the help of groundwater modeling.

Requirements assessed by groundwater modelling (1/2)
1) Whether the level of groundwater use at the current situation is appropriate, and whether continued use of groundwater is possible
This relates to "amount of groundwater resource". As for the formulation of development plan, the examination of "the hydrologic property of catchment area" and "hydraulic property of the aquifer" such as composition, distribution, scale, productivity, and storage coefficient of the aquifer will be needed.
2) Whether groundwater is used economically
Item relates to "economy of the underground water use" and its examination is to be made through comparison between the convenience of groundwater usage and the facility cost that includes construction, operation and maintenance cost of intake facilities. This item is closely related to the above-mentioned "hydraulic property".
3) Whether the quality of groundwater suits the purpose
Item relates to "chemistry of underground water". If the water quality does not match with the purpose and requires any treatment, the cost-effectiveness will be affected.
In addition to the above items, the following requirements are needed long-term perspective: 4) Whether a sharp drawdown in groundwater head will occur in the future, and 5) Whether the groundwater resource will be depleted in the future.
Item (4) and Item (5) are related to "amount of the resource of underground water". The groundwater is renewable resources within a certain limit of hydrologic cycle. A sustainable groundwater use is possible as far as it is within the recharge potential. Therefore, this groundwater recharge is the same meaning as "amount of the groundwater resource". And the understanding of "hydrologic behaviour of underground water" is essential for this evaluation. This perception is also important to determine the plan of "groundwater resource management" and "environmental influence evaluation".
6) Whether the quality of groundwater will be maintained in the future.
Item (6) may take place when the saline water intrudes into the development area from an adjacent resource. This relates to Items (4) and (5) above. However, this often occurs secondary as a result of sharp draw-down of the groundwater head or the exhaustion of groundwater resources. In any case, Items (4) to (6) will affect "influence on the environment", which include elements of the natural environment such as the eco-system and soil contamination as well as the socio-economic environment (i.e. existing water rights).

Among above six (6) items, (1) and (2) have accomplished through the establishment of current groundwater balance. (3) and (6) are satisfied by relevant quality information to groundwater movement and balance, Further, if the groundwater monitoring system is to be designed, concrete information are to be required, as below:

Requirements assessed by groundwater modelling (2/2)
(a) Select Monitoring Locations
To detect the release from the pollution source to groundwater, monitoring features must be installed within aquifers at locations; so-called as "Target Monitoring Zone" that is impacted by a release from the potential source. The Target Monitoring Zone should be selected to interpret potential contaminant migration pathways.
(b) Select Monitoring Features
Appropriate monitoring features must be selected for obtaining the required samples or data from the Target Monitoring Zone. Monitoring features may include ground water monitoring wells, piezometers, sampling probes, etc. However, the combination in facility spacing and location is not often selected in suitable form due to lack of hydrogeological information particularly groundwater pathway.
(c) A Particle-Tracking
Both "Monitoring Zones" and "Monitoring Futures" are only selected to interpret potential contaminant migration pathways or hydrogeological information especially of groundwater pathways. If there are uncertainties about the ability of the proposed monitoring system, then efficiency can be estimated by using computer programs with particle-tracking capability to identify zones within the potential source area from which a release would not likely be detected. MOD PATH is useful to determine the pathway in the basin to monitor groundwater quality. These model requirements must be satisfied for obtaining necessary information to construct the initial plan of groundwater monitoring system. These are achieved by groundwater model composed of two parts: "Groundwater Flow Model" by "MODFLOW" and path-line analysis by "Particle Tracking Model" as described in following sections.

In proper way, above requirements must be solved by "Management Model (refer to subsection 7.6)" including various evaluation tools: groundwater budget model, groundwater flow model, particle tracking (movement) model; and contaminant transport model and etc. However in this operation study, two tools of them, "Groundwater Flow Model" and "Particle Movement Model", are tentatively employed within the course of the Study's objectives. Requirements (1) and (2) are satisfied through the simulation of the regional hydrogeological phenomena of the basin by "Groundwater Flow Model(MODFLOW)" until 2021. Requirement (a), (b) and (c) are fulfilled by forecasting path-line of polluted particles by "Particle Movement Model (MODPATH)".

5.2.2 Water Operation for Groundwater Use

For the purpose of the evaluation of water resources as well as the formulation of the M/P with limited resources in the future, a simulation till 2021 is planned with the use of MODFLOW and MODPATH.

<u>Setting-up Simulation Cases</u>

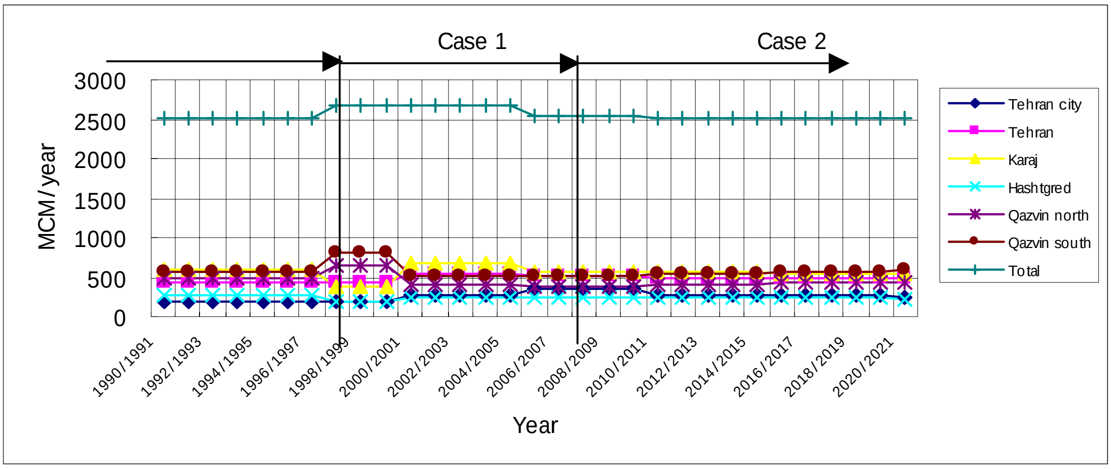
The simulation are planned for the purpose of evaluating the water allocation plan of M/P and JICA review in next decades. It examines the system response of basin till 2021 by cases with M/P scenarios: Secnario-2 (medium-term plan for the year 2011) and Scenario-3 (long-term scenario for the 2021). Besides, 100 and 150 m of marginal depths is concerned, as below:

<table>
<tr><th rowspan="2">Case</th><th rowspan="2">Period of Simulation</th><th colspan="2">Condition Applied for Simulation Cases</th></tr>
<tr><th>Groundwater Recharge / Groundwater Inflow /Return Flow /Evaporation / Qanat Extraction/Groundwater Outflow</th><th>Well Extraction Amount for Plan (Amount allocated for Model)</th></tr>
<tr><td>Case0 (Current)</td><td>1990-2000</td><td rowspan="3">Groundwater Recharge: values given as “Direct Recharge from Precipitation” and “Infiltration of River” are estimated from the mean value of metrological records shown in “hydrologic sectors”.
Groundwater Inflow: values given are estimated from the contour map of groundwater table in average year (Oct. 1994).
Return Flow: Estimation is mede from the result of “Statistical Reports of Groundwater Resources (1996/1997)” and land use survey (1997/1998).
Evaporation: evaporation values are estimated from the groundwater contour map delineated in the average year (Oct. 1994).
Qanat Extraction: “Statistical Reports of Groundwater Resources (1996/1997)” is given as extraction amount.
Groundwater Outflow: value is based on the analytical result of the average year (Oct.1994).</td><td>Value is obtained through trail runs of model simulation:
1990-1995:3920(2500) MCM/year
1995-2000:3920(2700) MCM/year</td></tr>
<tr><td>Case 1 (Senario2)</td><td>1990-2011</td><td>Value is determined by the trail runs of the Model by 2000 and Scenario-2 by
1900-1997: 3290 (2500) MCM/year
1998-2000: 3290 (2700) MCM/year
2001-2005: 3285 (2680)MCM/year
2006-2010: 3340 (2550) MCM/year
2010-2011: 3310 (2520) MCM/year</td></tr>
<tr><td>Case (Senario3)</td><td>1990-2021</td><td>Value is determined by the trail runs of the Model by 2000 and Scenario-3 by
1900-1997: 3290 (2500) MCM/year
1998-2000: 3290 (2700) MCM/year
2001-2005: 3285 (2680) MCM/year
2006-2010: 3340 (2550) MCM/year
2010-2015: 3310 (2520) MCM/year
2016-2020: 3310 (2520) MCM/yea
2021-2021: 3285 (2500) MCM/year</td></tr>
</table>

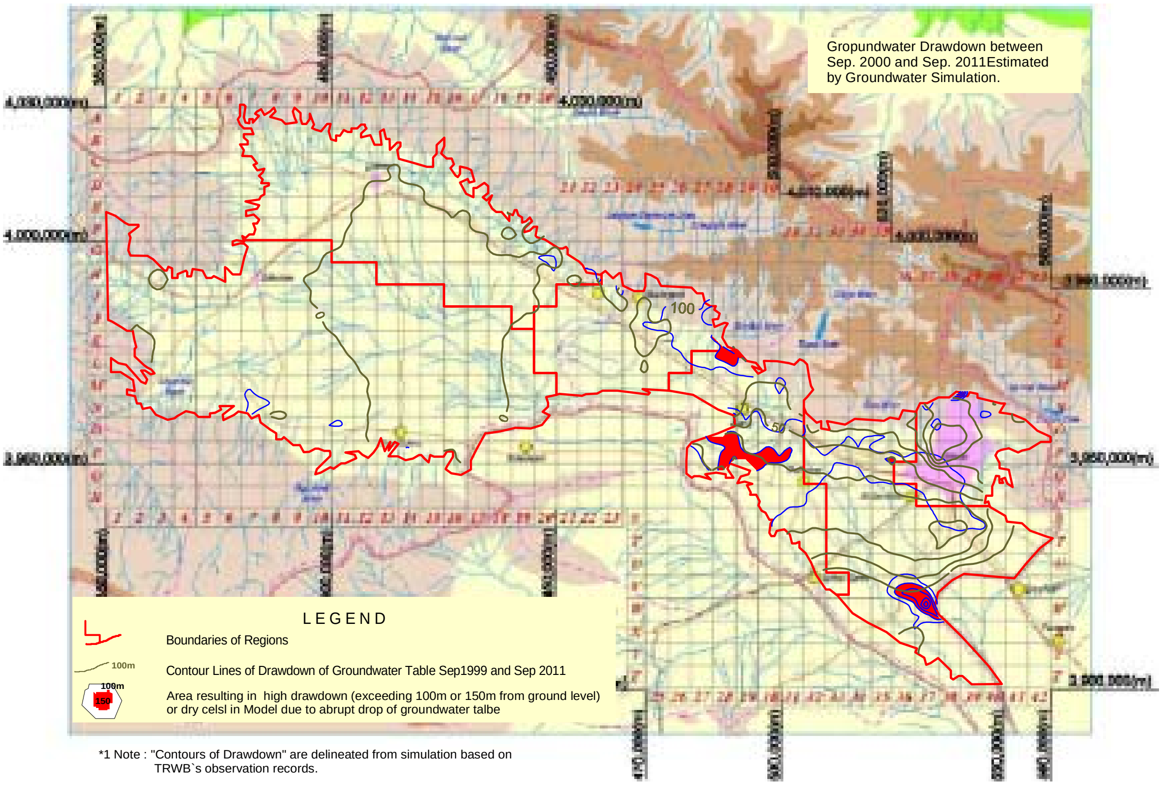
In fact, this simulation study is to outlook the degree of groundwater lowering achieved by effort to examine basin responses by re-producing the hydrological phenomena and materializing the groundwater development plan. In this context, the both conditions of Case 1 and 2 are made for forecasting the timing of drying up of the groundwater resources, and the evaluation of “mining yield of groundwater basin” with planned future water demand.

Result of Case 1 (Senario-2)

The conditions of Case 1 are prepared for evaluation of water demands planned in Scenario-3. The demands are processed into four sections settled for each time periods, as below:



In the calibration period from1990 to 2000, the amount of groundwater extraction is calibrated in a practical manner. This means, the original extraction value (3,290 MCM/year) estimated in "Statistical Reports of Groundwater Resources (1996/1997) is revised to a specific value (2500 which is of 76 % of the original. Therefore, in the simulation since 2001, the net value (76-81% of that of per value by Scenario 3) is applied with stepwise increase/decrease form the 2,500 MCM to 2680 MCM/year. The groundwater draw-down is estimated as below and Figure 5.2.2.1.

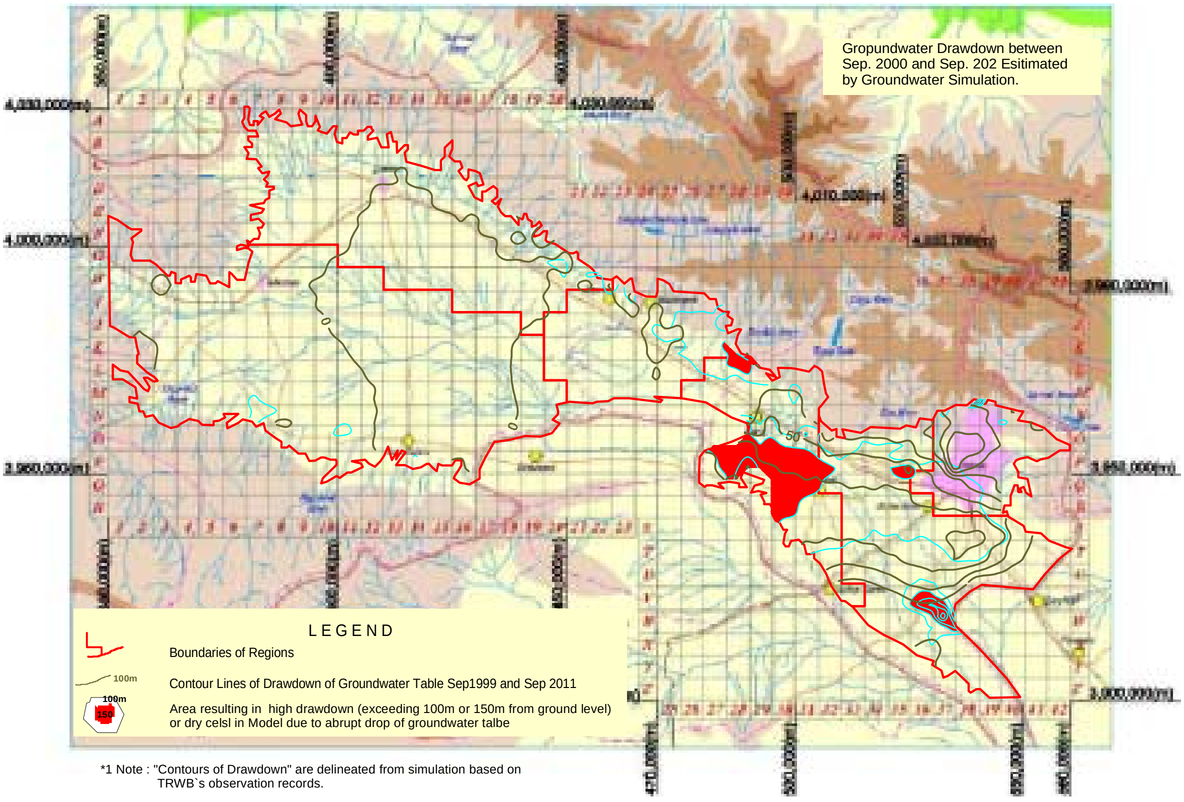


If Marginal Depth is settled at 100 or 150 m, the obstacles for pumpage are taken place at wide range between Tehran and Hashtgerd.

Marginal Depth
Pumpage from aquifer must be evaluated by "Marginal Depth", which is defined by available groundwater level within economical guarantee. In the Study, "Marginal Depth" is decided as a realistic border whether water is pumped up within profitable level for agricultural use. In fact, large amount of groundwater is consumed for irrigation in the Plain. While in water cost in this area, it can be estimated by requirements on the capacity and cost of equipment necessary to be installed to pumping depths. At least, pumpage form deeper than 150 m is not profitable activity for the irrigation purpose based on actual market price as of 2001 in Qazvin Area.

Result of Case 2 (Senario-3)

Case 2 is aiming to evaluate the Senario-3 and to predict basin-wide impacts, affecting the consumed areas. The demand applied is 100% of that of Scenario 3. This value is also set as "phased development plan" since 2011, as to stepwise development of groundwater followed by Case1 (Senario2). The drawdown of groundwater is shown below and Figure 5.2.2.2.



Even the groundwater extraction is decreasing from that of Case 1, the area shown in high draw-down is wider than that of Case 1. It is extended far to the south of Tehran. This should indicate the "mining of groundwater resources" in particular Tehran, Karaj and Hashtgerd region. Amount extracted on M/P must be managed, as far as possible, within minimum necessity to supplement shortage especially at water sources in domestic use, with respect to the "concept of basin yield" which is useable yield within sustainable amount in groundwater basin.

There are some discrepancy in the amount of extraction between those abstracted from “Statistical Report of Groundwater Resources (1996/1997) and that from mathematical model simulation. It may be derived from inaccuracy of “Statistical Report”, as well as methodology for the estimation, such as lack of realistic information for the usages of wells. This estimation was originally based on an assumption that every wells were working 16 hrs in a day. On other hand, the mathematical model must deal with real information and data. Hence, the amount from simulation always gives less amount than that from “Statistical Report”. To make up this gap between both and to confirm the actual extraction amount, factual inventory survey which involves questionnaire and interview to the uses for at least 5% of every wells and qanats are to be required in the future.
Since 40 years ago, the most of water used in Tehran City have been conveyed from outside of the City. Therefore, the “Tehran Aquifer” has been recharged and has rises of groundwater tables especially at the upper parts of the city or upper horizons of aquifer. As result of simulation, the storage of Tehran Aquifer is not changed or few impacts suffered by the future extraction. However, the risk for groundwater contamination is considerably high from wasted water through the city water supply, as result of path-line analysis.

Groundwater Path-line Analysis

With the transient state simulation of groundwater flow model, the components of the velocity vector at every cells adjacent to Tehran and Qazvin is being estimated. The groundwater path-lines are obtained by which this vector of flow are apply to “Particle Tracking Model” together with staring locations. If sources of pollution are assumed to be settled along the fringe of Tehran, Karaj and Qazvin city and industrial areas, groundwater pathway starting from pollutants are hypothetically delineated in Figure 5.2.2.3. The particles originated form the outskirts of cities and industrial areas are spreading toward the south and are spreading far beyond 20 km during 30 years. In some cases, particles are terminated by capturing at production wells. In fact, some contaminations are found in observation wells locating in and around Tehran city. With the use of locations of these observatories, backward tracing of particle is carried out as shown in Figure 5.2.2.4 As the result of backward tracing, sources of contaminations are traced on several ways in the west of Tehran city, Kan river. In other words, these range covered by estimated path-lines are represented as necessary coverage to be monitored by observation network for water quality. Using these results, the designing of monitoring wells in appropriate number and location is described in next section.

5.3 Reuse of Sewerage Water

There is no significant water reuse in the Study Area at present. The treated water from sewerage system is released to watercourse at about 6 MCM in Tehran, and counted as rechargeable water source.

The waste water treatment systems have been and are being installed in Tehran, Karaj and Hashtgerd.

But the treated water is not significantly used for certain purpose and is released through the watercourses.

5.3.1 Sewage Water Treatment Plan in Tehran

The sewage treatment plant-1 is now ready for the start of construction in Tehran city to serve the population of 2.6 million and will be completed in 2006. This treated water is scheduled to utilize for agricultural purpose but the difficulty exists for the farmers to use this water. The farmers are conservative to give up present wells which is totally under their control. Accordingly the distribution canal system for the treated water to farm area shall be carefully studied under participation of farmer water user group.

The implementation schedule of the above sewerage treatment in Tehran city plant is as shown in the following table:

Sewerage Implementation Plan in Tehran City

	2001	2006	2008	2011	2013	2016	2018	2023
Phase 1								
North	-	1.84						
Central	0.78	1.26			0.1	0.82		
South-West	2.00	-						
South & South-East	1.10	0.80		0.82				
Sub-total	3.88	3.90	0	0.82	0.1	0.82		
Phase 2								
North-East & East			2.16	0.80			1.47	
North-West & West			0.73		1.47		2.20	
West Bank of Kan River					1.05			4.00
Sub-total	0	0	2.89	0.8	2.52	0	3.67	4.00
Total	**3.88**	**3.90**	**2.89**	**1.62**	**2.62**	**0.82**	**3.67**	**4.00**
Accum. Total (m^3/sec)	**3.88**	**7.78**	**10.67**	**12.29**	**14.91**	**15.73**	**19.40**	**23.40**
Accum. Total (MCM)	**122**	**245**	**336**	**388**	**470**	**496**	**612**	**738**

(Source: The Tehran Water & Sewerage Company)

In Karaj, the pipeline network for sewerage system is under construction. There are two main areas of networks, one in the central north and another in the southwest, where has very low permeability having pollution of human activity. In order to solve the problem, the main part of the system has been designed and the pipeline networks are under construction. The treatment system has been designed with a lagoon type but the construction work has not started yet.

In Hashtgerd, the treatment system with lagoon is ready for industrial zone locating adjacent to the salt marsh but its detail is not available.

5.3.2 Reuse of Sewage Water for Irrigation

The reuse irrigation water is assumed at about 80% of the treated water by sewerage plant and its annual production is as follows;

	2001	2006	2008	2011	2013	2016	2018	2023
Treated Water (MCM)	122	245	336	388	470	496	612	738
Reuse Water for Irrigation	100	200	270	310	380	400	490	590

It is assumed to allocate the reuse water of 100MCM to Karaj irrigation area, 250MCM to Tehran region and 240MCM to the Varamin irrigation area in the eastern capital area.

5.4 Water Allocation Plan

5.4.1 Review of the Master Plan Study

Water allocation plans have been prepared in the Master Plan on the basis of projection of water demands for various uses, evaluation of potential and available water from surface and underground sources, water balance study between demand and supply under the present situation, at the year 2006 as the short-term plan, at 2011 as the medium-term plan and at 2021 as the long-term plan. The JICA Study has also made careful studies on the plan of water allocation based on a review of the Master Plan Study and on additional investigation and analyses. Basic approaches employed by the JICA Study are as follows:

- Various water demands projected by the Master Plan are not altered in principal whenever they are reasonable and acceptable.
- No comment was made on the volume of water to be imported from Lar and Latian dams to Tehran City for domestic and Industrial uses.
- Uses of water from Karaj and Taleghan dams were reviewed based on operation studies of reservoirs, consideration of priority of water use between domestic/industrial uses and irrigation, and timing of project implementation for water resources development.
- All scenarios of water allocation were linked with the above schedule of project implementation for water resources development and management.
- Due to lack of reliable data, evaluation of available water resources from tributaries flowing into Tehran region and Qazvin plain followed the assumption made by the Master Plan.
- Reuse of water from sewage treatment plants was estimated based on the implementation schedule of sewerage projects proposed by the Tehran Water Supply and Sewage Company.
- Availability of groundwater was reviewed taking into account the present decreasing tendency of groundwater levels and extraction. Groundwater use for agriculture in Karaj and Hashtgerd regions will decrease largely in future.

The results of review made by JICA Study on the Master Plan are summarized as follows:

(1) Surface Water Resources

Potential and available surface water resources in the Study Area are summarized as per Figure 5.4.1.1 and as shown below, according to the data and information employed in the Master Plan Study and additional collected and analyses made by JICA Study.

Potential and Available Surface Water Resources

Unit: MCM

River	Master Plan		JICA Review		Remarks
	Potential	Avail -able	Potential	Avail -able	
Taleghan at Damsite	480	460	480	450	Qazvin irrigation/Tehran urban water
Taleghan Downstream	325	308	40	-	Qazvin irrigation
Almout at Proposed Diversion			325	250	
Small Streams in Tehran Area	265	170	200	170	Tehran area/Northern Qazvin plain
Karaj at Bileghan	480	435	490	435	Tehran urban water/Karaj irrigation
Kordan at Dehsommeh		180	120	60	Hashtgerd irrigation
Qazvin North Streams			95	60	Qazvin irrigation
South Qazvin Three Rivers			250	140	Qazvin irrigation
Jaj-rud at Latian (Lar Dam incl.)	460	400	460	400	Tehran urban water
Total		**1,953**	**2,460**	**1,965**	

Of 2,460 MCM of the total potential surface water resources in the Study Area, about 1,390 MCM or 57% are being utilized at present and additional 575 MCM will be usable in future amounting to 1,965 MCM of water supplied from surface resources in the target year of 2021. Here, the "potential water" is given in terms of an average annual runoff of river and figures employed in the Master Plan are proved acceptable through JICA review. Potential water is, however, not always available or usable because of large fluctuation of monthly flow in rivers. Without controlled by storage reservoirs, peak flood discharges during flood season are usually spilled downstream without utilized and low flows during dry season are insufficient to meet the demand for domestic and irrigation uses. Potential water becomes available only when seasonal flows in river are controlled by storage-type facility such as a reservoir. Available or usable water should therefore be evaluated through water operation study. In addition, about 590 MCM of re-used water from sewage treatment plants may become available in the project target year of 2021. Out of 590 MCM, 100 MCM for Shariyar and Robatkarim, 250 MCM for Tehran region and 240 MCM for Varamin will be allocated.

Available water resources of Karaj and Taleghan rivers for diversion are estimated on the basis of reservoir operation study, while water diverted from Almout river can become available when it is used in combination with groundwater in Qazvin plain. Because of topographical, geological and economic difficulties, it is rather difficult to construct a storage-type dam on Almout river. Seasonal fluctuation of Almout flow can not be controlled and therefore deficit of water due to low flow in river is to be supplemented by groundwater. About 80% of rich runoff from April to June could be used for irrigation and nearly 100% of dry season flow, after released partially for river maintenance and irrigation uses, would be diverted in order to recharge groundwater resources and in turn to minimize extraction of groundwater in the Qazvin plain.

Except Kordan river where irrigation system is extended including diversion weir, potential water resources in small streams are at present used mainly to recharge groundwater aquifers. Share of such water used for domestic and/or irrigation purposes is very limited since no facility to divert, control and use river water is distributed over the area. For effective use of surface water resources in small rivers and streams, it is necessary to provide water-use facilities.

Potential water of Shah-rud river is to be studied carefully, because proposed water diversion from Taleghan and Almout to Qazvin and the western capital area will reduce the Shah-rud flow considerably throughout a year. This decrease of river flow influences the operation of Sefid-rud dam (Manjil dam) and as a result will give some influence to the Giran irrigation area located downstream of the dam. A preliminary study on this subject is given in Chapter 9 of this report.

(2) Groundwater Resources

Groundwater resources in the Study Area have been estimated by JICA on the basis of existing statistics consisting of 11,200 deep wells and 13,800 shallow wells. Comparison of extraction of groundwater is shown in the following table.

Present Extraction of Groundwater

Unit: MCM

Area	Master Plan			JICA Review		
	Water Spply	Irrigation	Total	Water Spply	Irrigation	Total
1. Tehran Capital Area						
Tehran City	269	-	269	270	-	270
Tehran	144	541	685	150	450	690
Karaj	414	433	847	415	430	845
Hashtgerd	32	288	320	30	290	320
Sub-total	859	1,262	2,121	865	1,260	2,125
2. Qazvin Plain						
Sub-total	91	1,074	1,165	90	1,070	1,160
Total	**950**	**2,336**	**3,286**	**955**	**2,330**	**3,285**

There is no useful and reliable data as well as description on groundwater in the Master Plan report. Accordingly, groundwater data are collected and analyzed mainly by JICA Study Team with close cooperation of Deputy Water Resources Studies and Research of TRWB and Qazvin Water Board.

(3) Water Demand and Water Supply Sources

Unit water demand for domestic use in urban area (liter/capita/day) employed in the Master Plan is judged reasonable, however, unit demand of water proposed for irrigation seems to be high requiring a reviewing study that may be done on the premise of application of proper and rational irrigation method and proper management of water at irrigation facilities along canal and of water use at on-farm level, in order to minimize losses of irrigation water.

Water demand and corresponding source of water in each service area are designated in the Master Plan for the period from 2001 to 2021. Following issues and figures given in the Master Plan are, however, subjects for further reconfirmation.

Allocation of Taleghan Water to Tehran City

- Water supply demand in Tehran city increases to 1,080 MCM in 2011 and 1,230 MCM in 2021. In order to meet above increasing demand of water in Tehran city, 137 MCM of Taleghan water is scheduled to be supplied in 2006 through Ziaran-Karaj pipeline now under construction, and additional 205 MCM is anticipated to be supplied toward 2021 through a new pipeline, according to the Master Plan. As far as volume of water to be diverted from Taleghan concerns, JICA Study confirmed that it is quite possible.

- Allocation of 310 MCM of Taleghan water to Tehran capital area could become available in 2011 when all of the proposed Taleghan storage dam, 2nd stage of pipeline between Ziaran and Bileghan and water diversion tunnel to connect Karaj dam and Tehran City have been completed. Water allocation plan of 2011 given in the Master Plan is, however, to be modified as follows:

- Karaj dam water to Tehran through Karaj-No.6 tunnel	150 MCM
- Karaj dam water to Tehran through Bileghan pipeline	170 MCM
- Taleghan water to Tehran through Bileghan pipeline	150 MCM
- Karaj water to Karaj irrigation	115 MCM

Tehran Region

- Water demand for domestic and industrial uses in Tehran region will increase to 190 MCM in 2021 from 150 MCM in 2001 due to growing population in urban areas such as Eslamshah, Charchak, Akbarabad, etc. as well as increasing demand in existing Industrial areas. This increment of water of about 45 MCM will be supplied from groundwater since there is no more source of surface water in the region.

- In the Master Plan, agricultural water demand in the area is estimated to increase from 710 MCM in 2001 to 870 MCM in 2021. Out of 710 MCM presently allocated, the greater part of 540 MCM is supplied from groundwater while remaining 170 MCM is covered by surface water of small streams flowing down from the northern mountains of Tehran city. Out of the future demand of 870 MCM, the amount of 250 MCM is planned to be supplied by reused water of sewage after simple treatment, 450 MCM by groundwater and 170MCM by small rivers.

Karaj Region

- Urban and industrial water in Karaj area will increase from 415 MCM in 2001 to 600 MCM in 2021. Groundwater is expected to cover such an increase of future demand of water, mainly converted from agricultural use to domestic and Industrial uses.

- Agricultural water demand will decrease from 565 MCM in 2001 to 440 MCM in 2021 due to acceleration of urbanization in this area. Consumption of groundwater for agricultural use will decrease to 175 MCM in 2021 from 430 MCM in 2001, while allocation of surface water from Karaj dam will increase to 165 MCM in 2021. About 100 MCM of re-used water from sewage is expected to cover a part of irrigation demand in the year 2011.

Hashtgerd Area

- Urban and industrial water demand in this area is 30 MCM in 2001 and will increase remarkably to 120 MCM in 2021 in association with urban and industrial development newly nominated by the government. Incremental demand of 90 MCM will be served by groundwater, after converted from agricultural use at present.
- Agricultural water demand will decrease from 350 MCM in 2001 to 260 MCM in 2021 due to conversion of farmland to settlement and industrial area. In association with this conversion of land use, groundwater presently utilized for agriculture will be converted to domestic and industrial uses.
- Kordan river has a renewable surface water resources of 120 MCM, of which 60MCM is being used for agriculture. Large alluvial plain of Kordan river has a possibility to recharge groundwater aquifers when groundwater recharge dam is constructed.

Qazvin Plain

- Urban and industrial water demand in this area will increase largely to 180 MCM in 2021 from 90 MCM in 2001. Increment of 90 MCM is expected also in this area from new development of groundwater. Numbers of deep wells have been excavated to develop groundwater centralized in urban zones such as Qazvin, Takestan, Buin Zahra, etc.
- Agricultural water demand increases to about 1,740 MCM in 2021 from 1,455 MCM in 2001, of which 1,070 MCM is supplied from groundwater and 385 MCM from surface sources. In this area, increasing demand of water will be supplied mainly from surface sources such as Taleghan and Almout rivers. Potential and available surface water resources estimated in the Master Plan will need a little correction when compared with data collected from TRWB as well as reviewing study made by JICA.
- Allocation of Taleghan water to Qazvin irrigation around the year 2006 will be 170 MCM distributed in relatively higher elevated service area of existing Qazvin north irrigation system. After completion of the proposed Taleghan dam at the year 2011, 300 MCM will be distributed to Qazvin plain consisting of 170 MCM for the northern higher area and 130 MCM to serve irrigable area in the northern lower area and central plain. At the year 2016 when implementation of the proposed Almout water diversion project will be completed together with implementation of the 2nd stage of Ziaran – Karaj pipeline and 2nd stage of new

Qazvin irrigation system, the lower northern Qazvin area and the area to be newly developed in the central plain will be irrigated by about 250 MCM of water diverted from Almout river.

- Existing achievement of Taleghan water diversion is recorded at 160 to 200 MCM annually, requiring revision of figures given in the Master Plan. Results of the water balance study of Taleghan diversion made by JICA for the cases with and without construction of the proposed Taleghan storage dam have proved that about 290 MCM of water diversion from Taleghan river under existing conditions could be possible.
- The Khooban dam, proposed in the Master Plan on Almout river at the upstream-most site, has been investigated also by JICA, but canceled due to the fact that potential water of some 150 MCM from a small catchment of 240 sq.km is to little to satisfy demand of water required and diversion of water from the proposed site of Khooban dam to the Taleghan dam or Qazvin plain is rather difficult from both technical and economical points of view.
- Groundwater use in the Qazvin plain is estimated at 1,070 MCM in 2001, which will increase to 1,150MCM in 2021 by groundwater recharging project in the plain. Proposed water diversion from Taleghan and Almout rivers to the Qazvin plain will however contribute to recharge of groundwater aquifer underneath the plain, resulting in increase of potential groundwater extraction in future.
- As regards practical measures of water use in Qazvin plain, after diversion of water from Taleghan and Almout river, nothing has been described in the Master Plan. Such practical and rational measures of water management inclusive of specification of irrigation service area have been made by JICA taking into account allocation of Taleghan water to the western capital area of Tehran. Figures given in the Master Plan will need modification referring to the output of JICA Study.

(4) Water Allocation Plan

Allocation plans of water from major surface resources made by the Master Plan and JICA are compared as shown below:

Comparison of Water Allocation Plans of Taleghan and Almout Water

Unit: MCM

Items	JICA Study	Master Plan (Final)	Remarks
1. Tehran Water Demand	**1,230**	**1,232**	JICA followed Master Plan
2. Karaj Dam Water			
for Tehran Urban Water	270	-	Karaj dam to No.6 plant by tunnel
-do-	-	250	Bileghan to No.1/2 plants
for Karaj Irrigation	165	185	
Total	**435**	**435**	
3. Taleghan Diversion Water			
for Tehran Urban Water	310	342	Bileghan to No.1/2 plants
for Karaj Irrigation	-	-	from Taleghan dam
for Qazvin Irrigation	140	124	-do-
for Downstream Release	30	14	-do-
Total	**480**	**480**	-
4. Almout Diversion Water			
from Khuban Dam	-	208	Available water is only 120 MCM
from Downstream Taleghan	-	100	method of diversion not clear
from Dozdaksar Diversion Dam	250	-	by gravity
Total	**250**	**308**	

Based on the reviewing study of water demand and allocation given in the Master Plan, JICA Study result for water demands and water allocation plans is shown in Table 5.4.1.1.

In preparation of above plans by JICA, particular attention was paid for the following items:

Tehran Urban Water

- Since urban water demands of Tehran City are the fundamental issue to formulate the Master Plan occupying majority part of the total demand, and because that these figures have already been approved by the Ministry of Energy, JICA Study followed the same values.
- Evaluation of allocation plan of water from Latian and Lar dams was excluded from JICA Study, and hence same figures given in the Master Plan were simply employed in the JICA study.

Taleghan Water and Its Allocation

- As aforementioned, allocation plan of Taleghan and Karaj water proposed in the Master Plan needs modification taking into account the construction plan of a diversion tunnel to connect Karaj dam and the proposed No.6 treatment plant in Tehran City.
- In 2011, 150 MCM of Taleghan water could easily be allocated to Tehran water supply system, while 300 MCM of Taleghan water would be supplied to existing irrigation system in the northern Qazvin plain and new developed area in the central Qazvin plain.
- In order to achieve the water supply plan to cope with demand of water in Tehran City in 2011, construction of a tunnel to link Karaj dam and proposed No.6 treatment plant shall be

implemented urgently since construction of this 24 km long tunnel will require a long period of 6 years.

Karaj Agricultural Water

- Agricultural area in Karaj region will decrease year by year due to expansion of urban and industrial areas. Accordingly water demand and allocation of water for agriculture from groundwater resources will decrease towards 2021. Groundwater corresponding to the decrease of agricultural water will be used in future for urban and industrial purposes.
- Amount of surface water supplied from Karaj dam for agriculture in Karaj region will maintain almost same order as it is at present and sewage water produced from Tehran City after simple treatment will become available at the year 2011.

Qazvin Agricultural Water

- The Master Plan describes that water demand reaches the largest volume of 1,723 MCM in 2011 and then decreases to 1,685 MCM in2021. On the contrary in due consideration of importance of Qazvin plain as the center of food production in the national food security program and also availability of land and water, JICA expects sustainable growth of agricultural development in Qazvin plain in future and, as a result, estimates that agricultural water in 2021 will increase to 1,740MCM..
- The Master Plan allocates 144 MCM of Taleghan water during the period from 2001 to 2006, and JICA allocates 200 MCM for the same period because that Qazvin plain has received actually 200 MCM at least of water through Taleghan diversion facility and moreover water balance simulation made by JICA at the existing Sangban diversion dam has proved it is possible. Allocation of Taleghan water to Qazvin will decrease to 140 MCM in 2016 because by this time water of 250 MCM will become available through the Almout water diversion.
- Construction of Khooban dam together with diversion tunnel to connect the dam with existing Ziaran reservoir is proposed in the Master Plan. However, this plan is likely unfeasible in both technical and economical points of view since small catchment of the proposed Khuban dam, 240 sq.km, will produce only 150 MCM of annual water that is quite far from actual requirement of water.

Karaj Urban and Industrial Water

Urban and industrial water in Karaj area is expected mainly from groundwater sources after conversion from agricultural use. Allocation of groundwater between agriculture and other uses is compared in order to present the progress of such conversion, as follows:

Allocation of Groundwater in Karaj Area

Unit: MCM

	2001	2006	2011	2016	2021
Decrease of Water Allocated to Agriculture	430	305	265	220	175
Increase of Water for Urban/Industrial Uses	415	460	500	550	600

Qazvin Urban and Industrial Water

Urban and industrial water in Qazvin plain depends also on groundwater at present and even in future. 90 MCM of the present allocation of groundwater will increase to 180 MCM in 2021, amounting to about two times of present consumption. Groundwater resources around Qazvin and Takestan have already been developed to a full extent, and therefore safe yields of groundwater in these areas should be examined carefully.

5.4.2 Water Allocation Plan by Region

Taking all of aspects aforementioned into consideration, allocation plan of surface and groundwater resources has been established as summarized in Figures 5.4.2.1 to 5.4.2.4

(1) Water Allocation Plan for Tehran City

Comparison of the water allocation plans for Tehran city between the Master Plan and the JICA Study is shown in the following table;

Water Allocation for Tehran City (Urban Water Supply)

Unit: MCM

Water Sources	Master Plan				JICA Review				
	2001	2006	2011	2021	2001	2006	2011	2016	2021
1. Surface Water									
Lar Water	180.0	180.0	180.0	250.0	180.0	180.0	180.0	180.0	250.0
Latian Water	159.1	157.3	154.5	146.2	160.0	160.0	160.0	160.0	150.0
Karaj Water	300.0	300.0	300.0	250.0	300.0	340.0	320.0	300.0	270.0
Taleghan Water	-	137.0	137.0	342.0	-	-	150.0	250.0	310.0
Sub-total	639.1	774.3	771.5	988.2	640.0	680.0	810.0	890.0	980.0
2. Groundwater									
Sub-total	268.8	245.0	309.1	245.9	270.0	340.0	270.0	270.0	250.0
Total	**907.9**	**1,019.3**	**1,080.6**	**1,234.1**	**910.0**	**1,020.0**	**1,080.0**	**1,160.0**	**1,230**

Present Situation (2001)

JICA Study simply followed the water allocation plan given in the Master Plan. The proposed urban water demand of 910MCM could be supplied easily from existing water sources such as Lar, Latian and Karaj dam as well as groundwater. Groundwater to be used for urban water supply is 270MCM that is sustainable extracted by the existing deep well system.

Short-term Plan (2006)

The water demand reaches 1,020MCM in 2006 with increment of about 110MCM against the demand of 910MCM in 2001. It is proposed in the Master Plan to cover this increment by the existing Taleghan diversion water because of no additional available water in the existing reservoirs. It is impossible, however, to convey the Taleghan water to Tehran city by 2006 due to the following reason;

Although the Taleghan water of 150MCM could be conveyed from the outlet of existing Taleghan tunnel at Ziaran to Karaj river at Bileghan though the water pipeline to be completed by 2001, this Taleghan water can’t be supplied to Tehran city before the new conveyance facility from Karaj to Tehran city has been completed. T.R.W.B intends to construct a new water conveyance facility to link the site immediate downstream of the existing Karaj re-regulating dam with the proposed No.6 water treatment plant located at a high elevation of more than 1,600m in Tehran City. There are two alternatives, the diversion tunnel under gravity flow with a long distance of 24km and the pipeline system equipped with the pumping station requiring high lifting head of more than 200m. Details of these plans are described in paragraph 6.1.2 of this report.

However this project will require a long implementation period of more than six years including period for survey and design. Accordingly the Taleghan water is unusable at this time for Tehran water supply but for Karaj agriculture.

It is therefore necessary in 2006 to use the stored water of Karaj reservoir as well as groundwater at the maximum level instead of Taleghan water. In accordance with the careful study for the past operation of both water sources, Karaj water of 340MCM and groundwater of 340MCM could be supplied to Tehran urban water in 2006. Of course it is not recommendable to continue such excess water uses for a long time, and hence the new water conveyance project to connect Karaj river and No.6 treatment plant is the very urgent subject for study and implementation, otherwise Tehran water supply will face critical water shortage problems during the period from 2006 to 2010.

<u>Medium-term Plan (2011)</u>

Water demand increased to 1,080MCM in 2011 will be easily supplied because the new water conveyance facility from Karaj to No.6 plant will be completed not later than 2011 and the Taleghan water will become available for Tehran water supply.

Volume of water to be supplied from Taleghan river is proposed at 137MCM in the Master Plan, however, it could be increased to 150MCM under the full design capacity of the pipeline from Ziaran to Bileghan since there still remains plenty of excess water in the Taleghan river before completion of the dam construction by 2011. It is recommendable to utilize the Taleghan water at maximum in view of minimizing the use of groundwater.

Use of water from Karaj dam and groundwater in 2011 is cut down to 320MCM and 270MCM respectively from the excessive use of 340MCM in 2006. Available waters from other sources are same as those scheduled in the Master Plan.

Long-term Plan (2016)

Water allocation plan in 2016, not described in the Master Plan, is studied by JICA based on the averaged water demand between 2011 and 2021. Total water demand in 2016 is estimated at 1,160MCM and will be supplied sufficiently from water sources as shown in the above table.

Karaj water of 300MCM in 2016 will be directly conveyed through the water conveyance facility from the Karaj river to No.6 treatment plant. Taleghan water of 250MCM will be conveyed from the Taleghan dam through the new water pipeline connecting Ziaran and Karaj river to be completed by 2016, and then supplied to the existing No.1 and No.2 water treatment plants in Tehran City through the existing pipeline between Karaj and these plants. Other available waters from different sources are same as those in the Master Plan.

Long-term Plan (2021)

Water demand in 2021 reaches 1,230MCM in total, which will be supplied from sources as shown in the above table.

Available water from Taleghan reservoir to Tehran water supply, estimated at 340MCM in the Master Plan, is reduced to 310MCM by JICA after reviewing study because that water from other sources is available to meet the proposed demand and Qazvin irrigation also requires the Taleghan water as much as possible.

(2) Water Allocation Plan for Tehran Region

Water Allocation for Tehran Region

Unit: MCM

Water Sources	Master Plan				JICA Review				
	2001	2006	2011	2021	2001	2006	2011	2016	2021
1. Surface Water									
Karaj Water for Greenery	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Small River for Agriculture	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0
Reuse Water for Agriculture	-	-	-	500.0	-	-	50.0	150.0	250.0
Sub-total	170.0	170.0	170.0	670.0	170.0	170.0	220.0	320.0	420.0
2. Groundwater									
Domestic Use	90.1	97.6	105.2	122.3	90.0	100.0	110.0	110.0	120.0
Industrial Use	54.3	59.2	64.2	73.4	60.0	60.0	60.0	60.0	70.0
Agricultural Use	541.4	646.0	547.2	231.8	540.0	540.0	500.0	485.0	450.0
Sub-total	685.8	802.8	716.6	427.5	690.0	700.0	670.0	655.0	640.0
Total	**855.8**	**972.8**	**886.6**	**1,097.5**	**860.0**	**870.0**	**890.0**	**975.0**	**1,060.0**

Note; Greenery water amount to be supplied by groundwater includes in agricultural use in groundwater.

Present Situation (2001)

- Available water from small rivers is estimated at 160MCM which will be brought from the Kan river and small streams originated in the northern mountains flowing down southward in the

Tehran region. These waters appear mostly during spring flood season, being utilized for wheat and barley plantation. It is however very difficult to estimate the actual amount of available water because no record of such water use is available. Present use of water of 160MCM may be reasonable judging from the existing plantation area of 20,000 to 25,000ha for wheat and barley in the region.

Short-term Plan (2006)

- As far as surface water is concern, there is no significant difference between both plans by the Master Plan and JICA Study.
- Allocation of groundwater for domestic and industrial uses is same between both plans, however, the Master Plan estimates agricultural water demand to be supplied from groundwater in 2006 at 650MCM, which is fairly large as compared with the 540MCM in 2001 or 550MCM in 2016. Accordingly, this high water demand of 650MCM in the Master Plan is reduced to 540MCM in JICA review.

Medium-term Plan (2011)

- Proposed plans of surface water allocation for agriculture and groundwater allocation for domestic and industrial uses in the Master Plan and JICA Study are same.
- Although reused water for agriculture from the sewerage treatment plant in Tehran City is not considered in 2011 in the Master Plan, 50MCM of this water is proposed by JICA Study after review of the implementation schedule of the treatment plant designed by the Tehran Water Supply and Sewage Company (Tehran WSC). Consequently groundwater use for agriculture is reduced to 500MCM in 2011 from 550MCM in the Master Plan, taking into account the safety and sustainable uses of groundwater.

Long-term Plan (2016 and 2021)

- Allocation of waters from all sources except re-used water is the same between the Master Plan and JICA Study.
- Although the amount of reused water in 2021 in the Master Plan is estimated at 500MCM, this amount is reduced to 250MCM after reviewing the sewerage treatment program proposed by Tehran WSC together with consideration of allocation of reused water to Karaj agriculture.
- Accordingly the available groundwater of 231.8MCM for agriculture in the Master Plan is increased to 450MCM by JICA review. Groundwater use of 450MCM is a little small amount as compared with 540MCM in 2011 and could be supplied under proper groundwater management because many recharging waters to groundwater will increase in 2021.

(3) Water Allocation Plan for Karaj Region

Water Allocation for Karaj Region

Unit: MCM

Water Sources	Master Plan				JICA Review				
	2001	2006	2011	2021	2001	2006	2011	2016	2021
1. Surface Water									
Karaj Water for Agriculture	135.0	135.0	135.0	135.0	135.0	95.0	115.0	140.0	165.0
Taleghan Water for Agriculture	-	-	-	-	-	120.0	-	-	-
Reuse Water for Agriculture	-	-	-	-	-		100.0	100.0	100.0
Sub-total	135.0	135.0	135.0	135.0	135.0	215.0	215.0	240.0	265.0
2. Groundwater									
Domestic Use	195.3	218.9	245.1	305.6	195.0	220.0	245.0	270.0	300.0
Industrial Use	219.1	236.7	256.9	293.5	220.0	240.0	255.0	280.0	175.0
Agricultural Use	433.0	390.2	342.4	250.0	430.0	305.0	265.0	220.0	775.0
Sub-total	847.4	845.8	844.4	846.1	845.0	765.0	765.0	770.0	775.0
Total	**982.4**	**980.8**	**979.4**	**981.1**	**980.0**	**980.0**	**980.0**	**1,010**	**1,040**

Total Water Demand

Total water demand in 2021 will slightly increase to 1,040MCM from 980MCM in 2001. Since the use of Karaj dam water has been converted from Karaj agriculture to Tehran urban water and as a result groundwater resources in Karaj have decreased, and it is now very difficult to find additional source of water to meet increasing water demand. Accordingly water allocation plan in the Master Plan is formulated so as to allocate more water to the domestic and industrial sectors but on the contrary to decrease the agricultural water. Namely the domestic and industrial water demand of 415MCM in 2001 to be supplied by groundwater is increased to 600MCM and agricultural water of 565MCM in 2001 is reduced to 440MCM in 2021.

Present Situation (2001)

The water allocation plans in the Master Plan and JICA review are same.

Short-term Plan (2006)

- Although the Taleghan water is proposed to be used in Tehran City in 2006 in the Master Plan, however, it should be conveyed to Karaj agricultural area in order to support irrigation and groundwater recharge because the existing facility of water conveyance to Tehran is being occupied fully by the water from Karaj dam and has no room to transport additional water from Taleghan. JICA proposed the Taleghan water of 120MCM to be allocated to Karaj agriculture, especially in Shahriyar and Robatkarim area where has been irrigated by Karaj reservoir water and suffered from chronic water shortage.
- Groundwater for agriculture will be reduced to 305MCM from 430MCM in 2001 in order to carry out the safety and sustainable operation of groundwater resources.

Medium-term Plan (2011)

- Reused water from sewerage treatment plant in Tehran City is not planned in the Master Plan, however, JICA proposed to allocate 100MCM of reused water for agriculture uses on the basis of implementation schedule of the plant.
- The Taleghan water of 120MCM allocated for agriculture in 2006 will be cut and converted to use for Tehran water supply in 2011.
- Groundwater for agricultural use in 2011 decreases to 265MCM from 305MCM in 2006 and the surplus groundwater is converted to the domestic and industrial uses in Karaj region.

Long-term Plan (2016 and 2021)

JICA proposes the reused water of 100MCM to be used for agriculture continuously for the period from 2016 to 2021 in order to minimize the use of groundwater.

(4) Water Allocation Plan for Hashtgerd Region

Water Allocation for Hashtgerd Region

Unit: MCM

Water Sources	Master Plan				JICA Review				
	2001	2006	2011	2021	2001	2006	2011	2016	2021
1. Surface Water									
Kordan Water	32.0	32.0	32.0	32.0	60.0	60.0	60.0	60.0	60.0
Sub-total	32.0	32.0	32.0	32.0	60.0	60.0	60.0	60.0	60.0
2. Groundwater									
Domestic Use	22.1	38.4	50.4	73.8	20.0	40.0	50.0	65.0	80.0
Industrial Use	10.0	18.9	27.0	43.0	10.0	20.0	30.0	35.0	40.0
Agricultural Use	287.8	276.8	266.3	245.8	290.0	260.0	240.0	220.0	200.0
Sub-total	319.9	334.1	343.7	362.6	320.0	320.0	320.0	320.0	320.0
Total	**351.9**	**366.1**	**375.7**	**394.6**	**380.0**	**380.0**	**380.0**	**380.0**	**380.0**

Total water demand and water allocation

Water demand for domestic, and industrial is same in both Master Plan and JICA study. As for irrigation water demand, JICA proposes the Kordan surface water of 60MCM instead of 30MCM in the Master Plan because the new Kordan irrigation canal system was completed in 1999 and takes about water of 60MCM. However groundwater use for agriculture is planned to decrease at 200MCM in 2021 from 290MCM in 2001 taking into account the large decreasing of groundwater level by over extraction in urban and industrial use in recent years.

(5) Water Allocation Plan for Qazvin Region

Water Allocation for Qazvin Region

Unit: MCM

Water Sources	Master Plan				JICA Review				
	2001	2006	2011	2021	2001	2006	2011	2016	2021
1. Surface Water									
Taleghan Water for Agriculture	144.0	144.0	122.0	122.0	200.0	170.0	300.0	140.0	140.0
Almout Water for Agriculture	-	-	308.0	308.0	-	-	-	250.0	250.0
Small River Water for Agriculture	185.0	185.0	185.0	185.0	185.0	185.0	200.0	200.0	200.0
Sub-total	329.0	329.0	615.0	615.0	385.0	355.0	500.0	590.0	590.0
2. Groundwater									
Domestic Use	70.0	78.1	87.2	104.3	70.0	80.0	90.0	95.0	105.0
Industrial Use	21.3	37.2	50.7	74.8	20.0	35.0	50.0	65.0	75.0
Agricultural Use	1,074.0	1,052.3	1,108.2	1,070.0	1,070.0	1,100.0	1,130.0	1,140.0	1,150.0
Sub-total	1,165.3	1,167.6	1,246.1	1,249.1	1,160.0	1,215.0	1,270.0	1,300.0	1,330.0
Total	**1,494.3**	**1,496.6**	**1,861.1**	**1,864.1**	**1,545.0**	**1,570.0**	**1,770.0**	**1,890.0**	**1,920**

The Qazvin plain has a large extension of agricultural area of 350,000ha and therefore water allocation plan is to be studied focusing mainly on irrigation water, while the region holds a large scale surface water resources of Taleghan and Almout rivers, various small rivers flowing down from the mountains surrounding the Qazvin plain and groundwater resources of large recharging capacity. Accordingly JICA Study has reviewed carefully the water allocation plan proposed in the Master Plan as explained below;

Present Situation (2001)

- The total water demand in 2001 proposed by JICA Study is 1,545MCM, with a slight increase from 1,494MCM estimated in the Master Plan because of difference in evaluation of existing achievement of Taleghan water diversion, 200MCM in JICA Study and 144MCM in the Master Plan. Available Taleghan water through existing water diversion facility is estimated at 144MCM in the Master Plan but amount reported by Qazvin Water Board is 200MCM.. JICA Study has checked the actual amount of diversion in recent years based on the operation data submitted by the Qazvin Irrigation Management Company in charge of Taleghan water operation. JICA Study has also carried out operation study of water diversion based on the runoff record of the Taleghan river and the actual requirement of irrigation water used in the beneficial area. As a result of such study, water of 200MCM is available for Qazvin irrigation on average year condition.
- Available water in many small rivers flowing down to the Qazvin plain is assumed at 185MCM in the Master Plan. Small rivers in Qazvin plain include small streams originated in the Taleghan mountains in the north of Qazvin and three large rivers of the Abhar-rud, Khah-rud, and Haji Arab flowing into western and southern Qazvin plain. Those rivers keep relatively rich runoff in the spring flood season but no or scarce runoff in other months. The spring flood

is used mainly for irrigation of winter crops such as wheat and barely by individual farmers and for groundwater recharge. It is very difficult accordingly to review the available water of 185MCM proposed in the Master Plan because of absolute lack of available data. As a result JICA Study adopted the value of 185MCM in the water allocation plan in consideration of recorded potential runoff of about 350MCM from all rivers and the present agricultural area of 25,000 to 30,000ha under irrigation by small river waters.

- Available groundwater of 90MCM for the domestic and industrial use and 1,070MCM for agriculture proposed in the Master Plan is not modified by JICA review.

Short-term Plan (2006)

- Available Taleghan water in 2006 is reduced to 170MCM from 200MCM in 2001 by JICA Study. In accordance with the water operation study for Taleghan water diversion carried by JICA Study, Taleghan water of about 290MCM on average year condition could be diverted through the existing facility without the storage reservoir. Of this 290MCM, 120MCM is allocated to Karaj region and 170MCM to Qazvin plain. Since the rehabilitation works will be carried out on the existing north irrigation canal system and thus efficiency will be improved, the irrigation water losses are minimized and the existing irrigation area could be covered with the water of 170MCM instead of 200MCM.

- Available groundwater in 2006 will slightly increase to 1,215MCM as compared with 1,168MCM proposed in the Master Plan according to acceleration of groundwater recharging works under planning by Qazvin Water Board.

Medium-term Plan (2011)

- The Taleghan water of 300MCM will be available for Qazvin irrigation in 2011 after completion of Taleghan storage dam. Of 450 MCM of water available from the Taleghan reservoir, estimated by JICA through operation study, 150MCM is allocated for Tehran water supply and 300MCM for Qazvin Irrigation.

- Availability of small river water will increase to 200MCM by means of development of Khah-rud river and Haji Arab river in the southern Qazvin Plain. Availability of groundwater will also increase to 1,130MCM from 1,100MCM in 2006 because of implementation of groundwater recharge projects by constructing recharging dam and dike.

Long-term Plan (2016 and 2021)

- As the Taleghan water of 310MCM will be conveyed to Tehran water supply, the Taleghan water to Qazvin irrigation reduces to 140MCM which is used only in the high land area with elevation of more than 1,250m in the north Qazvin irrigation area.

- The Almout water diversion project to compensate reduction of Taleghan water will be completed by the year 2016 and 250MCM of Almout water will become available in the low land area in the north Qazvin area, the central and southern Qazvin plain.
- Groundwater will also increase by acceleration groundwater recharge project.
- In 2021, total available water in Qazvin will increase largely to about 1,920MCM as compared with 1,545MCM in 2001 and stabilized irrigated agriculture could be expanded.

5.4.3 Water Allocation Plan by Scenario

(1) Scenario-0: Present Situation

Figure 5.4.3.1 shows the "Scenario-0", present situation of water allocation in the Study Area. About 200 MCM/year of Taleghan water has been diverted to and distributed in the northern Qazvin plain mainly for irrigation. About 300 MCM of Karaj water and 340 MCM of Latian water including water diverted from Lar dam are being distributed to Tehran City. Some water of Kordan and Karaj rivers are utilized for irrigation, and other requirements of water for various uses are balanced by the extraction from groundwater aquifers.

Present Situation of Water Allocation (Scenario-0)

Beneficial Sub-Basin	Source of Water	Allocated Water (MCM)
Tehran City	Karaj Dam	300
	Latian (Lar) Dam	340
	Ground Water	270
Tehran Area	Small Streams	170
	Ground Water	690
Karaj Area	Karaj Dam	135
	Groundwater	845
Hashtgerd Area	Kordan River	60
	Groundwater	320
Qazvin Plain	Taleghan Diversion	200
	Northern Streams	60
	Southern Rivers	125
	Groundwater	1,160
Total		**4,675**

(2) Scenario-1: Short-term Plan in 2006

In order to meet immediate needs of additional water required in the Tehran capital area, a water pipeline has been under construction at present to connect Ziaran and Karaj river and to transfer about 120 MCM of Taleghan water to the capital area as is shown in Figure 5.4.3.2. The initial plan of water conveyance of 120 MCM from Taleghan river to the capital area proposed in the Master Plan was to meet deficit of water in Tehran City, however, existing pipeline between Bileghan on Karaj river and No.1 and No.2 treatment plants in Tehran City has been occupied fully by the water from the Karaj dam without any additional room, and therefore this amount of water has to be planned tentatively to meet the shortage of water in agricultural sector in Karaj region. This case of water allocation is defined as “Scenario-1” of water allocation and will meet a short-term solution at the year around 2006. During this short-term period, expecting the effect of rehabilitation works on the existing irrigation system, about 170 MCM of Taleghan water will be distributed to Qazvin plain under average year conditions and 120 MCM under a critical dry year condition which would occur once in 10 years. Under the plan, 200 MCM at minimum or 240 MCM on average of water will be supplied to Qazvin plain while 40 MCM at minimum or 120 MCM on average will be allocated to Karaj, if priority is placed on irrigation in Qazvin plain. Total annual volume of Taleghan water diversion during this period will exceed 290 MCM on average. Deficit of irrigation water in Qazvin plain during this short-term period will be covered by over-pumping of groundwater.

Allocation of water under the Scenario-1, with the priority placed on water supply, will be as follows:

Water Allocation under the Scenario-1

Beneficial Sub-Basin	Source of Water	Allocated Water (MCM)
Tehran City	Karaj Dam	340
	Latian (Lar) Dam	340
	Ground Water	340
Tehran Area	Small Rivers	170
	Groundwater	700
Karaj Area	Karaj Dam	95
	Taleghan Diversion	120
	Groundwater	765
Hashtgerd Area	Kordan River	60
	Groundwater	320
Qazvin Plain	Taleghan Diversion	170
	Northern Streams	60
	Southern Rivers	125
	Groundwater	1,215
Total		**4,820**

(3) Scenario-2: Medium-tern Plan in 2011

As a medium-term solution, Taleghan dam will be constructed and additional 160 MCM of Taleghan water will become available. Under the plan, of 450 MCM of annual production of the dam, about 300 MCM will be allocated to Qazvin plain while 150 MCM will be conveyed from Taleghan to Karaj within the maximum capacity of the stage 1 pipeline between Ziaran and Karaj as shown in Figure 5.4.3.3. Of 300 MCM of Taleghan water allocated to Qazvin, 170 MCM will be conveyed to the northern plain through existing irrigation system while 130 MCM will serve the central plain through the Central Irrigation Canal to be constructed at this time. At the same time, construction of a diversion tunnel connecting the Karaj dam and the proposed No.6 treatment plant of Tehran City should be completed to convey 150 MCM of Karaj dam water directly to the proposed plant.

Existing pipeline between Bileghan and Tehran will convey 150 MCM of Karaj dam water and 150 MCM of Taleghan water. This plan is defined as "Scenario-2" and would be a medium-term solution at the year around 2011.

After completion of the proposed Sangban storage dam on Taleghan river, allocation of water will be as follows:

Water Allocation under the Scenario-2

Beneficial Sub-Basin	Source of Water	Allocated Water (MCM)
Tehran City	Karaj Dam	320
	Latian (Lar) Dam	340
	Taleghan Diversion	150
	Ground Water	270
Tehran Area	Small Streams	170
	Re-used Water	50
	Groundwater	670
Karaj Area	Karaj Dam	115
	Re-used Water	100
	Groundwater	765
Hashtgerd Area	Kordan River	60
	Groundwater	320
Qazvin Plain	Taleghan Diversion	300
	Northern Streams	60
	Southern Rivers	140
	Groundwater	1,270
Total		**5,100**

(4) Scenario-3: Medium-tern Plan in 2021

Even if the proposed demands of some 450 MCM are met by the construction of the storage dam on Taleghan river at Sangban, increasing water demand in the capital area would exceed such a demand in near future. A long-term development plan defined as the Scenario-3 at the target year of 2021 will provide the development plan of Almout water diversion. As the "Scenario-3" of water resources development and management for a long-term solution in 2021, water diversion from the Almout river to Qazvin will thus become necessary. About 250 MCM of Almout water would be developed and distributed to the Qazvin plain, while out of 450 MCM of Taleghan water 310 MCM will be conveyed to the western capital area of Tehran as shown in Figure 5.4.3.4. In consideration of serious contamination of Karaj dam water at downstream areas, 270 MCM of Karaj water will be transmitted from immediate downstream of the Karaj dam to Tehran City through the diversion tunnel already completed by this time, and existing pipeline between Bileghan and Tehran will convey 310 MCM of Taleghan water to Tehran City through stage 1 and 2 pipelines connecting Ziaran and Karaj. Existing Qazvin north irrigation system will receive 140 MCM of Taleghan water through existing irrigation system to serve irrigable area reduced at this time due to construction of new irrigation system to cover the central and southern plain. 250 MCM on average of Almout water