Chapter 2 Contents of the Project

2-1. Objectives of the Project

The Ministry of Housing and Utilities, in charge of water works and sewerage sector in the Syrian Government, is undertaking not only consolidation, rehabilitation and expansion of water distribution network for improving water supply in new residential areas and rural provinces but also rehabilitation of existing wells and drilling of new ones for more water supply to the public as they require.

The rural province of Damascus surrounds Damascus city, the capital of Syria, is currently being developed as residential area of Damascus city. The population is rapidly growing due to inflow of people to Damascus city. In four district of Daraya, Moadamiya, Sehnaya and Ashrafia in western Ghoutah, in the southwest of Damascus city and in areas 15 km from Damascus city, new houses in the districts are increasingly being built due to population increase. Population of four districts was 160,000 in 1994 and will be 247,000 in 2005, with a population growth rate of approximately 4 percent. Therefore water supply and expansion of supply facilities are urgently needed.

Main water sources in the rural province of Damascus are used to supply water to Damascus city in the highest priority. Regarding the groundwater sources in four districts, the ground water table is dropping due to excessive pumping by existing wells. The quality is also being contaminated through urbanization. Therefore, new water source directly from the underground in the districts cannot be expected.

Water consumption in the four districts is approximately 85 liter per capita per day at present because of drastic increase of population against the shortage of water development and distribution network. Suspension of water supply or water shortage occurred in the districts by changing the seasonal water level.

Under these situations, the General Establishment of Drinking Water and Sewerage in the Rural Province of Damascus (hereinafter referred to as “the Establishment”), in charge of water works sector in this region, has found new water source in the mountain area in Rima, approximately 35 kilometers far from Damascus city. The Establishment is accordingly going to implement this project in order to secure stable water source and supply safe drinking water to the public through construction of transmission and distribution facilities.

2-2. Basic Concept of the Project

The Syrian Government identified the procurement of equipment and materials for transmission and distribution facilities for drinking water from the existing nine (9) wells in Rima district, 35 km far from the service districts, to the existing nine (9) reservoirs in its application. The following components were also presented.

(a) Service districts

Four (4) districts in the rural province of Damascus as;

Daraya

Moadamiya

Sehnaya

Ashrafia

(b) Equipment/Facilities being requested

Submersible well pumps (20 l/s to 68 l/s)	9	units
Diesel Generators (700KVA)	2	units
Electric Transformer (1000KVA)	1	unit
Collection pipes (φ200 to φ450mm)	2,550	m
Transmission pipes (φ150 to φ500mm)	51,999	m
Fuel tank (25m3)	1	unit
Reservoir (FRP-made, 2000 m3)	1	lot

The request was carefully examined before submitting an Inception Report to the Syrian Government. Some unfavorable design of the facilities have been noted specifically in hydraulics, operation and maintenance aspect. In view of these, an alternative plan is hereby proposed.

The alternative plan intends to deliver the pumped well water, not directly to the new ground reservoir across the highest place, but first to a receiving tank and then to a new ground reservoir at the highest place using transmission pumps. From the reservoir, water is designed to flow by gravity to the existing reservoirs in the four (4) districts. (See Fig. 2-2-1)

The elevation difference of about 850m in the gravity flow section, i.e. the water head to the pipeline will have to be reduced to not more than 120 m for safety of the pipeline. Pressure control tanks and pressure reducing valves will be needed. Considering that the ground elevation of Madamiya district is higher than the other three districts by the ground elevation 50m and its distribution route partially runs in higher elevation, an additional booster pump is required to deliver water to the existing ground reservoir.

Investigations on water sources revealed that there were 13 existing wells in Rima district. Seven (7) wells including two (2) observation wells of small casing size were identified to have potential for tapping, excluding the collapsed, failed and reserved ones for irrigation. The Syrian Government requested for additional grant for casings and screens during the field survey. However, in line with the basic understanding by Japan that water source shall be prepared by the Syrian Government, the additional grant was not included in the project. The Syrian Government dug four (4) new wells later. Finally, nine (9) wells are considered as water source for this project.

Regarding the requested FRP reservoir and fuel tank, these facilities were omitted from the list for procurement because the former may be substituted by reinforced concrete tank while the latter may be locally manufactured.

The series of field investigations, discussions and examinations conducted provided a framework from which the basic concept of this project has been concluded. That Japan grants the request for equipment and materials such as pump machinery and pipes for transmission facilities for drinking water from 9 wells developed by the Syrian Government in Rima district to the service districts. On the other hand, the Syrian Government shall prepare detailed designs for additional facilities such as pumping stations and pressure reducing chambers and shall install the supplied equipment and construct the transmission and distribution facilities.

Fig 2-2-1　Proposed Alternative Plan

2-3. Basic Design

2-3-1. Design Concept

The most suitable facility and the selection of the equipment and materials are designed based on following concepts.

(1) Natural Condition

Rima district the location of new water sources has a sloping topography at 1,450 m in elevation. It is surrounded by orchard gardens which serve as its watershed. The average monthly temperature from November to March is below 10℃ and the maximum is 24.5℃ in July, while annual average is 12.9℃. Annual precipitation exceeds 1000 mm, with snowfall from October to April.

On the other hand, the service districts lie on the plateau at 700 m in elevation. Temperature widely vary reaching as high as 40℃ in summer season, while it freezes and snows in winter season. The annual average temperature is 22℃.

Taking account of the natural conditions as above mentioned, the structural design shall take advantage and make effective use of ground elevation differences between water source area and service districts. The specifications of mechanical and electric design shall be considered to fit the low temperature and high ground elevation.

(2) Social condition

The water source area is located near the Israel border and within the military control zone. The service districts are adjacent to Damascus city and within the anticipated rapid population increase in near future. The facilities plan therefore, has to be studied to complement the future city planning and population projection. A safe power source has to be secured for the equipment and facilities to generate a stable water supply condition.

There are natural fountains within the water source area and these fountains are used for drinking and water for irrigation in Rima district. Therefore, the available water source for the project shall be that which remained from such reserved water uses.

(3) Construction

The water source is located 35 km away from the service districts and the difference between two elevations is significant. The major road connecting Rima district is almost paved consisting of a two-lane trunk road with continuous daily traffic. However, some sections of the road run across steep hilly land through having a narrower width. There are no other alternative roads to connect Rima district so that closure of traffic during pipe laying work is hardly possible. This suggests the importance of selecting equipment and pipe materials for ease in transportation and laying work. Furthermore, as the receiving tank, ground reservoir and pressure control tanks are large in size and to be installed underground, locations and acquisition of land for them are also important.

(4) Local contractor and use of local materials

Equipment and materials granted under the project compose the major part of the project and such will mostly be imported. There may be difficulties in procuring some spare parts so that these will also have to be granted as much as possible. The Establishment will install the equipment and local contractors will construct the civil structures and lay pipes of special materials. Competent local contractors shall be needed to complete the works within the limited period. In case some works requiring strict precision or a new technology will be applied, provision of technical assistance for field supervision may be considered.

(5) Coverage of equipment materials and their grade

The project facilities are those for well pumps and transmission facilities till the existing reservoirs. Due to severe natural condition of the long distance and elevation difference, it is important to plan for the whole system including the total facilities from wells to reservoirs. The system shall therefore be designed by selecting equipment and materials which are simple to operate and maintain, and those which are locally applied in Syria.

The design and construction of the pumping stations, receiving tank and ground reservoir will be undertaken by the Syrian Government, and therefore the proper sizes, displacements and lands for them must be presented in drawings and be prepared for efficient planning and construction. Particularly for pumping facilities, standard drawings for the displacement, installation, foundation, etc., including those of accessories shall be produced and presented.

(6) Project implementation, operation and management capability

The Phase I Project (grant of equipment and materials in 1996 and construction in 1997–1998) has been completed and operation and management activities have started. However, some problems have been found on planning, operation and management of pumps. Under this project, the facilities shall be carefully planned in order not to encounter the same problems as in the Phase I Project. To ensure proper operation and management guidance in installation of major equipment and materials shall be provided.

(7) Construction period

From the period of E/N to completion of equipment and material delivery has been programmed within one-year period. However, some difficulties such as budget allocation by the Syrian Government, increase in civil work more than what was originally requested, longer rock excavation section for pipe laying, etc. are expected, the total construction period has been estimated to be four (4) years. Therefore, the procurement of equipment and materials will be planned in two phases.

2-3-2. Basic Design

(1) Target year for the project

In their request, the Syrian Government indicated the target year for the project to be 2010. Recognizing the urgency of this project and being short-term in nature, the project has to be proposed for consideration under the Grant Aid Program for year 2005.

(2) Target population

There had been difference in population data presented in various documents. Based on the data from 1994 census, from the Establishment, as indicated in the application of the project and actual field investigation in 1998, the population in the subject districts is shown in the table below.

Table 2-3-1 Population data by source

District	Population in 1994 by			Interview survey in 1998
	Census	Survey by the Establishment	Application	
Moadamiya	34,306	40,000	50,000	50,000
Daraya	65,066	120,000	90,000	100,000
Sehnaya	8,271	15,000	8,000	17,000
Ashrafia	14,482	35,000	12,000	18,000
Total	122,125	210,000	160,000	185,000

Judging from the explanation given by the Establishment, information on urbanization development from the field offices through interviews and the observed rapid increase of house units, a considerable number of unregistered residents may not have been covered by the census.

Assuming that the population data gathered from the interview survey in 1998 is realistic, population growth rate from 1994 by data source can be calculated as shown inTable

2-3-2.

From Table 2-3-2 and by taking account of the stage of development and population dynamism in each district, the population in 1994 has reasonably been assumed as follows.

Table 2-3-2 Population growth rate in the service districts

District	Population growth rate from 1994			Interview survey in 1998
	Census	Survey by the Establishment	Application	
Moadamiya	9.9	5.7	0.0	0.0
Daraya	11.3	- 4.5	2.7	0.0
Sehnaya	19.7	3.2	20.7	0.0
Ashrafia	5.6	-15.3	10.7	0.0
Mean	10.9	- 3.1	3.7	0.0

① Moadamiya

Developing areas are these surrounded by the old city and the railroad, and in the northwest of the old city. Small buildings such as housing units are dominant. Comparing the project service districts with the present housing zone, residential development in future will be oriented to the belt zone, between the highway in the northwest and the railroad. The scattered buildings in the area, suggests that the types of buildings to be constructed are anticipated to be small factory buildings or small-scale condominiums. Therefore the 1994 population provided by the Establishment as 40,000, seems reasonable.

② Daraya

The whole urban area surrounding the old city is dominated by houses and shops which are mostly of 4 to 5 stories, and still many of those types are under construction. This suggests that the population provided by the Establishment as 120,000, which is lesser than that in 1994 is not reasonable. Comparing the figure with that by the interview survey, the number has accordingly been assumed as 90,000. Major causes of further population increase will be new residents into the condominiums currently under construction, and the pace for the house construction is anticipated to slow down.

③ Sehnaya

Individual houses dominate around the old city, except for a housing complex in the southeast. Assuming the population in the complex to be 5,000 from the numbers of the condominium, blocks and households (40 condominiums, 25 blocks and 5 households), the population of 8,000 presented in the application seems too small. The population around the old city may be estimated between 8,000 and 10,000, so that the population data of 15,000 given by the Establishment seems realistic. A vast land under planning in the south of the old city is available for complex-type development.

④ Ashrafia

Housing complexes are being built in the east of the old city and along the main roads. There is the Damascus-Jordan Trunk Highway on the east of the town. The population in the complexes is estimated to be 7,000. Judging from the development pace, the population in the district including the old city seems smaller than that of Sehnaya, and therefore a population of 15,000 seems reasonable as being close to the number by the census. A vast land for development is still available around the old city for individual-house and housing complex-type development.

The national population growth rate estimated from 1981 to 1994 statistics data stood at 3.3% in 1997, while the data in the rural province of Damascus indicated as high as 4.6%. The 1992 census predicted a 4.5% growth rate up to 2005 in the province. As mentioned, the growth rate in Moadamiya and Daraya will drop, in Sehnaya and Ashrafia growth rates will be maintained. By taking the concept of the Grand Aid Program and the urgency of the project into account, the future growth rate of 4 %, presented in the application, has been considered and employed in the project.

The projected population in 2005 was estimated from 1994 populations in the districts and this is presented in the table below. As such, water supply facility will be planned for these 2005 population level.

Table 2-3-3 Population in the service district

District	Population	
	In 1994	In 2005
Moadamiya	40,000	62,000
Daraya	90,000	139,000
Sehnaya	15,000	23,000
Ashrafia	15,000	23,000
Total	160,000	247,000

(3) Unit water consumption

The overall unit water consumption of the four (4) districts has been estimated at 83 liter/day/person. This is base on factors such as the number of operating pumps, operation hours and their capacities as shown in the table 2-3-4.

The unit water consumption is between 80 and 90 liter/day/person in Moadamiya and Daraya while in Sehnaya and Ashrafia, approximately 65 liter/day/person.

Table 2-3-4 Total and per-capita water consumption

District	Pump (unit)	Pump Capacity (m3.hr)	Opera-tion (hr/day)	Quantity (m3/day)	Service populati-on (pers.)	Unit water consumption (l/day/pers.)
Moadamiya	21	5.0	24	2,520	31,000	81.3
Daraya	28	12.5	16	5,600	62,000	90.3
Sehnaya	6	7.5	15	675	10,000	67.5
Ashrafia	7	15.0	24	720	11,000	65.5
Total				9,515	114,000	83

N.B. the figures are estimation based on the interview survey.

The 8^{th} 5-year Development Plan (1996-2000) indicates the target unit water consumption in 2000 at 108 and 193 liter/day/person in rural and central part of provinces, respectively. Meanwhile, the standard unit water consumption applied by the Establishment are 40 liter/day/person in desert zone, 75 to 100 liter/day/person in villages remote from major cities and 125 to 150 liter/day/person for major cities. Damascus City Water Supply and Sewerage Authority employs a standard of 250 liter/day/person for Damascus city.

The study on water source in Rima district as presented in the Section "(5) Water Source", has shown that approximately 411 l/s may be expected including 54 l/s reserved for drinking and irrigation water in Rima district. The available water source in this project may rely on becomes the remained 357 l/s.

This available water for the projected population to be served becomes approximately 125 liter/day/person (=0.358x86,400/247,000). This unit rate is equivalent to the present daily average as 83 liter/day/person (=125/1.5) if applying a load of 1.5 factor (=daily maximum/daily average).

On account of limited water source, urgency of the project and in conformity with the basic Grant Aid policy, the design daily average consumption is taken as 83 liter/day/person which approximates the present unit rate.

(4) Design discharge

The design discharge for transmission pipeline is the maximum daily consumption, and a load factor of 1.5 employed in Syria. It also takes into account the daily and seasonal fluctuation. Therefore, the design maximum daily consumption rate is taken as 125 liter/day/person as aforementioned.

The design discharge for transmission has been calculated from the maximum daily consumption rate and the projected population in 2005. Of the presently operating water source facilities in the service districts, only about 20% of the capacity is expected to remain operational in 2005 due to dropdown of groundwater table by excessive pumping and water contamination by urbanization. The design discharge has accordingly computed to 28,972 m3/day or 335.3 l/s.

Table 2-3-5 Design water consumption in 2005

District	Population	Design capacity (m3/D)	Existing capacity (m3/D)	Available exist.Cap (m3/D)	Design discharge (m3/D)	Design discharge (l/s)
Moadamiya	62,000	7,750	2,520	504	7,246	83.9
Daraya	139,000	17,375	5,600	1,120	16,255	188.1
Sehnaya	23,000	2,875	675	135	2,740	31.7
Ashrafia	23,000	2.875	720	144	2,731	31.6
Total	247,000	30,875	9,515	1,903	28,972	335.3

(5) Water source

(a) Potential water source

Quantification of available water source is based on the hydro-geological report under the Helmon Project, as follows.

① Size of underground basin in Rima water source area: 3.5 km2

② Geology in Rima water source area: Limestone at middle and latter Jurassic period

③ Limestone at latter Jurassic period appears 250～250 m under ground.

④ Thickness of effective aquifer: Well No. 528A; 34 m
No. 825B; 99 m
No. 825C; 117 m
No. 826; 26 m
No. 863; 82 m
No. 864; 129 m
No. 867; 65 m

⑤ Permeability (average): 21.4 l/s/m or 1,848 m3/day/m

⑥ Drop of water table in well is not proportional to increase of pumping but affects only a slight increase.

⑦ Potential ground water is estimated to be 411 l/s in Rima underground basin.

Meanwhile, recharge and usable ground water have been estimated as follows.

Recharge capacity (Qr):

Watershed area (A); Watershed area of the Rima water source is estimated to be about 12 km2 from 1:2,500 topographic map. However, judging from geological formation, river system and geology, the substantial watershed area is expected to be about 20 km2.

Precipitation (P); isohyetal map (Fig. 2-3-1) indicates the precipitation at 1,100 to 1,200 mm during winter months (October to April). The interview survey indicates that most precipitation is caused by snowfall and the snow water that has been retained for a long time. Accordingly, the annual precipitation is assumed as 1,200 mm/year.

Percolation rate (I); assumed as 0.6.

Accordingly, the recharge capacity has come to;

$$Qr = A\ P\ I = 456\ l/s$$

Potentially usable capacity is calculated using the formula;

$$Q = I \times T \times B$$

where, I : hydraulic gradient between well No. 825C and No. 867

$$I = (1427.01 - 1419.82)/130 = 0.055$$

T : permeability (T = 21.4 l/s/m)

B : width of effective cross-sectional area of aquifer (B = 400 m)

Then, the potential usable capacity is about to 470.8 l/s.

Based on the above, the 411 l/s of the allowable pumping discharge worked out by Syria is reasonable. However, there is one well used for the drinking water and irrigation for orchard in Rima area. That amount is estimated to be approximately 54 l/s as shown in "Appendix-6 Discharge of Natural Fountain in Rima District". Finally, the allowable pumping discharge is 357 l/s, 54 l/s less to assume the discharge of the existing wells.

The nine (9) new wells prepared by the Syrian Government and their locations in relation to the existing ones are presented in Fig. 2-3-2.

(6) Pipeline

(a) Base conditions

Water pumped from the wells will first be delivered to the receiving tank (cum suction pit for transmission pumps), then will be again pumped with booster pumps to the new ground reservoir with 2,000 m3 in capacity and 2.4 km away from the highest elevation. Water will be conveyed from the new ground reservoir to the existing reservoirs in the 4 service districts by gravity through the pressure control tanks. Collection and transmission facilities will be designed at the maximum daily consumption for 24-hr operation.

As for pipe material for main transmission facilities, ductile iron pipe (DIP) will be used for easy laying and considering the previous experience by the Establishment.

Hazen-William's formula will be applied for the hydraulic design of pipeline, as shown below.

$$H = 10.666\ C^{-1.85}\ D^{-4.87}\ Q^{1.85}\ L$$

where, H : friction loss head (m),
C : flow index (=110),
D : pipe bore (m),
Q : discharge (m3/s), and
L : length (m)

(b) Section from well to receiving tank

The outline of the nine (9) new wells to be prepared was been studied as shown in the table below. The collection pipelines will be unified into 3 systems due to similarity of their hydraulic and topographic conditions.

Table 2-3-6 Outline of subject wells

New well name	Old well name	Well bore (inch)	Pump bore (mm)	Ground elevation (EL-m)	Present static WL (EL-m)	Total WL drop (m)	Dynamic WL (EL-m)	Actual pump head (m)	Total Pump head (m)
NW- 1	2	12”	150	1446.02	1424.56	19.12	1405.44	36.56	41.58
NW- 2	867	12”	150	1449.43	1424.58	19.12	1405.46	34.97	41.17
NW- 3	3	14”	150	1441.96	1420.18	19.12	1401.06	41.90	47.67
NW- 4	825A	9”	150	1432.85	1427.02	19.12	1407.90	34.10	38.19
NW- 5	825B	9”	150	1433.40	1427.11	19.12	1407.99	34.01	38.92
NW- 6	825C	9”	150	1436.96	1427.01	19.12	1407.89	34.11	39.53
NW- 7	4	14”	150	1436.68	1423.01	19.12	1403.89	38.11	45.19
NW- 8	1	12”	150	1437.30	1422.90	19.12	1403.78	38.22	41.72
NW- 9	864	12”	150	1427.17	1415.37	19.12	1396.25	45.75	52.56

Water level of the ground reservoir is 1,442.0 m

(c) Section for pumped transmission pipeline (from receiving tank to new ground reservoir)

The length of pumped transmission pipeline and difference in elevations are approximately 2.6 km and 125 m, respectively. The economic flow velocity for pumped pipeline is generally set at approximately 1.5 m/s. In the case of the project the most advantageous pipe diameter is 500 mm as shown in the table below.

Table 2-3-7 Flow velocity by pipe diameter

Pipe diameter	Velocity
450 mm	2.11 m/s
500 mm	1.71 m/s
600 mm	1.19 m/s

(d) Section for gravity flow from new ground reservoir to the last pressure control tank

It is gravity flow section after the new ground reservoir. The length and elevation differences in the section are approximately 23 km and 760 m, respectively. Such topography may cause high inner pressure to the pipe and limits the pipe materials for direct delivery to the last pressure control tank. The specification of DIP (PN16) employed by the Establishment, allows elevation difference of 120 m at maximum, so that installation of pressure control tanks and pressure reducing valves every 120 m elevation interval is most practical. Six (6) sets of the pressure control tank and the pressure reducing valve will be required.

In the selection of pipe diameter to make effective use of the 120 m-head, the flow velocity has to be 3.0 m/s or less while the loss head in a section of 120 m elevation difference is preferably 120m. The table below shows such conditions at different pipe diameters.

Table 2-3-8 Flow velocity and sectional loss head by pipe diameter

Pipe diameter	Flow velocity	Sectional loss head	Evaluation
400 mm	2.68 m/s	131.1 m	No
450 mm	2.11 m/s	73.9 m	Yes
500 mm	1.71 m/s	44.2 m	Yes
600 mm	1.19 m/s	18.2 m	Yes

N.B. Section length is taken as 6.4 km (the longest section in the route)

(e) Gravity flow section from last pressure control tank to existing reservoirs

From the last pressure control tank to the existing reservoirs, the maximum elevation difference will similarly be designed at 120 m. However, the ground elevation in Moadamiya is higher than that of other 3 districts by 50 m, and the existing ground reservoir in Moadamiya is located further higher than the ground elevation in the service district. The three districts of similar elevations will be gravity supplied by the same system while Moadamiya district will be by another system.

Moadamiya district may be further divided into high area being served from the existing ground reservoir on the hill and low urban area being served from the existing elevated reservoir. Supply to the low area can be made by gravity from the last pressure control tank while supply to the high area requires booster pump. The transmission pipeline to Moadamiya district shall be branched on the way and the flow for a half of the service districts of the district shall be boosted to the existing ground reservoir.

Layout and hydraulic calculation of transmission pipeline are shown in Fig 2-3-3 and “Appendix 8 Design Data”, respectively.

Fig 2-3-3　Layout of Transmission Pipeline

Among the existing facilities, base information on the reservoirs provided by the Establishment for connection is presented in the table below.

Table 2-3-9 Outline of existing reservoirs

Name	Type	Capacity (m3)	Ground level (EL m)	Storage depth (m)	HWL (EL m)	LWL (EL m)
Moadamiya district No. 1 reservoir	Elevated RC	100	735.02	4.00	753.08	749.08
Moadamiya district No. 2 reservoir	Grounded RC	500	795.61	4.50	799.50	795.00
Daraya district No.1 reservoir	Elevated RC	250	689.53	5.00	719.53	714.53
Daraya district No.2 reservoir	Elevated RC	300	696.45	6.15	728.45	722.30
Daraya district No.3 reservoir	Elevated RC	300	684.10	6.15	716.10	709.95
Daraya district No.4 reservoir	Elevated RC	300	701.98	6.15	733.98	727.83
Daraya district No.5 reservoir	Elevated RC	300	700.18	6.15	732.18	726.03
Sehnaya district No.1 reservoir	Elevated RC	500	695.42	6.00	726.42	720.42
Ashrafia distict No.1 reservoir	Elevated RC	300	690.30	6.15	722.30	716.15

(7) Pumping facilities

(a) Well pump

The results of pumping tests conducted indicate the water source to be from deep well and the pump must be placed at 40 m below the ground. Accordingly, submersible motor pumps will have to be installed.

Hence, the total design discharge of 335 l/s from nine (9) wells means per well production as

335 / 9 = 37 l/s = 2.3 m3/min

The pumped water will be first delivered to the No.1 receiving tank in the transmission pumping station.

Calculations for pumping head and output of motor are shown in “Appendix 8 Design Data”, and their specifications are as follows.

Pump type: submersible motor pump
Pump bore: φ150 mm
Delivery: 2.3 m3/min
Total head: 45 m and 55 m
Driver: electric motor; 380 v, 30 kW
No. of unit: 9 units

(b) Transmission pump

Transmission pump delivers water from the receiving tank (cum suction tank) to the new ground reservoir installed at the highest location of the transmission pipeline. The topography allows pump to be placed on the ground level for boosting without negative suction head, and the actual pump head is as much as 125m. Therefore volute type pump is most advantageous and thus selected.

The number of pump units has been studied for 3 cases; a case of 2 units, a case of 3 units and a case of 4 units with and without a stand-by. Comparisons have been made as presented in table below.

Table 2-3-10 Comparison of pump-unit cases

Case	2 units		3 units		4 units	
Delivery per unit	10.1 m3/min		6.7 m3/min		5.1 m3/min	
Pump diameter	φ250 x φ200 mm		φ200 x φ150 mm		φ200 x φ150 mm	
Head	150 m		150 m		150 m	
Motor output (total output)	400 kW/unit (800 kW)		280 kW/unit (840 kW)		210 kW/unit (840 kW)	
Stand-by unit	without	with	without	With	Without	With
No. of pump	2 sets	3 sets	3 sets	4 sets	4 sets	5 sets
Initial cost (%)	x¥1000 202,200 (100%)	x¥1000 224,800 (111%)	x¥1000 197,800 (100%)	x¥1000 213,400 (108%)	x¥1000 207,800 (100%)	x¥1000 222,000 (107%)
Balance	¥ 22,600,000		¥ 15,600,000		¥ 14,200,000	
Running cost (%)	x¥1000 20,935 (100%)	x¥1000 22,132 (106%)	x¥1000 20,508 (98%)	x¥1000 21,333 (102%)	x¥1000 20,768 (99%)	x¥1000 21,520 (103%)
Operation & Control	Delivery adjustment by 100% & 50% only. Less advantaged than others for operation of receiving tank and transmission pump.		Smooth delivery adjustable by control of number of wells and pumps. Advantaged for delivery management.		Better adjustment of delivery than others. Disadvantaged upon repair, maintenance and failure.	
Size of facilities	Small		Medium		Large	
Capacity of Motor	Large per unit capacity and affects more initial load to power source on starting.		Small per unit capacity but total capacity to the source is large than 2 units.		Same as 3 units case.	
Evaluation	No good		Best		Good	

The 3-units case is most advantageous in terms of attaining economic efficiency. In addition, each unit delivers 1/3 of the total delivery and can easily adjust the delivery rate from the receiving tank in meeting the varying demands. The case of 3-units with a stand-by is more expensive than the same case without a stand-by, but the stand-by unit is essential to supply water even during the maintenance. Accordingly, the case of 3-units with a stand-by has been employed for transmission pump.

Calculations for pumping head and output of electric motor are presented in "Appendix 8 Design Data", and the specifications are as follows.

Pump type:	horizontal multi-stage volute pump
Pump bore:	φ200mm×φ150mm
Delivery:	6.7 m3/min.
Total head:	150 m
Driver:	Electric motor; 380 v, 280 kW
No. of unit:	4 units (one unit for stand-by)

(c) Booster pump

As it is impossible to transmit water directly to the existing ground reservoir in Moadamiya district by gravity, a booster pump is planned in the transmission line. There are two ways to set booster pump. One is a direct settlement type on pipeline wherein the booster pump is settled directly on the pipeline in order to add necessary head until the reservoir. The other is receiving tank type wherein the booster pump is settled after the receiving tank on the pipeline to open the remaining pressure free and to add necessary head. The receiving tank type is recommendable because this type guards the pipeline before the booster pump against influence of pressure fluctuations in the pipeline directly caused by starting and stoppage of the booster pump. The type also prevents the troubles of the booster pump itself caused by pressure fluctuations in the pipeline.

In terms of the number of booster pumps for 3 cases have been studied; a case of 2-units with and without a stand-by and a case of 3-units with a stand-by.

As the booster pump is of little capacity of delivery, the size of facility of two cases of 2-units is nearly the same. The case of 3-units is a little bit expensive. Supply area covered by the booster pump is also less than one by the transmission pump. The stand-by unit is essential to supply water during the maintenance, same as the transmission pumps. Accordingly, the case of 2-units with a stand-by unit has been employed for the booster pump in view of economical point and limited supply area.

Table 2-3-11 Comparison of pump-unit cases

Case	2-units without a stand-by unit	2-units with a stand-by unit	3-units with a stand-by unit
Delivery per unit	1.25 m3/min	2.5 m3/min	1.25 m3/min
Pump diameter	φ125 xφ100 mm	φ150 xφ125 mm	φ125 xφ100 mm
Head	45 m	45 m	45 m
Motor output (total output)	18.5 kW/unit (37 kW)	37 kW/unit (37 kW)	18.5 kW/unit (37 kW)
Initial cost (%)	¥ 16,200,000 (100%)	¥ 18,000,000 (111%)	¥ 21,000,000 (130%)
Balance		¥ 1,800,000	¥ 4,800,000
Running cost (%)	¥ 1,218,100 (100%)	¥ 1,372,600 (113%)	¥ 1,472,300 (121%)
Operation & Control	Smooth delivery adjustable and advantaged for delivery management. Less advantaged for management and accident of pump because of no stand-by.	Delivery adjustment by 100% & 0% only. Less advantaged for delivery management	Smooth delivery adjustable, advantaged for delivery management and accident of pump.
Size of facilities	Small size	Large size for accommodating a stand-by unit	Largest size
Others	No difference of capacity of electricity and generator		
Evaluation	No good	Best	Good

Calculations of pumping head and driver output are presented in “Appendix 8 Design Data”, while their specifications are as follows.

Pump type: horizontal multi-stage volute pump

Pump diameter: φ150×φ125 mm

Delivery: 2.5 m3/min.

Total head: 45 m

Driver: Electric motor; 380 v, 37 kW

No. of unit: 2 units (one unit for stand-by)

(d) Driver output

The output of the electric motor to drive pump is estimated using the equation below.

$$P = 0.163 \ \gamma \ Q H (1 + R) / (\eta_p \ \eta_e)$$

where, P : required output of driver (KW)

γ : density of water

Q : delivery (m3/min)

H : total pumping head (m)

η_p : pump efficiency

η_e : transmission efficiency of axial joint (1.0 for direct driving)

R : margin

The output calculations of pump drivers for wells, transmission and boosting are presented in "Appendix 8 Design Data".

(e) Accessories

Considering the long distance from water source to the existing reservoirs, significant elevation differences in the transmission route as well as the large flow capacity, the facilities for pumping and transmission pipeline are required for systematic functioning. In order to assure continuous operation and maintenance of the pumping equipment, it is rational to grant their request for accessories including those for well pumps. The accessories to be granted are as follows.

- Riser pipe and bends for well pump
- Suction-side and delivery-side pipes for transmission and booster pump
- Check valves
- Stop valves
- Automatic air valves
- Pressure gauges and compound pressure gauges
- Flow indicator
- Water level sensing units (electrode relay)
- Motor protection relays

(8) Transformer

The pumps in the transmission and booster stations are normally driven by public power source, and therefore high voltage from the source has to be transformed into low voltage required by the pumps. Capacity of transformer can be derived from the following equations.

(a) Capacity for regular operation

$$TF = \sum_{k}^{n} \frac{PLk}{\eta_{LK} \times \cos\phi k} \times \beta \times \alpha \quad (kVA)$$

where, TF : capacity for regular operation (kVA)

PLk : output by load (kW)

ηLk : efficiency of load

$\cos\phi k$: power factor

β : demand ratio

α : margin

(b) Capacity for starting on maximum load

$$T_S = \frac{TSF}{\%V} \times \%ZT \quad (kVA)$$

where, Ts : capacity for starting on max. load (kVA)

TSF : total capacity at starting

$$TSF = \sqrt{(P_b + P_{ms})^2 + (Q_b + Q_{ms})^2}$$

Pb : effective input at base load

$$P_b = \sum_{k}^{n'} \frac{PLk}{\eta LK}$$

Qb : ineffective input on base load (kVAr)

$$Q_b = \sum_{k}^{n'} \frac{PLk}{\eta LK} \tan\phi k$$

Qms : ineffective input at starting on max. load (kVAr)

$Qms = Ps \sin\phi s \times C$

Pms : effective input at starting on max. load (kVAr)

$Pms = Ps_1 \cos\phi s \times C$

Ps1 as direct starting input on max. load (kVA)

$\cos\phi s$ as power factor on max. load.

C : starting coefficient

V : % voltage drop

%ZT : impedance voltage of transformer

Larger value of TF and Ts are adapted in selecting the capacity of transformer. Results of calculation are in the table below.

Table 2-3-12 Capacity of transformer

Pumping Station	Total output of loads (kW)	TF (KVA)	Ts (KVA)	Selected capacity (KVA)
Transmission	1,142	1,740	1,628	1,750
Booster	42	62	39	75

(9) Generator

The locations of transmission and booster stations are served by public power supply and the stations will definitely have to rely on the supply for regular operation as a main source. It is generally accepted to install a diesel generator to secure operation of intake, transmission and distribution facilities in case of power failure or some accidents in water works. However, the generator shall not be planned in this project because of the policy of the Grand Aid Program on budgetary and significance terms.

(10) Water hammer prevention facility in transmission pipeline

The transmission pipeline from the transmission pumps to the new ground reservoir is 500 mm in diameter, 2.6 km in length and 125 m in elevation difference. Pressure at delivery side of the pump in the transmission pipeline is as high as 15 kgf/cm2, and may cause water hammer intense rise and drop of pressure in pipeline, upon sudden stop of pumping by power failure, shutting of valves or some incidents. Water hammer may cause damage on pipes, pumps and negative effects to the equipment and accessories due to excessive pressure. The pressure by water hammer has been estimated as follows and shown in “Appendix 8 Design Data”.

Pressure drop (minimum pressure)	- 9.0 kgf/cm2
Pressure rise (maximum pressure)	+ 23.7 kgf/cm2

As the pressure drop exceeds –1.0 kgf/cm2, water column separation merges and may destroy the pipe. And as a reaction right after the drop, the pressure rises up to 23.7 kgf/cm2. Therefore, special specifications may be required to guard against high-pressure for pumps, valves, delivery pipes and more than 1/3 of the transmission pipeline. Failure of pumps, pipes or valves by hammering may also be anticipated.

The following measures are most commonly adopted, however, their effectiveness differs depending on type of facilities, profiles of pipeline, etc. Effectiveness and applicability of the measures for the project are as presented in Table 2-3-13 for pressure drop and Table 2-3-14 for pressure rise.

Measures against water hammer

(a) For reduction of pressure drop

- use of flywheel
- installation of conventional surge tank
- installation of one-way surge tank
- installation of pressure tank (air vessel)

(b) For reduction of pressure rise

- use of slow-action check valve
- use of quick-action check valve
- use of safety valve
- automatic closure of main valve

After examining the above measures, the installation of a pressure tank (air vessel type) in the transmission pumping station for reducing the pressure drop and application of quick-action check valves at delivery side of the pumps are considered for reducing the pressure rise. The result is shown in “Appendix 8 Design Data”.

Specifications of equipment against water hammer:

- Pressure tank (air vessel):	steel-made 30 m3	1 unit
- Air compressor:	11 kW	2 units
- Valves and pipe fittings:		1 L.S.
- Quick-action check valve:	φ200mm automatic	3 units

(11) Pressure reducing method

The water transmitted to the new ground reservoir by the transmission pumping station flows by gravity. The elevation difference between the new ground reservoir (HWL+1570m) and the lowest part (EL+709m) of the subject 4 supply districts, is 861m and this gives maximum static pressure of 86 kgf/cm2. Considering the durability of pipes and specifications of equipment as well as operation and maintenance, the pressure is required to be 12 kgf/cm2 or less. Accordingly, some pressure reducing facilities installed at every 120m elevation interval have been examined.

Pressure reduction means to dissipate residual energy of elevation difference (static pressure) after subtracting head losses in pipeline by use of pressure reducing valve. However, the following issues may emerge.

① Cavitation by a large pressure difference may damage valve, and need valve protection work.
② Water hammer by valve open/close may require some measure for reduction and protection of pipeline.
③ Careful examination on reliability of function and safety of the pressure reducing facilities is required.

Methods of pressure reduction are applicable, as follows.

① Use of self-control reducing valve
② Use of combination of constant WL self-control valve and pressure control tank
③ Reduction by flow control valve

Advantages and disadvantages of the methods and applicability to the project have been examined and presented in Table 2-3-15.

By taking reliable action, safety to the whole system and past performance into consideration, the combined method by use of constant WL self-control valve and pressure control tank has been employed.

(12) Required equipment and materials

The following equipment and materials are required for the project.

(a) Water source

- Well pump:	submersible motor pump, ϕ150mm x 2.3 m3/min, 45 m & 55 m, 30KW;	9 unit
-Accessories:	rising pipes, stop valve, check valve, air valve, pipe fittings, protection relay, etc.	9 sets

(b) Transmission pumping station

- Transmission pump;	horizontal multi-stage volute pump, ϕ200mm x ϕ150mm, 6.7 m3/min, 150m and 280KW;	4 units (one stand-by)
- Accessories:	stop valve, check valve, pipe fittings, protection relay, etc.;	4 sets
- Pressure tank and air compressor:	a 30 m3 tank and 2 units of 11kw compressors	1 set
- Transformer:	22kv/380v, 1750kVA;	1 unit

(c) Booster pumping station

- Booster pump:	horizontal multi-stage volute, ϕ150mm x ϕ125mm, 2.5 m3/min, 45m and 37kw;	2 units (one stand-by)
- Accessories:	stop valve, check valve, pipe fittings, protection relay, etc.;	2 sets
- Transformer:	22kv/380v, 75kVA	1 unit

(d) Pressure reducing facility

- Constant water level self-control valve:	ϕ450mm, PN16;	6 units
- Strainer :	ϕ450mm, PN16;	6 units
- Butterfly valve:	ϕ450mm, PN16;	12 units
- Sluice valve:	ϕ250mm, PN16;	6 units

(e) Spare parts

- Spare parts for pumps	1 L.S.
- Spare parts for pressure tanks	1 L.S.
- Spare parts for constant WL self-control valves	1 L.S.

(f) Pipe material

① Collection pipe

- Ductile iron pipe:	PN16, φ350mm	135 m
	φ300mm	139 m
	φ250mm	253 m
	φ200mm	629 m
- Ductile pipe fittings:	PN16, φ350-φ200mm	1 L.S.
- Valves:	PN16, φ350-φ200mm	1 L.S

② Pumped transmission pipeline

- Ductile iron pipe:	PN16, φ500mm	2,604 m
- Ductile pipe fitting:	PN16, φ500mm	1 L.S.
- Valves:	PN16, φ500mm	1 L.S.

③ Gravity transmission pipeline

- Ductile iron pipe:	PN, φ600mm	5,997 m
	φ500mm	3,360 m
	φ450mm	23,381 m
	φ400mm	4,266 m
	φ300mm	3,134 m
	φ250mm	5,603 m
	φ200mm	4,190 m
	φ150mm	400 m
- Fitting:	PN16, φ600 to 150mm	1 L.S.
- Valves:	PN16, φ600 to 150mm	1 L.S.

(13) Reference drawings

The above mentioned equipment and materials are shown in the “Appendix 9 Reference Drawings”. Tanks planned in the project, such as a receiving tank, new ground reservoir, pressure control tanks, suction pit for booster pump, shall be kept at necessary capacities for efficient control, as follows.

Receiving tank	500 ・	(10.0m×10.0m×2.5m×2 units)
New reservoir tank	2,000 ・	(10.8m×31.0m×3.0m×2 units)
Pressure control tank	100 ・	(6.0m× 6.0m×3.0m)
Suction pit	50 ・	(4.0m× 5.0m×2.5m)