6. Priority Project

6.1 Selection of the First Priority Project

The first priority project is the 6 MCM/year brackish groundwater development in the Hisban/Kafrain area to provide 5 MCM/year product water to Jordan Valley area. The Project consists of the construction of a desalination plant and a water transfer trunk line.

6.1.1 Summary of the Project Evaluation

Selection of the priority project is based on the results of the project evaluation regarding the five alternative development plans summarized as follows.

(1) New Water Resource

Water resources in the study area are absolutely limited and at present the only method to increase water supply to the Jordan Valley area is to reduce the quantity of water transfer to the Amman capital area under the allocation of the conventional water resources. Therefore, the development of a new water source which has not been utilized is significant to the water sector.

(2) Fulfillment of Demand

The water demand of the whole Jordan River Valley area where development potential is very high in the context of regional peace will be fulfilled by the 6 MCM/year brackish groundwater development for the year of 1998 - 2000.

(3) Water Cost and Financial Burden

With the development in desalination technology, it has become possible to produce drinking water by desalination at an allowable cost for domestic and industrial water supply. The estimated cost for desalination and water distribution to the Jordan Valley area will be 0.52 JD/m^3 which is much lower than the cost when product water is to be pumped up for more than 1,200 meter to Amman area.

Government subsidy is required for the operation of the priority project under the current water tariff system. However the amount of subsidy will be affordable comparing with the estimated water cost of other water resource development projects in Jordan.

(4) Water Quality and Quantity of the Brackish Groundwater Aquifer Concerned

Since brackish groundwater quality at the Kafrain area is better than that at the Deir Alla area, lower energy consumption is expected for RO desalination. Besides, production wells at the Kafrain area are expected to be under artesian conditions at the amount of 6 MCM/year development, and pumps will not be required.

(5) Concentrated Brine Discharge

The quality of concentrated brine (less than 35,000 ppm in TDS) from the desalination process is allowable to be discharged to the Dead Sea. Wadi Ijarfa which flows directly to the Dead Sea can be used for brine discharge of the priority project. According to a preliminary examination of groundwater pollution to be caused by discharging the concentrated brine to Wadi Ijarfa, negative impact is not so significant on the shallow aquifer because the amount of brine discharge is comparatively small (about 1,500 liters/min) and an alternative measure of moving a few numbers of wells may be considered with a lighter cost of about 15,000 JD than the cost of brine discharge pipeline (approximately 520,000 JD). However, a brine discharge pipeline will be provided to a point near the coast of the Dead Sea (about 10 km from the proposed plant site) in order to wipe out the negative impact on the environment such as existing wells and farm lands beside the wadi (see Supporting Report Chapter 15).

(6) Water Transfer Trunk Line

The existing pipe line will not be sufficient for transferring water to the Northern part of Jordan Valley. Therefore a water transfer trunk line with pumping facilities will be required.

6.1.2 Configuration of the Priority Project

The priority project consists of the following structures, equipment and facilities;

(1) Production Wells and Collection Piping

- Production wells penetrating to the Zarqa group aquifer
- Raw brackish groundwater collection piping to the plant

(2) Desalination Plant

- Pre-treatment
- RO equipment
- Post-treatment

(3) Concentrated Brine Discharge

- Discharging pipe line to Wadi Ijarfa

(4) Electricity Supply

- A new 33kv transmission line from the existing JEA 132kv substation

(5) Water Transfer Stations and Trunk Line

- A water transfer trunk line from Kafrein to Deir Alla

6.2 Preliminary Design of the Project

6.2.1 Fundamental Conditions

The location of the priority project, i.e. a 6 MCM/year brackish groundwater development in the South of the Study Area is shown on Fig. II-6.2.1. The project includes constructions of (i) production wells, (ii) desalination plant and (iii) water transfer trunk lines to the two reservoirs at South Shuna and South Muaddi. The fundamental conditions for the project design are as follows.

(1) Topography and geology

a) Production wells and desalination plant sites (Fig. II-6.2.2)

The sites of production wells and desalination plant are located in Hisban area at the Northeast of the Dead Sea and South of Kafrain town. This is an area lying on the foot hills in between the escarpment and rift valley with an elevation varying from 0 to -200 meters.

Geologically, the sandstone and limestone layers of the Zerqa group are overlain by the Kurnub sandstone, and then the marl, clay, sand and gravel layers of the Jordan Valley group. The depth of Kurnub layers and that of the Zerqa layers increase dramatically westward to the rift valley side.

b) Water transfer trunk lines

The distance from the desalination plant site to the Shuna Reservoir is about 11 km, and that to the Muaddi Reservoir is about 41 km. The water transfer trunk lines shall be laid along the main road in the Jordan Valley (Road No. 65) which goes northward with a moderate variation in its elevation between -200 and -300 meters.

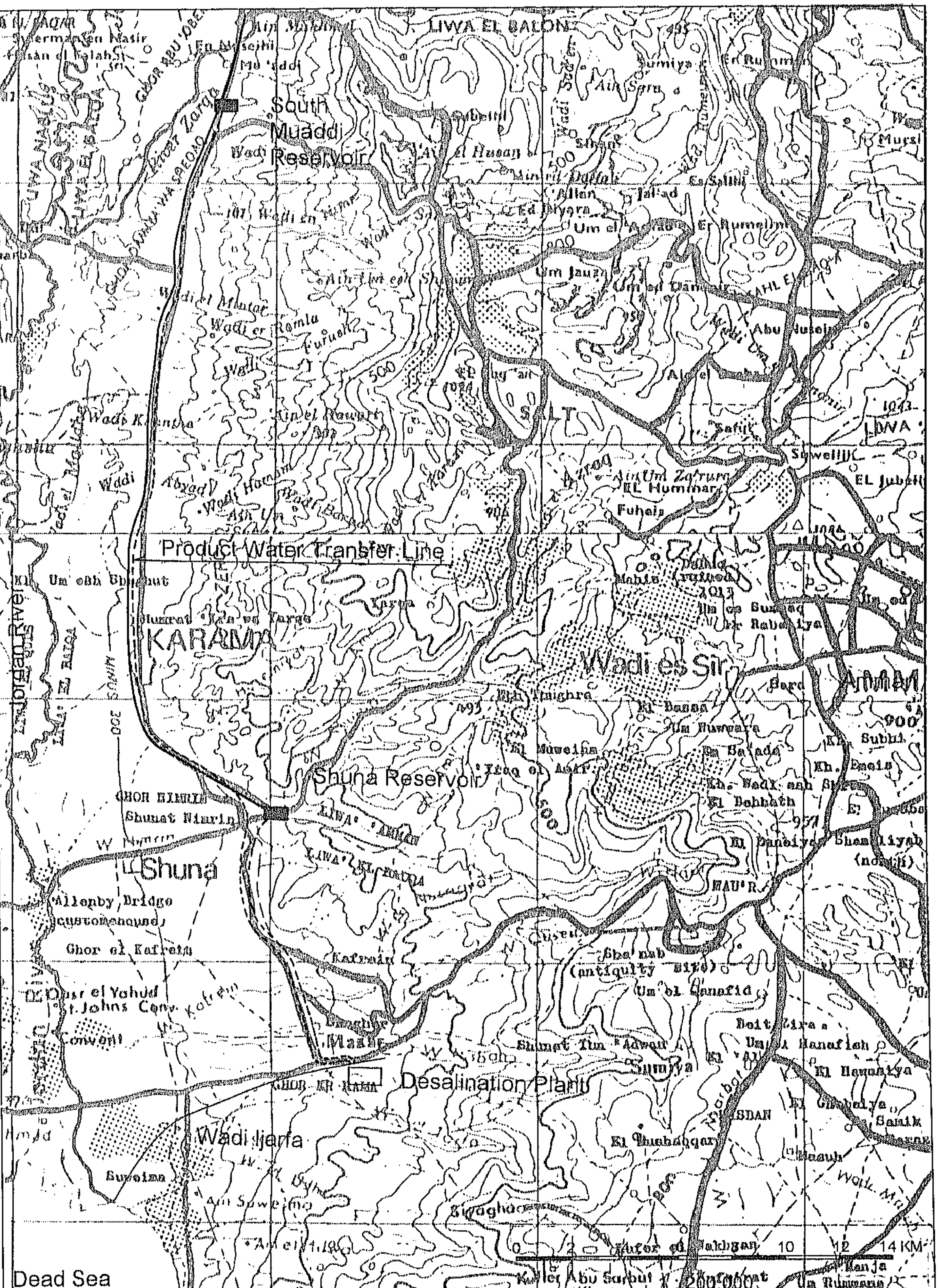


Fig. II-6.2.1 Location of the Priority Project

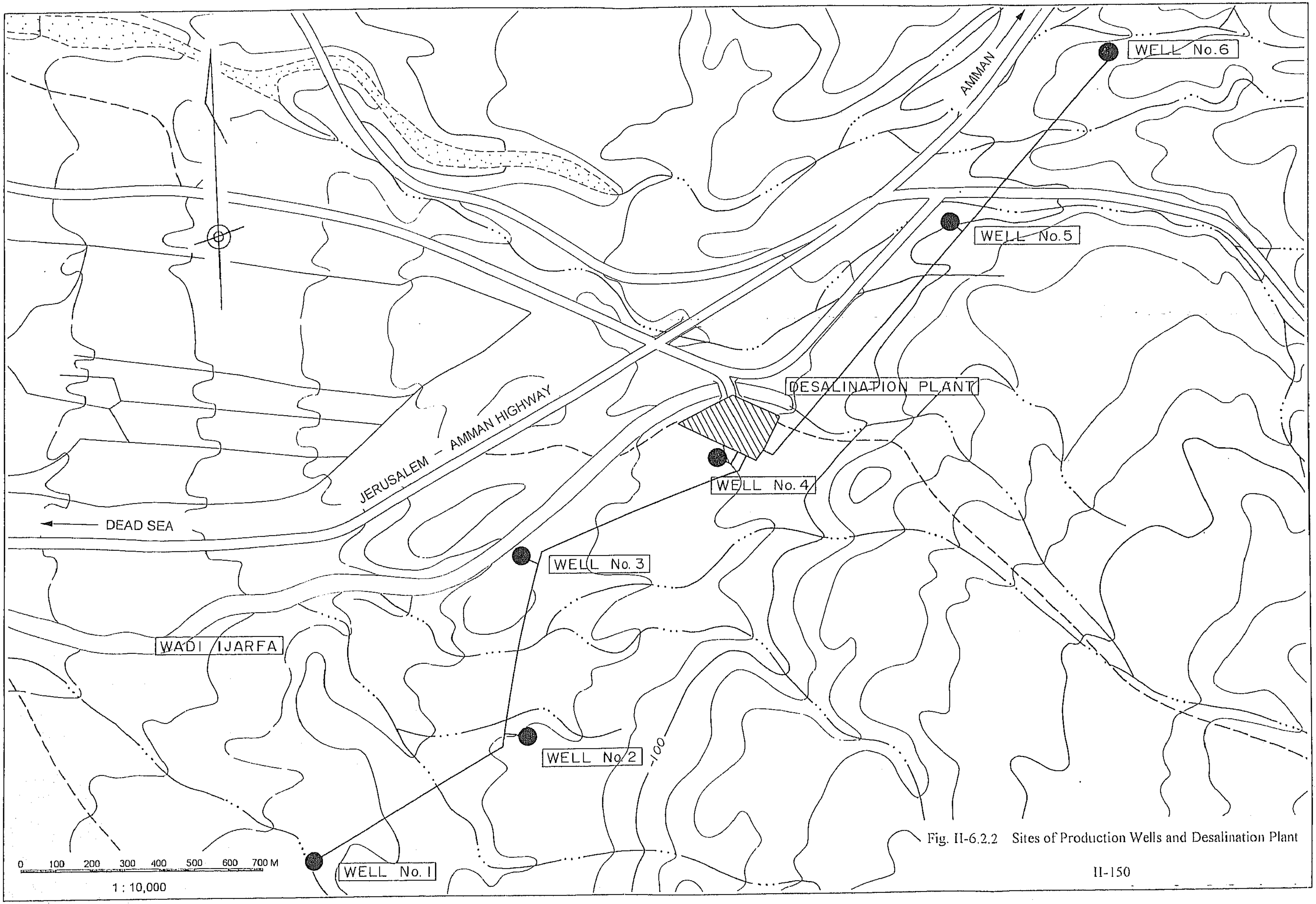


Fig. II-6.2.2 Sites of Production Wells and Desalination Plant

(2) Raw water

The raw water for the project is the brackish groundwater from the Zerqa Aquifers in the South of the Study Area. The design quantity and quality of the raw water are as follows.

- Raw water quantity: 18,000 m^3/day
  (330 operation days/year at a load factor of 0.9)
  750 m^3/hour (continuous operation)
- Raw water quality: TDS 5,000 mg/L

(3) Water supply

- Water supply area: South Shuna and Deir Alla Districts in the Jordan Valley
- Water supply quantity: 15,000 m^3/day (a water recovery about 90%)
  625 m^3/hour

6.2.2 Preliminary Design

The project basically consists of three parts - raw water system (production wells and water collection pipes), desalination system (RO process) and water transfer system. Fig. II-6.2.3 shows the flow diagram.

(1) Production wells and water collection pipes

a) Production wells

The profile of a typical water production well is shown on Fig. II-6.2.4. The specifications are as follows:

- Well depth[11]: 350 m
- Production capacity: 125 m^3/hour/well (1 MCM/year/well)
- Number of wells: 6
- Casing material: top zone (depth 0 - 50 m): stainless steel[12]
  lower zone (depth 50 - 350 m): ordinary API steel
- Well pump: not required[13]

[11] A depth to the Zerqa Aquifers.

[12] For protection of parts exposed in the air from salt corrosion..

[13] In the South area with a 6 MCM/year development, the production wells are expected to be under an artesian condition and well pumps are not needed. However, under the conditions of brackish groundwater development in the North area and developments of larger amounts in the South area, pumping will be required and a pumping head to a height of 60 m above the ground is needed.

b) Raw water collection pipes

The layout of raw water collection pipes is shown on Fig. II-6.2.2. Because the brackish groundwater is corrosive, Polyvinyl Chloride (PVC) pipe shall be used for raw water collection.

(2) RO desalination system

Fig. II-6.2.5 shows the process flow of the RO desalination system which consists of (i) pre-treatment facility, (ii) RO unit, (iii) post-treatment facility and (iv) chemical cleaning and waste water treatment facility.

1) Pre-treatment facility

a) General processes of pre-treatment for a RO system

Before feeding to a RO membrane unit, impurities which may cause membrane fouling have to be removed from the raw water and pre-treatment facilities are thus required. Generally speaking, the pre-treatment aims to removing or controlling the following substances if their concentrations are considerably high.

- Turbid matters: silt, clay particles and other suspended solids
- Colloidal matters: silicate and other colloids
- Organic matters: microorganisms, bacteria and other TOCs
- Oil and grease: mineral and vegetation oils, fats and so on
- Ions related to $CaCO_3$ precipitation: Ca, HCO_3, etc.
- Corrosive metal ions: Fe, Mn
- Other scale forming ions: Ba, P, etc.

Besides, temperature control may also be required when raw water is at a high temperature.

The general methods to remove or control these substances are shown in Table II-6.2.1.

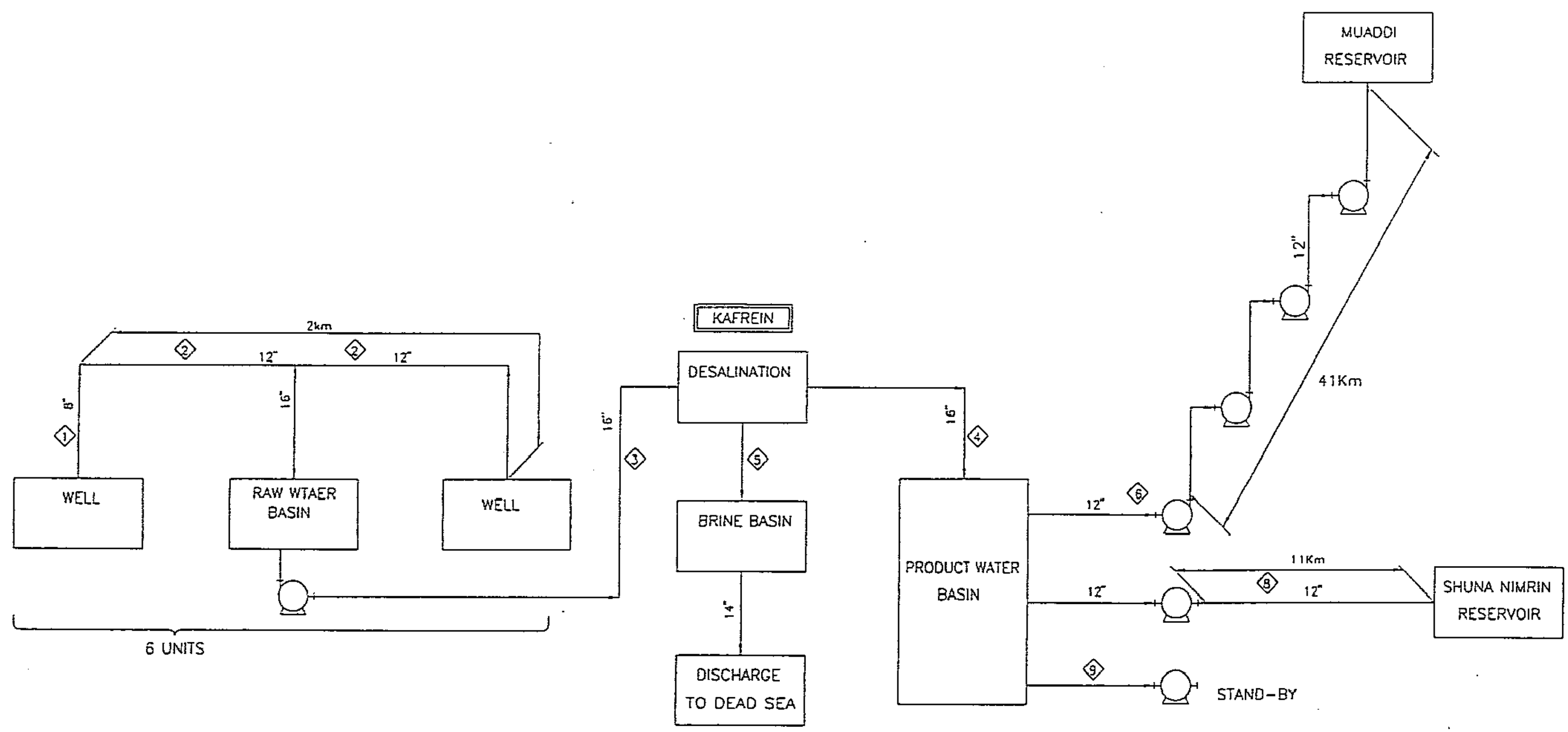


Fig. II-6.2.3 Flow Diagram of the Priority Project

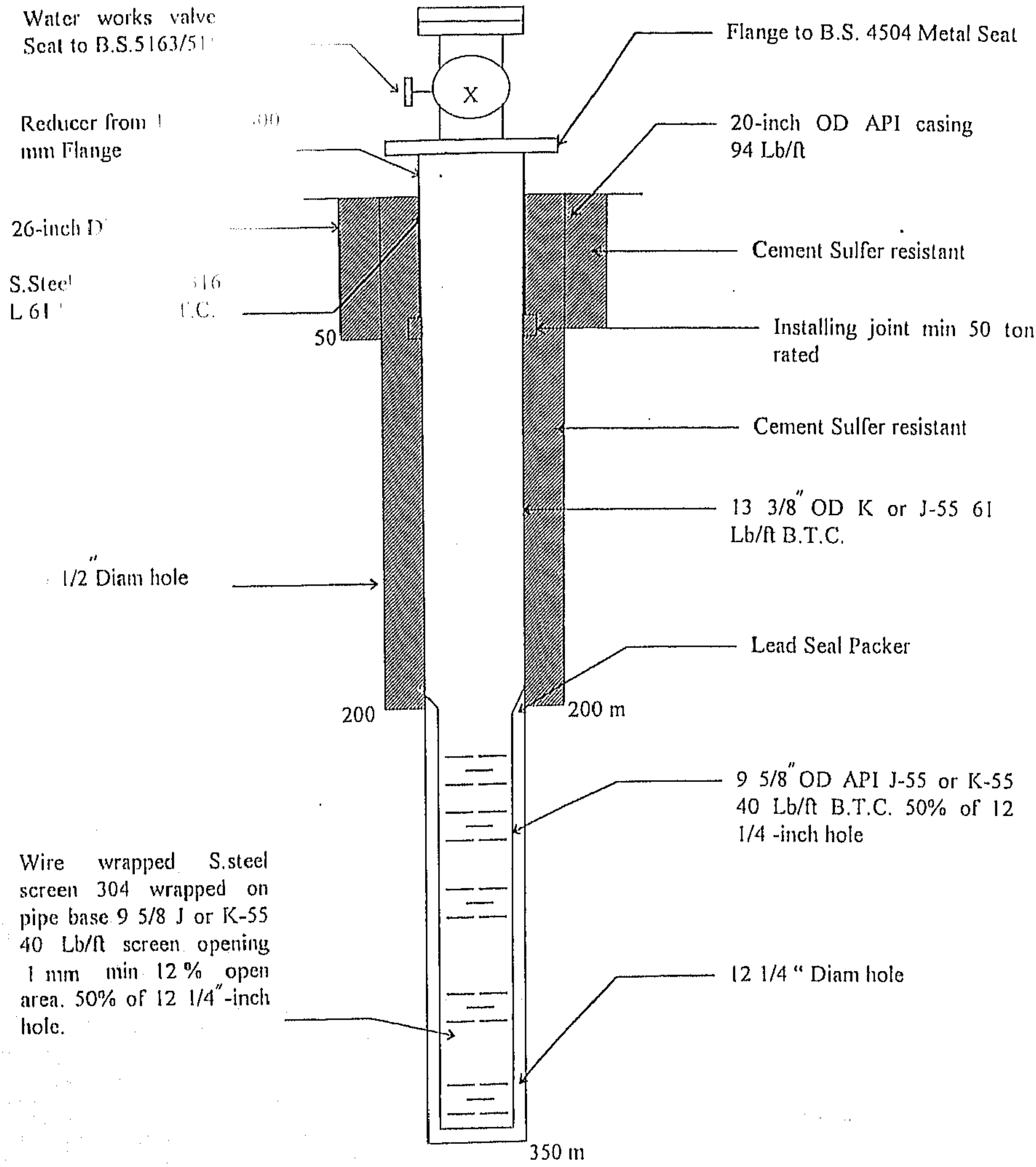


Fig. II-6.2.4 Profile of Water production Well

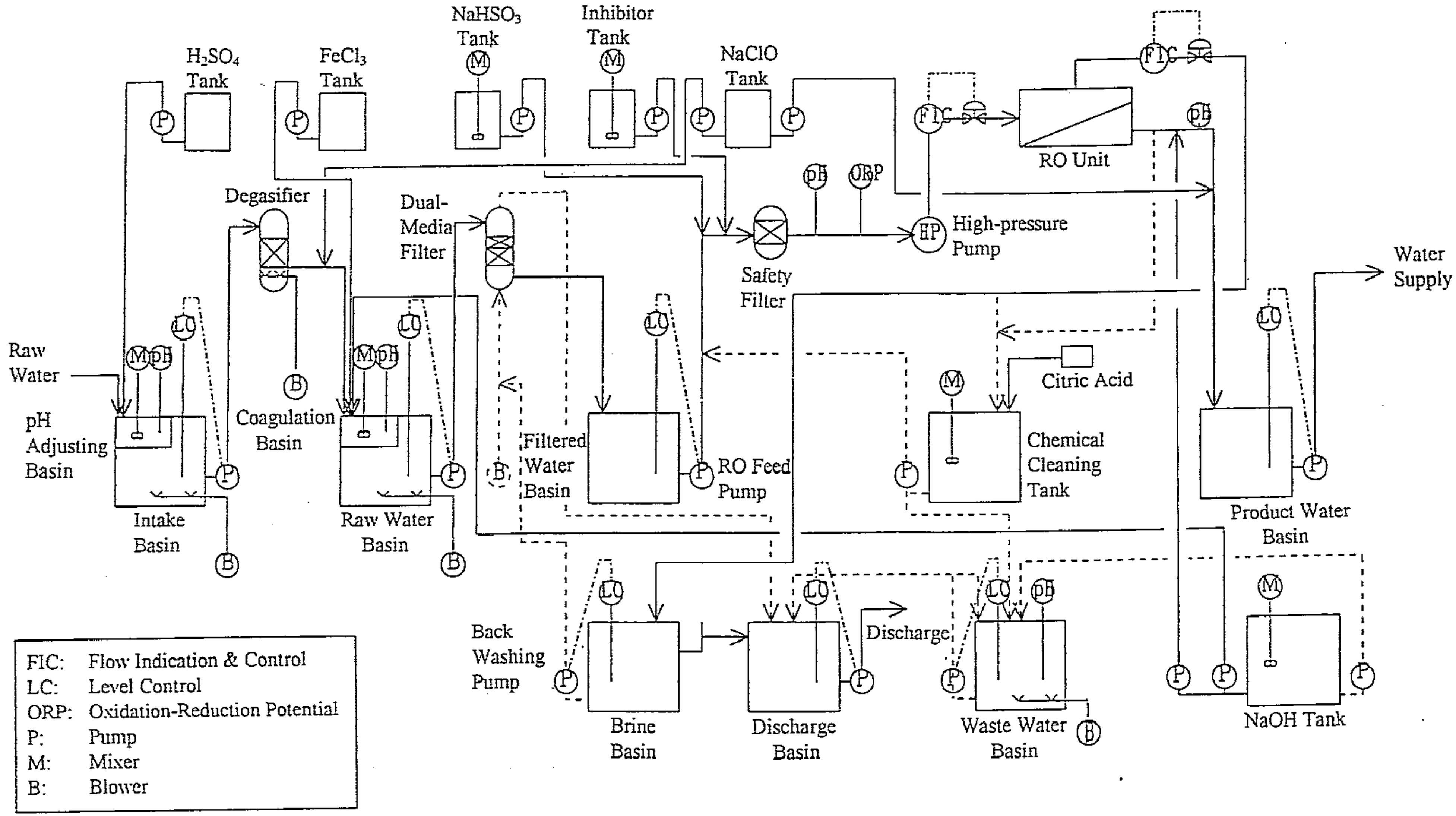


Fig. II-6.2.5 Process Flow of the RO Desalination System

Table II-6.2.1 Impurities in Raw Waters and General Pre-treatment Methods

Impurities	Treatment Methods	Characteristics
Turbid matters, Silicate etc.	(1) Dual-media filtration	-To remove particulate matters -In the case of low turbidity and low silicate concentration -Easy to operate
	(2) Coagulation-filtration	-Dual media filters with coagulant dosing and mixing devices -To remove particulate and colloidal matters
	(3) Coagulation-sedimentation-filtration (Clarification-filtration)	-To remove high concentration turbid matters -Coagulant dosing device is needed -Complicated O/M
Organic matters	(1) Coagulation	-Only high molecular organic matters can be removed
	(2) Oxidation (Chlorination)	-Most simple and widely used method -Easy to operate
	(3) Activated carbon absorption	-Efficient removal of all organic matters -Easy to operate -Higher cost
Oil & Grease*	(1) Plain flotation	-To remove high concentration free oils -Easy to operate
	(2) Coagulation-flotation	-To remove free, emulsion and dissolved oils -Coagulant dosing device and air compressor are needed -Complicated O/M
	(3) Polymer media adsorption	-To remove free oils -Easy to operate -Higher cost
	(4) Activated carbon adsorption	-To remove free, emulsion and dissolved oils -Easy to operate -Higher cost
Ca	(1) pH adjusting	-To decrease pH by H_2SO_4 dosing resulting in a decrease in CO_3 concentration to prevent $CaCO_3$ precipitation -Most simple and widely used method
	(2) Inhibitor dosing	-To prevent scaling -Widely used method
	(3) Softening-sedimentation	-In the case of high Ca concentration (especially as SO_4 concentration is high and $CaSO_4$ precipitation may occur) -Complicated O/M
HCO_3	pH adjusting-degassing	-To transform HCO_3 into CO_2 and then to remove CO_2 gas -In the case of high HCO_3 concentration
Fe, Mn	Oxidation (chlorination)-filtration	-To transform soluble Fe, Mn into precipitated state and then to remove them -Precipitated Fe, Mn may act as coagulants to promote turbidity removal -Simple and widely used method
Ba, P	Activated carbon adsorption	-High cost
Temperature	Cooling tower	-In the case of a higher temperature than 35 - 40°C
Chlorine**	(1) Dechlorination by using reductive agent	-Most simple and widely used method
	(2) Activated carbon adsorption	-High cost

* The substances which are soluble in organic solvents (Normal Hexane according to Japanese Standards, or Trichlorotrifluoroethane according to American Standards)

** Treatment is required to remove the excess of free chlorine from the chlorinated water to prevent the membranes from being damaged by oxidation.

b) Pre-treatment processes to be applied in this project

Table II-6.2.2 shows the quality of the brackish groundwater and a brief judgment of their impacts on RO membranes. For this project, the pre-treatment shall aim mainly at removal and control of turbidity, Ca, HCO_3, Fe and excess free chlorine resulting from chlorination. The following facilities are recommended for these purposes.

- pH adjusting: for a removal of HCO_3 and a reduction of water pH to 6.0
- Degassing: for a removal of dissolved CO_2 gas
- Chlorination: for oxidation of Fe, Mn and organic matters
- Coagulation and dual-media filtration: for a removal of turbidity
- Dechlorination: for a removal of residual free chlorine
- Inhibitor dosing: for anti-scaling

Table II-6.2.2 Impurities in the Brackish Groundwater and the Level of Their Impacts on RO Membranes

Impurities	Concentrations	Impacts to RO membranes
Turbidity	> 10 NTU	Considerable
Silt density index (SDI)*	> 5	Considerable
Silicate	10 - 20 mg/L as SiO_2	Low
Organic matters	TOC <= 2.0 mg/L	Low
Ca	400 - 600 mg/L	Considerable
HCO_3	800 - 1200 mg/L	Considerable
Fe	1 - 10 mg/L	Considerable
Mn	<= 1.0 mg/L	Low
Ba	<= 0.03 mg/L	Negligible
P	<= 0.1 mg/L as PO_4	Negligible
Temperature	30 - 35 °C	Negligible
Excess free chlorine**	-	Considerable

* A general parameter to evaluate fouling substances in water (also called as Fouling Index)
** Since chlorination is required

In the Draft Final Report, adsorption device was considered for a removal of oil & grease which were suspected to exist in the raw water at that time. Afterwards, JICA Study Team conducted further investigation of oil & grease by taking water samples from the brackish ground water aquifer and carrying out precise analysis in Japan. From the analysis results, it is clarified that the concentration of oil & grease is below the detection limit and will not affect the performance of RO membranes. Therefore, installation of adsorption device will not be necessary.

c) Specifications of the main pre-treatment devices

Specifications of the main pre-treatment devices is shown in Table II-6.2.3.

Table II-6.2.3 Specifications of the Main Pre-treatment Devices

	Pre-treatment Device	Specifications	
1	pH adjusting basin	Number: Retention time: Equipment:	1 basin 3 min Agitator, pH indicator, H_2SO_4 tank, H_2SO_4 dosing pump
2	Intake basin	Number: Retention time: Equipment:	1 basin 30 min Blower, Intake pump, Level indicator
3	Degasifier	Number: Liquid velocity: Equipment:	1 set 60 m/hour Blower
4	Coagulation basin	Number: Retention time: Equipment:	1 basin 3 min Agitator, pH indicator, Coagulant tank Coagulant dosing pump NaOH pump (pH adjusting)
5	Raw water basin	Number: Retention time: Equipment:	1 basin > 1 hour Blower Filter feed pump, Level indicator
6	Dual-media filter	Number: Filter media: Filtration velocity: Equipment:	8 sets sand & anthracite 10 m/hour Back washing pump & blower
7	Filtered water basin	Number: Retention time: Equipment:	1 basin > 1 hour RO feed pump, Level indicator
8	Chlorination	Equipment:	NaClO tank NaClO dosing pump
9	Dechlorination	Equipment:	SBS tank SBS dosing pump
10	Inhibitor dosing	Equipment:	Inhibitor tank Inhibitor dosing pump

2) RO Units

a) RO membrane modules

Selections of RO membrane modules are based on a comparison of the characteristics of the membranes widely used in water desalination (Table II-6.2.4). Spiral wound polyamide membrane modules are selected for this project under the following considerations.

- After pre-treatment, SDI of the feed water will be about 3.0 - 4.0 which is a quality suitable for using spiral wound membrane modules.

- Higher production capacity per RO element is expected and polyamide membrane can gain a higher flux at a low pressure.

The specifications of membrane elements are as follows:

- Module type: Polyamide spiral wound module
- Module size: 8 inch in diameter
- Operation pressure: 25 kg/cm^2
- Recovery ratio: 85 %

b) Accessory equipment

- Safety filters	Filter media:	polypropylene
	Filter pore size:	25 μm
- High pressure pumps	Pump head:	300 m

Table II-6.2.4 Characteristics of RO Membranes

Membrane material	Module type	Characteristics
Cellulose acetate (CA)	Hollow fiber (HF) and Spiral wound (SW)	-Operation pH: 4 -6 -Operation pressure: middle or high (to keep a high flux) -Sensitive to biological fouling -Resistant to residual chlorine -Water quality required: SDI<3.0 for HF, SDI<4.0 for SW -Typical capacity of a 8 inch SW module: 10 - 15 m^3/day
Polyamide (PA)	HF and SW	-Operation pH: 3-9 -Operation pressure: low (to keep a high flux) -Resistant to bacteria -Sensitive to residual chlorine -Water quality required: the same as CA -Typical capacity of a 8 inch SW module: about 20 m^3/day

3) Post-treatment

Post-treatment is the final control of product water quality for water supply. It includes pH adjusting and disinfection.

a) pH adjusting (to adjust the water pH to a neutral value for drinking purpose)

- Chemical: NaOH
- Equipment: NaOH tank and NaOH dosing pump.

b) Disinfection (to sterilize water and add residual chlorine)

- Disinfectant: Sodium hypochloride (NaClO)
- Target residual chlorine: > 0.5 mg/L

4) Chemical Cleaning and Wastewater Treatment

a) Chemical cleaning of RO membrane

Even though pre-treatment is carried out, membrane fouling and/or scaling may happen more or less after a period of operation resulting in a drop of pressure and a reduction of permeate flux. Therefore, chemical cleaning is required to be conducted regularly for a recovery of the membranes' performance.

- Chemical to be used: Citric acid
- Frequency of chemical cleaning: One time per 3 months for each membrane module
- Equipment: Cleaning tank with an agitator
  Cleaning pump

b) Waste water treatment

The chemical cleaning waste water shall be treated in the following ways before being mixed with the brine and discharged to the Dead Sea.

- Neutralization by adding NaOH
- Aeration for biological degradation of organic matters

The equipment includes:

- Waste water basin (for both neutralization and aeration)
- NaOH dosing pump
- pH indicator
- Blower
- Waste water pump

Figs. II-6.2.6 and II-6.2.7 summarize the preliminary design of the RO desalination plant:

- Plant Layout
- View and Sections

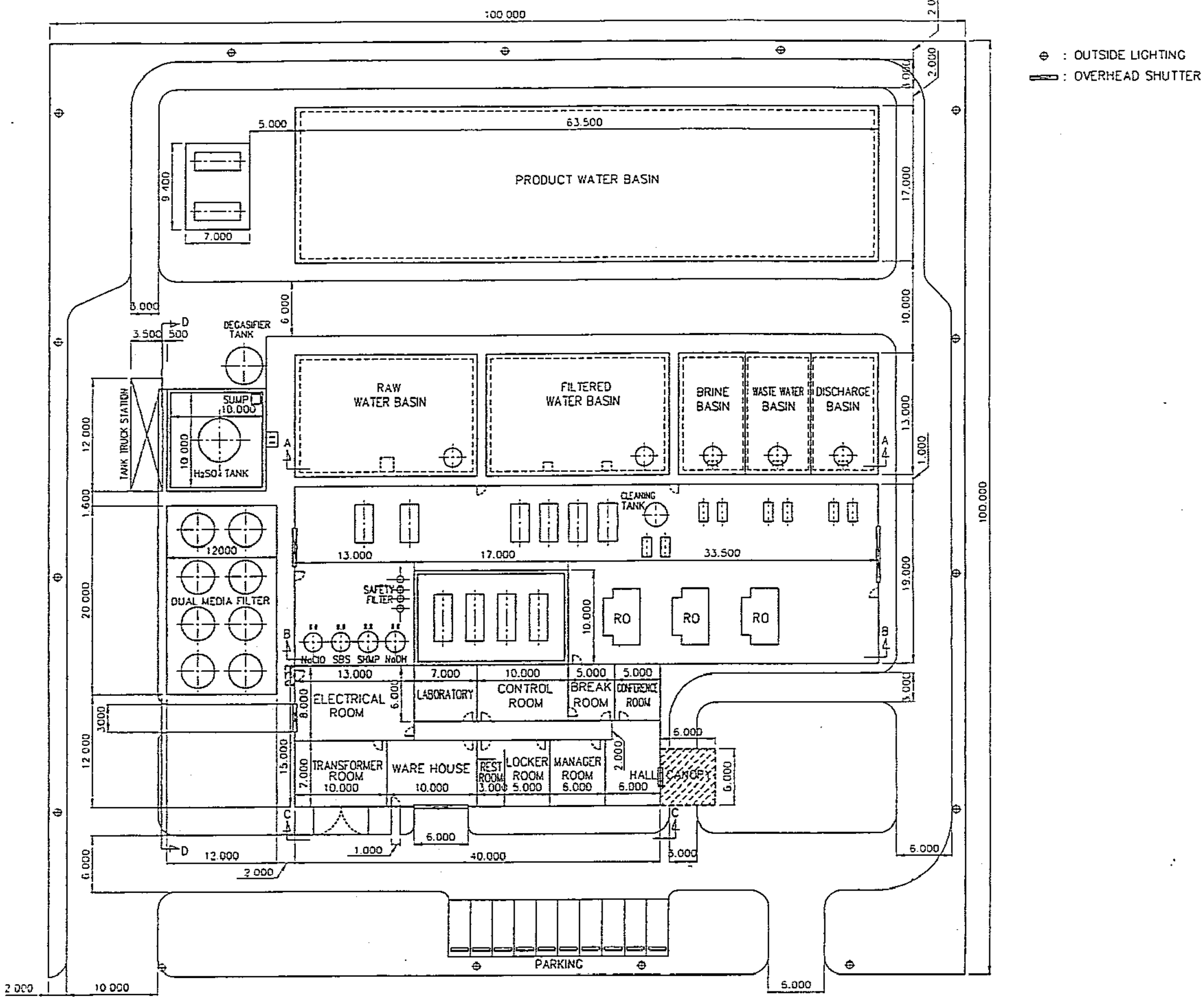
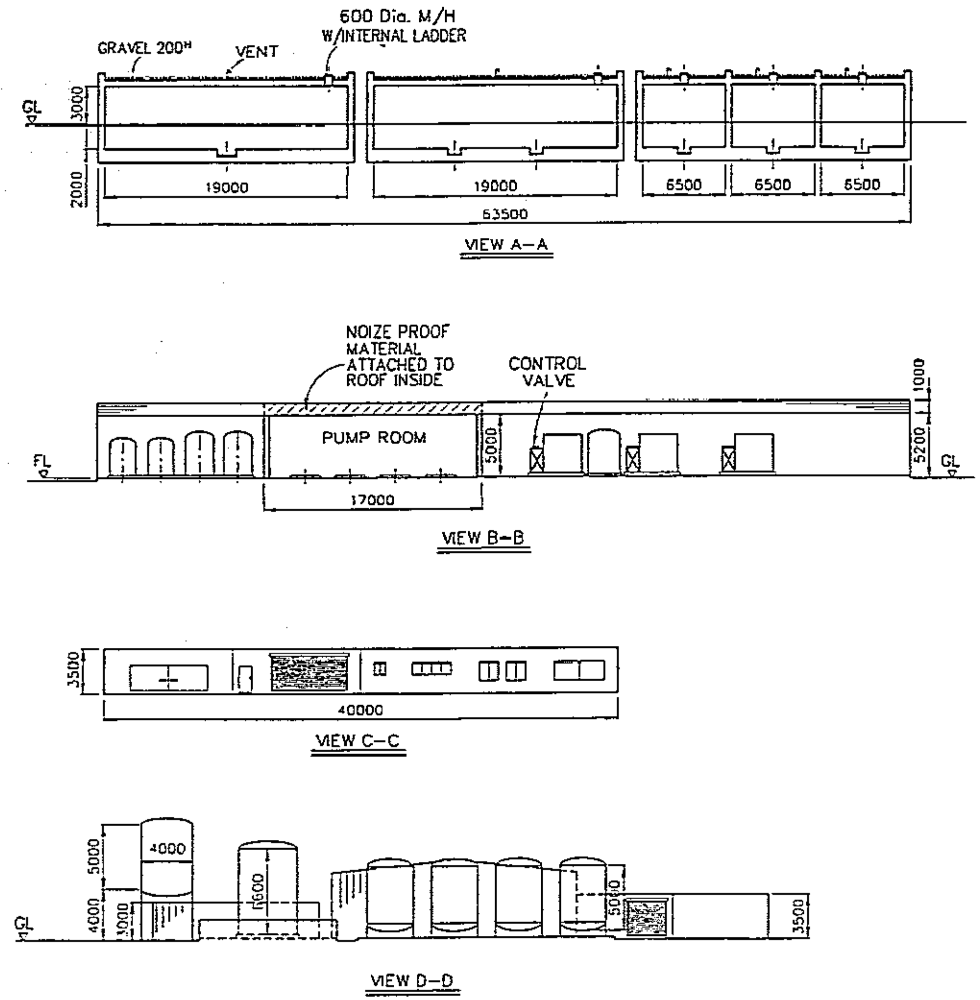


Fig. II-6.2.6 Layout of the RO Desalination Plant



NOTE :
(1) UNIT : MM

Fig. II-6.2.7 Views and Sections of the RO Desalination Plant

(3) Brine discharge

a) Consideration on brine quality

According to the raw water quality, design salt rejection ratio (> 95%) and water recovery ratio (85%), the quality of the discharged brine is estimated as shown in Table II-6.2.5.

Table II-6.2.5 Quality of Discharged Brine

Item	pH	TDS	Ca	Mg	Na+K	Cl	SO_4	HCO_3	Fe*	Mn	SiO_2	SS
Unit	-	mg/L										
Value	5.8 - 8.6	25,000-33,500	2,000 - 3,350	500 - 1,000	5,500 - 9,500	7,500 - 11,400	2,000 - 4,000	5,000 - 8,000	10 - 20	< 0.7	25 - 110	< 100

* In flocculated ferric hydroxide state.

From this table, it is seen that the brine mainly contains high concentrations of the component ions of 'Salts', i.e. Ca, Mg, Na+K as the main cations and Cl, SO_4, HCO_3 as the main anions. The estimated concentration of Fe is 10 - 20 mg/L because the washing waste of the dual-media filters which hold the ferric hydroxide flocs is mixed with the brine. However, this amount of iron is no longer in a dissolved condition but exists as suspended solids (SS). The concentrations of hazardous substances such as heavy metals are negligible. Therefore, it is thought that the brine can be discharged into the Dead Sea without causing environmental problems.

b) Brine disposal

- Final disposal site: the Dead Sea
- Brine discharge line: by a 10 km pipeline from the plant to the downstream of Wadi Ijarfa and then to the Dead Sea through the wadi course. (see Chapter 15 of the *Supporting Report* for the detailed plan.)

c) Brine discharge equipment

- Brine basin: to receive the brine from the RO unit
- Discharge basin: to receive the overflow from the brine basin and the filter washing waste and the treated chemical cleaning waste from the waste water basin.
- Discharge pump: to discharge the brine through Wadi Ijarfa to the Dead Sea.

(4) Water supply facility

The water supply facility includes product water storage basin and pumps in the plant, and water transfer trunk lines to the existing Shuna Nimrin Reservoir and Muaddi Reservoir. Fig. II-6.2.8 shows the schematic flow of the water transfer system.

a) Product water storage basin

- Capacity: 4,000 m^3 (a retention time more than 4 hours)
- Number of basins: 2 (2 x 2,000 m^3)

b) Product water pump

- Number of pumps: 3 (one for stand-by)
- Pump capacity: 5.7 m^3/min
- Pump head: 70 m

c) Water transfer pipelines

- Length: 11 km to Shuna Nimrin Reservoir
  41 km to Muaddi Reservoir
- Diameter: 300 mm
- Design flow rate: 5.7 m^3/min
- Design pressure: 10 kg/cm^2

d) Lift pumps

For the transfer pipeline to Shuna Nimrin Reservoir, the product pump in the plant is capable to lift the water directly to the reservoir. However, for the transfer pipeline to Muaddi reservoir, 4 stage lift is considered to be necessary and 3 lift pumps shall be installed along the pipeline at every 10 - 12 km distance.

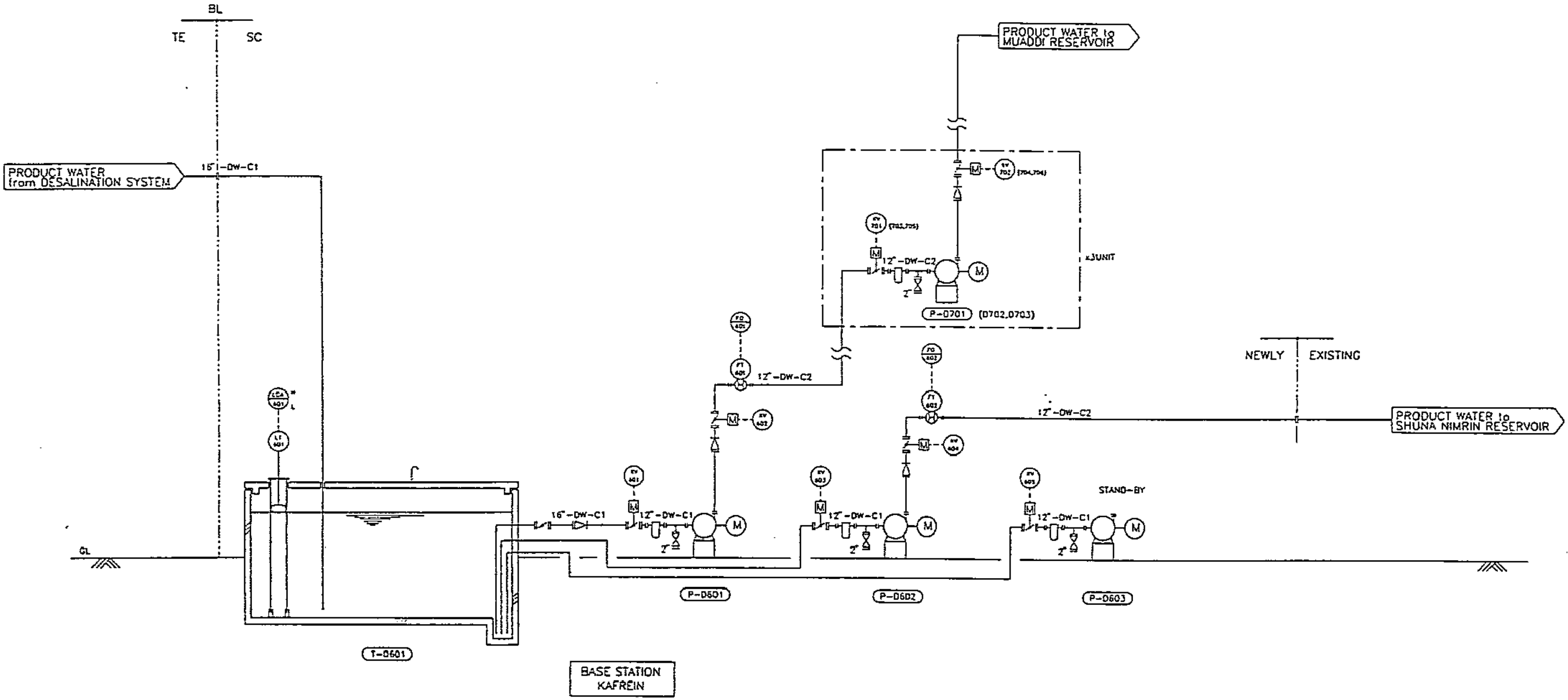
- Number of pumps: 3
- Pump capacity: 5.7 m^3/min
- Pump head: 70 m

Fig. II-6.2.9 shows the profile of the water transfer trunk lines.

(5) Electricity supply system

The oneline diagram of the electricity supply system is shown in Fig. II-6.2.10.

- Electricity consumption: approx. 1,700 kw
- Power resource: 33 kv transmission line available in the Jordan Valley near the project site



NOTE:
(1) TDS IN PRODUCT WATER SHALL BE 800 PPM.

Fig. II-6.2.8 Schematic Flow of Water Transfer Trunk Line

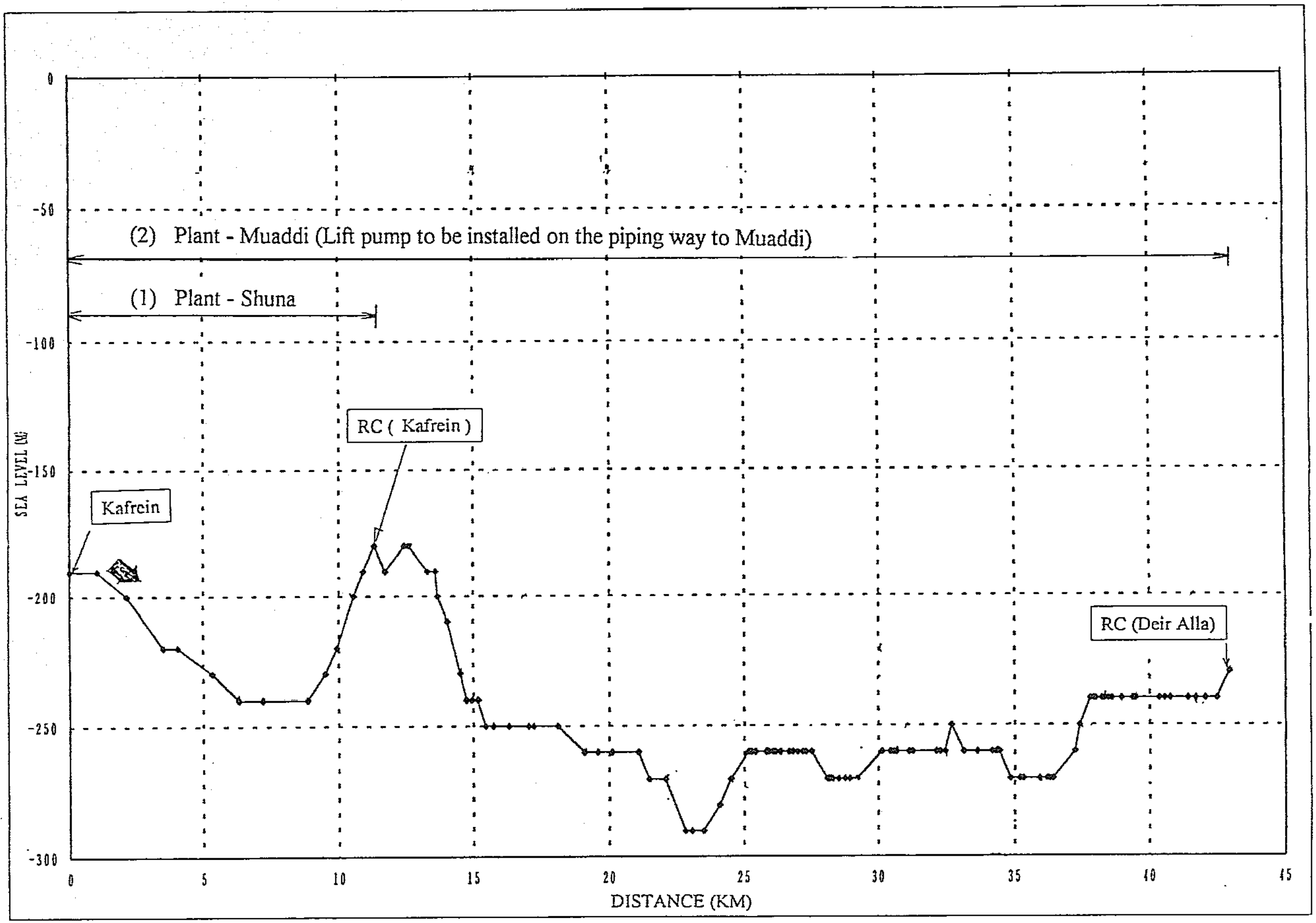


Fig. II-6.2.9 Profile of the Water Transfer Trunk Line

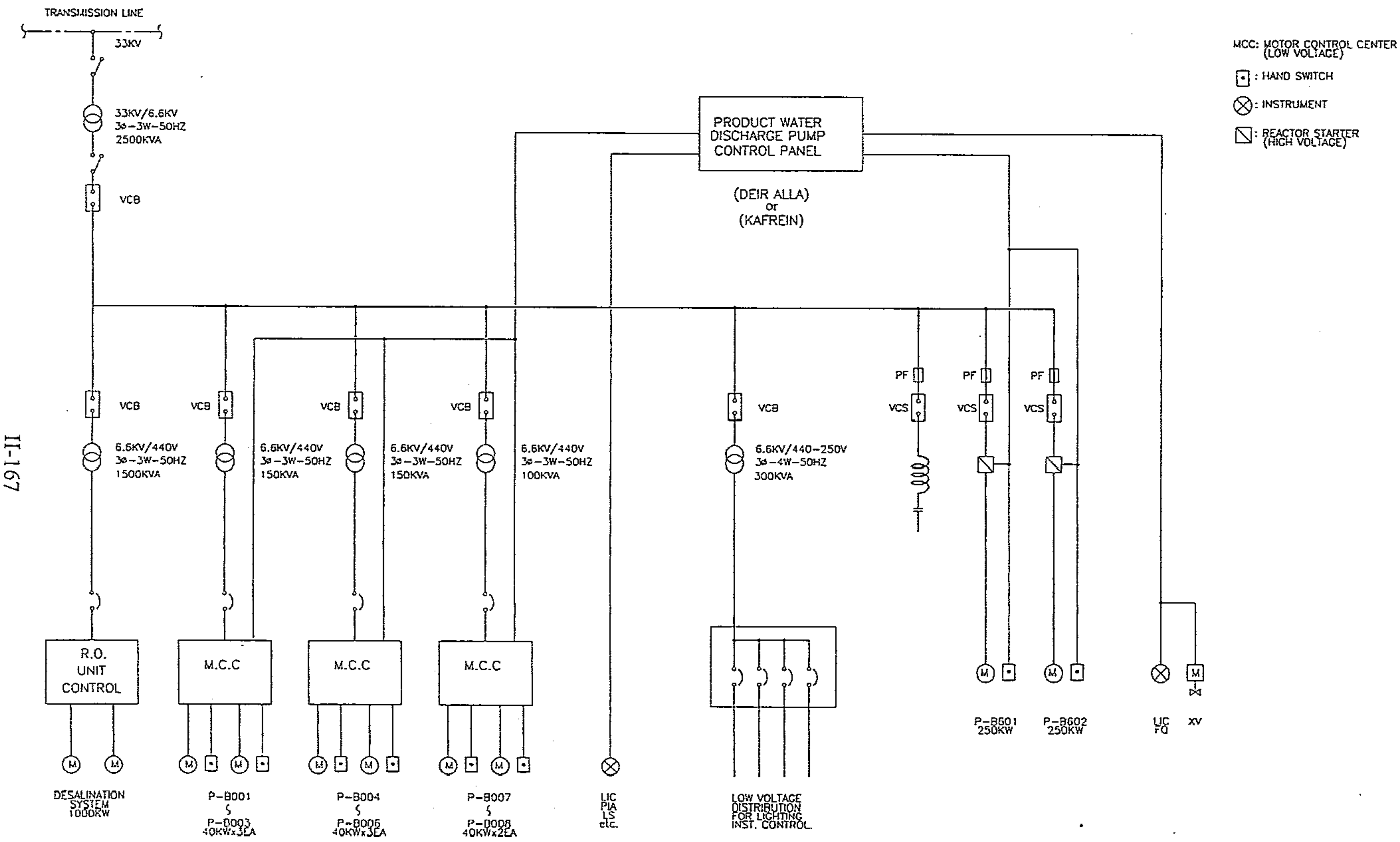


Fig. II-6.2.10 Oneline Diagram of Electricity System

6.2.3 Operation and Maintenance

(1) Items of O & M for the RO desalination plant

The RO desalination process will be operated and monitored by an automation system. Therefore, the daily work will mainly be inspections of machines and metering instruments, water quality tests, and repair and maintenance of machinery and electrical equipment as needed. Besides, chemical cleaning of RO membrane modules shall be conducted regularly, and deteriorated modules shall be replaced. The main items of operation and maintenance (O & M) can be summarized as follows.

a) Daily inspection items

i) Operating data: water temperature, raw water flow rate, product water flow rate, operating pressure, chemical dosing rate

ii) Water quality: pH, redox potential (ORP), silt density index (SDI), electric conductivity (EC)

iii) Operation conditions of

- Raw water facilities (production wells, intake basin)
- Pre-treatment facilities (raw water pump, degassifier, filter feed pump, dual-media filters, chemical dosing pumps)
- RO units (high pressure pumps, RO modules)
- Product water basin and product water pumps

b) Regular work items

- Preparation of chemical solutions (weekly): H_2SO_4, NaClO, NaOH, inhibitor, SBS
- Replacement of safety filters (per 3 months or so)
- Chemical cleaning of RO modules (per 3 months or so)
- Replacement of RO modules (about 20% per year)

c) Maintenance work: Small scale repair and maintenance of machinery and electrical equipment shall be involved in the daily work, and regular maintenance shall be conducted in the meantime as the work mentioned in b) is undertaken.

(2) Plant organization

According to the O & M work above mentioned, the organization of the RO desalination plant is planned as shown in Table II-6.2.6 which consists day time staff and shift staff because the plant will be operated continuously. The shift staffs are in charge of plant operation and security, and the day time staffs are responsible for plant management, carrying out regular work such as chemical preparation, chemical cleaning, replacement of safety filters and RO modules, water quality analyses and maintenance of machinery, electrical equipment and instruments.

Table II-6.2.6 Organization of the RO Desalination Plant

Duty		Number of Person
Day time staff	Director	1
	Office worker	1
	Chemist	2
	Mechanist	1
	Electrician	2
	Mechanical worker in charge of production wells	1
Shift staff	Operator	2 × 4
	Guard man	1 × 4
Total		21

(3) Control of chemical dosing

The chemicals to be used in the RO desalination plant includes pH adjusting agents (H_2SO_4, NaOH), oxidation and disinfection agent (NaClO), inhibitor (SHMP or Flocon-100), dechlorination agent ($NaHSO_3$) and membrane cleaning chemical (Citric acid). The estimated dosage and annual consumption of these chemicals are shown in Table II-6.2.7.

Chemical dosing affects greatly the results of water treatment and the life time of RO membranes. In principle, the accurate dosage of each chemical shall be selected by laboratory test regarding raw water quality. It is recommended that each chemical solutions should be prepared carefully to the design concentration, and the flow rates of chemical dosing pump should be checked everyday. Any adjustment of chemical dosage should follow the instruction of chemists.

Table II-6.2.7 Chemical Consumption

Chemical	Dosage (mg/L)	Consumption	
		Daily (kg/day)	Yearly (tons/year)*
H_2SO_4 (98%)	600	10,590	3,500
NaClO (10%)	5	735	243
Inhibitor	3	53	17.5
$NaHSO_3$	2	39	13
NaOH	20	144	47.5
Citric acid	-	360 (kg/3 month)	1.44

* with a load factor of 0.9 (330 operation days per year)

Table II-6.2.8 Water Quality Analyses Items

Items	Raw water	Treated water
1) to be analyzed in the plant		
pH	○	○
EC	○	○
Temperature	○	○
SDI	○	
Redox potential	○	
Residual chlorine		○
COD	○	
2) to be analyzed in a central lab.		
Na	○	○
Ca	○	○
Mg	○	○
Fe	○	○
Mn	○	○
SiO_2	○	○
Cl	○	○
SO_4	○	○
HCO_3	○	○
TOC	○	○

(4) Water quality analyses

Water quality analysis items are shown in Table II-6.2.8 which includes two groups - one group to be analyzed daily in the plant, another group to be analyzed twice per week in a professional water laboratory such as the central laboratory of WAJ. Therefore, the plant shall be equipped with the following water quality analysis equipment:

- pH meter 2 sets
- EC meter 2 sets

- SDI analyzer	1 set
- Redox (reduction-oxidation) potential meter	2 sets
- Residual chlorine meter	2 sets
- COD analysis apparatus	1 set

6.2.4 Cost Estimation

(1) Construction cost

The costs for the construction of the priority project are estimated as shown in Table II-6.2.9.

Table II-6.2.9 Estimated Construction Cost

Item	Cost (1000 JD)
(1) Production wells	**1,667**
1) Well construction	1,067
2) Water collection pipes	600
(2) RO desalination plant	**9,846**
1) Equipment	5,740
a) Pre-treatment equipment	(2,406)
b) RO equipment	(2,229)
c) Electrical & instrumental equipment	(1,105)
2) Material	1,306
3) Construction work	2,800
a) Mechanical work	(200)
b) Electrical & instrumental work	(67)
c) Civil work	(2,533)
(3) Brine discharge line	**33**
(4) Electricity power supply	**613**
(5) Water supply system	**6,266**
1) Equipment	533
a) Pumps	(333)
b) Electrical equipment	(200)
2) Material	3,333
3) Construction work	2,400
a) Mechanical work	(300)
b) Piping work	(1,833)
c) Civil work	(267)
Total for construction (A)	**18,425**
Design and supervision (B)	**1,256**
Total (A+B)	***19,681***

(2) Operation & maintenance cost

Table II-6.2.10 shows the costs for operation and maintenance which include those for the RO desalination plant and for water distribution system.

Table II-6.2.10 Operation & Maintenance Cost

Item	Price	Unit	Quantity
I. Desalination Plant			
1. Electricity	0.03 JD/Kwh	Kw	1,031
		Kwh/day	24,744
		1,000 JD/year	245
2. RO membrane replacement (20%/year)	667 JD/element	Elements/year	180
		1,000 JD/year	120
3. Chemicals and consumable			
1) H_2SO_4	0.087 JD/kg	kg/day	10590
		1,000 JD/year	310
2) NaClO (10%)	0.14 JD/kg	kg/day	735
		1,000 JD/year	34
3) $FeCl_3$ (40%)	0.35 JD/kg	kg/day	426
		1,000 JD/year	49
4) Inhibitor	0.7 JD/kg	kg/day	53
		1,000 JD/year	12
5) SBS	0.51 JD/kg	kg/day	35
		1,000 JD/year	6
6) NaOH	0.23 JD/kg	kg/day	418
		1,000 JD/year	31
7) Citric acid	0.77 JD/kg	kg/day	4
		1,000 JD/year	2
8) Safety filter	13.3 JD/unit	unit/day	2.2
		1,000 JD/year	7.5
Subtotal		1,000 JD/year	451.5
4. Labor	10 JD/man/day (30 JD/man/day)	Man	20 (+1)
		JD/day	230
		1,000 JD/year	76
5. Maintenance		1,000 JD/year	72
Total for desalination		1,000 JD/year	**972**
II. Water Supply System			
1. Electricity	0.03 JD/Kwh	Kw	406
		Kwh/day	9,750
		1,000 JD/year	99
2. Maintenance		1,000 JD/year	16
Total for water supply		1,000 JD/year	**115**
Total		1,000 JD/year	***1,087***

Note: 330 operation days per year under a load factor of 0.9.

6.2.5 Time Schedule for Project Construction

The estimated time schedule for the construction of the priority project is shown in Fig. II-6.2.11. A period of 21 months is scheduled from the beginning of basic design to the completion of the project.

6.2.6 Project Management and Technical Training

(1) Project management

Project management includes construction phase and operation phase.

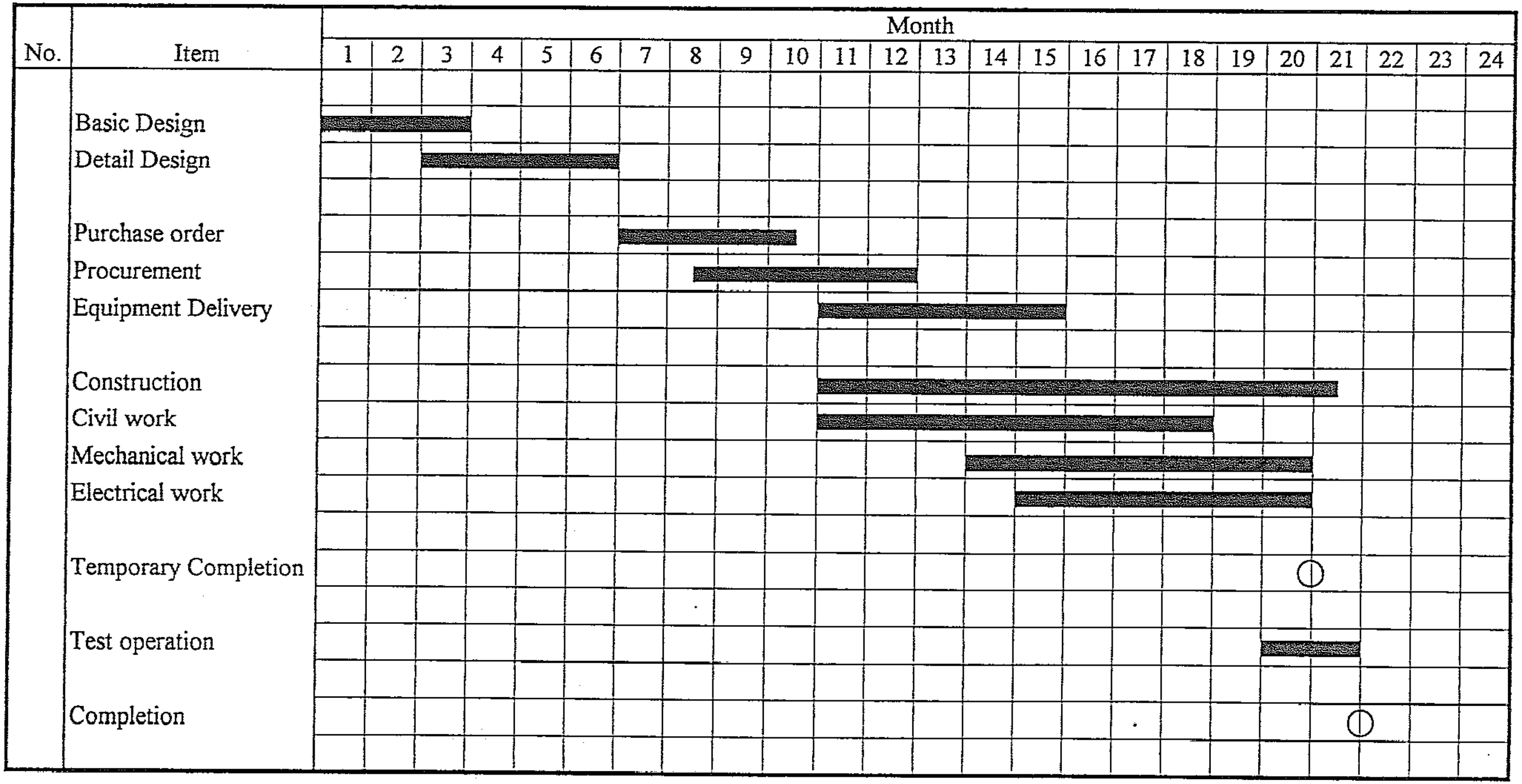
In the construction phase, consultants are to be employed to prepare the design and to supervise construction. However, because the project will be handed over to WAJ immediately after its completion, WAJ shall be prepared to administer and manage the activities while undertaking the operation and maintenance responsibilities. It is recommended that WAJ shall take part in some activities during the construction work and combine these activities with personnel training.

In order to efficiently manage the envisaged work load in the operation and maintenance phase, it shall be necessary for WAJ to upgrade its institutional structure and to increase human and technical resources.

(2) Technical training

Because RO desalination for water supply is a new practice in Jordan, personnel training shall need to be carried out through an ongoing program along with project implementation. It is recommended that all the personnel shall go through special training courses before being assigned to the posts for project management and operation. Jordanian and/or foreign experts shall be invited as the trainers for these courses, or trainees shall be sent to the existing RO plants in neighboring countries to acquire technical know-how through practical work.

Fig. II-6.2.11 Time Schedule for RO Plant Construction (6 MCM/Year)



7. Implementation Plan

7.1 Development Strategy

(1) Pre-requisite Discussion for the Formulation of Development Strategy

(i) Peace Treaty Water is a top priority to be attained.

(ii) Water demand in the study area will never be fulfilled.

The existing water resource developments will not suffice the water shortage of the study area. The shortage even after the full yield of Disi/Mudawarra groundwater and full extraction of Peace Treaty Water will be 50 MCM and will increase as time to pass. Therefore, water projects in an area should be implemented at a least cost principle, once finance is attained.

(iii) Brackish groundwater desalination is a new water resource in Jordan.

Brackish groundwater desalination has not been practiced in Jordan before. The amount of brackish groundwater will raise the development potential of the Northern Jordan Valley. Pilot plant project (priority project) will open the possibility of full exploitation of this new resource. Jordanian must be trained in the operation and management of the project, and master the techniques during the course of the project.

(iv) Disi/ Mudawarra project is also a good source of water supply.

Disi/ Mudawarra project is competing with brackish groundwater project in terms of production cost and water yield. Its development plan could be formulated within the same framework because both developments aim at conveying water to the Northern part of Jordan.

(2) Formulation of Development Strategy

With those discussion above, development strategy of brackish groundwater is formulated, although a modification may still be necessary. (See Table II-5.5.6.)

(i) Priority project of desalination at Kafrain (5 MCM) is developed first.

This project will supply water to the most needy region in the soonest manner. The size of capital investment is relatively small. The implementation of this project opens the possibility of full scale extraction of brackish groundwater.

(ii) Disi/ Mudawarra project (75 MCM) follows second.

Although this project requires nearly ten-times larger capital investment than the pilot project of desalination, its water production cost is smaller than that of desalination, and relatively close to the current production cost of WAJ. An introduction of huge amount of this water will decrease the average production cost. Experience of pipeline project of substantial distance will help in the full scale extraction of brackish groundwater in Kafrain.

(iii) Full scale development of desalination in Kafrain (31 MCM) will be developed next to the Disi/Mudawarra project. Its implementation will depend upon the financial availability of the Government. It may start at a parallel with Disi/Mudawarra, or after a substantial time period.

(iv) Full extraction of brackish groundwater for desalination (24 MCM) in Deir Alla should follow the construction of common brine discharge line. Since construction of the common brine discharge line requires a larger capital investment (JD 144 million) than the desalination plant, the implementation of this project in Deir Alla is most difficult.

7.2 Financial Plan

According to the development scheme in the formulated strategy, capital requirement and O&M cost in each year are calculated.

- During the course of development, a required capital for investment will range from JD 10.8 million to JD 81.8 million each year. Most required period in capital will be during the Disi/Mudawarra groundwater project and the construction of common waste water line.
- O&M cost will gradually increase as the construction of projects completes. Water production cost will stay between 0.40 JD/m3 to 0.52 JD/m^3 during the development period.
- In order to make the loan scheme possible, the discussion of grant element for the project or a measure of revenue increase should be developed.

8. Recommendation

8.1 Recommendation for Implementation of the Priority Project

8.1.1 Technical Preparation for RO Desalination Plant Management

Because the technology of RO desalination has not been applied for drinking water supply in Jordan, the implementation of the priority project will be significant not only in improving water supply condition in the Jordan Valley area, but also in upgrading WAJ's technical level, as well as spreading the RO technology in Jordan. On the other hand, the management of a RO desalination plant needs knowledge and skills other than those for a conventional water treatment plant. In these respects, technical preparation shall have to be started before project implementation. Such preparation will include the follows.

(1) Education on RO desalination technology

Education courses shall be programmed for WAJ staff at various levels - managers, engineers, technicians and so on, on the basic knowledge and specific technologies of RO desalination. The objectives are (i) to attract attention publicly in WAJ to the implementation of the RO plant, (ii) to enable managers, engineers and technicians to acquire the fundamental knowledge of RO technology and to be prepared to undertake the new work when some of them are assigned posts for managing and operating the RO plant.

(2) Study on brackish groundwater quality

As has been discussed in the former chapters, the performance of RO membranes is greatly affected by raw water quality, and some of the water quality items shall have to be further investigated after this Study. WAJ has a well equipped central laboratory and is able to conduct studies on water quality problems. It is recommended that a study group shall be organized by WAJ to carry out studies on the brackish groundwater quality. The study shall be related to the long term water quality monitoring which will be mentioned in sections 8.1.2 and 8.2.1.

8.1.2 Water Quantity and Quality Monitoring

(1) Well flow monitoring and control

It is estimated that with an amount of 6 MCM/year brackish groundwater development, the production wells will be under artesian conditions. Therefore, well pumps are not required for this project. However, as in any water treatment plant, a careful control of intake quantity of raw water is indispensable and in order to keep constant flow from each of the production wells, well pressure monitoring is also required.

(2) Continuous monitoring of water quality

From the results of hydrogeological and geochemical analyses and groundwater simulation, it is concluded that the salinity and the ionic composition of the raw water will not vary greatly. However, comparing with salinity, the concentrations of some other substances may be more hazardous to RO membranes, and there are many examples of modifications of pre-treatment process for RO desalination plants because of variations in raw water quality parameters other than salinity. Therefore, continuous monitoring of water quality is still recommended not only for water salinity but also for the water quality parameters listed in Table I-6.2.1 (Section 6.2.2).

8.2 Other Recommendations

8.2.1 Long Term Hydrogeological Observation

In this Study, future conditions of the Zerqa Group Aquifers were predicted by computer simulation based on the results of hydrogeological study and pumping and observation of the test wells drilled during this Study. The predicted results need to be verified through a long term hydrogeological observation in order to supply more reliable information for the stepwise implementation of the brackish groundwater development projects.

For this purpose, a plan is recommended to utilize the 6 test wells (Fig. II-8.2.1) for observations of groundwater table (or pressure) and quality before and during brackish groundwater development. by comparing the observation results with the simulation results, more understandings can be gained on the Zerqa Group Aquifers, and future development plans can be further confirmed or modified if necessary. The proposed observation methods are as follows.

(1) Observation before brackish groundwater development

The objectives of observation are to monitor (i) the natural variations in water tables of Zerqa Aquifers in the Study area and (ii) the variations in brackish groundwater quality. The contents of observations include:

a) Static water table or pressure at the site of each well

The water table of No.1 well shall be read from the attached water level recorder, and the water pressure of the other wells (artesian wells) shall be read from the attached pressure gauges

b) Water sampling and water quality tests

Water shall be sampled from well No.1 using a borehole sampler, and from the other wells by opening the well valves. Electric conductivity (EC) and temperature shall be tested for the samples.

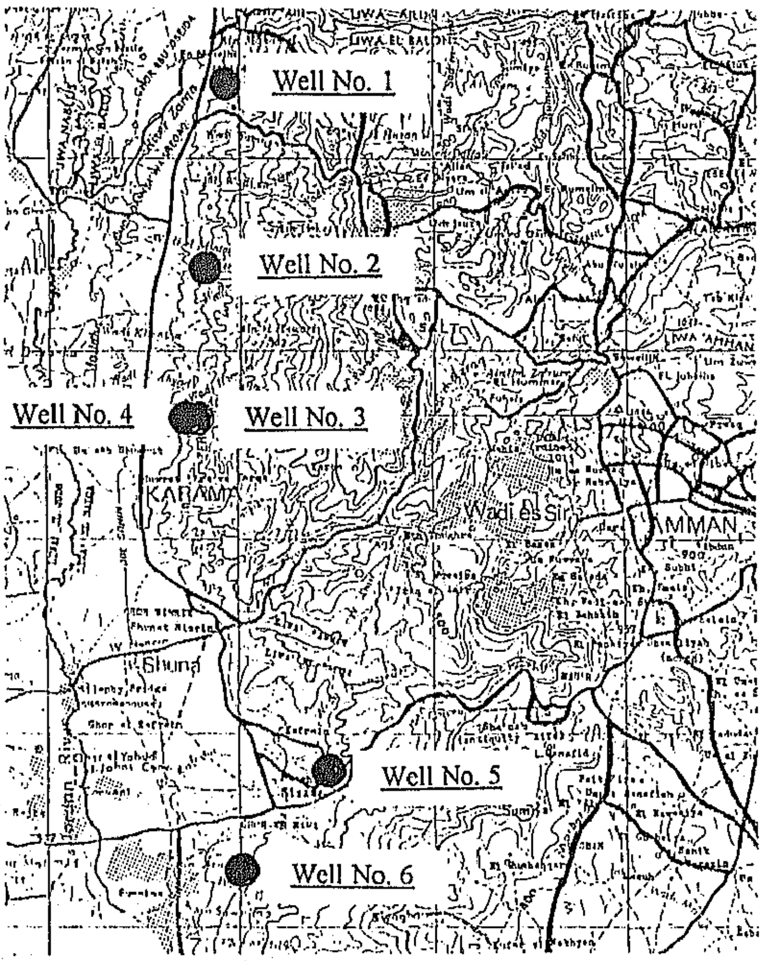


Fig. II-8.2.1 Wells to be Used for Groundwater Observation

In general, the above mentioned observations shall be carried out seasonally. Under a condition that considerable variation is observed, more frequent observation, such as monthly or even weekly, shall be required.

(2) Observation during brackish groundwater development

The objectives of the observation are (i) to monitor variations in water table (or pressure) and water quality (at the observation well sites) caused by brackish groundwater abstraction (at the development site), and (ii) to evaluate the influence of brackish groundwater development on the Zerqa Aquifers in the whole Study area and verify the suitability of the development plan.

The contents of observation shall be basically the same as those mentioned in (1). At the beginning, a large draw-down of groundwater table may occur and observations shall be carried out frequently, especially for the observation wells in the same area as the development site. Later, variations may become smaller and smaller and observation times shall be reduced.

8.2.2 Common Brine Discharge Line

Brackish groundwater and saline springs are the most important unused water resources in the Jordan Valley region and comprehensive development is a keen subject stipulated in Annex II of the Peace Treaty between Jordan and Israel. The potential of these water resources is considered to be very high, not only in the Deir Alla - Kafrain / Hisban area of which the specific potential and development strategy has been clarified in this Study but also near Lake Taberias and in the East and West banks of Jordan River Valley.

However, in the development of brackish groundwater and saline springs by desalination technology, especially in inland area, disposal of concentrated brine will become a critical issue for the protection of water quality and environment.

Therefore, a comprehensive development of these saline water resources in this region needs the construction of a common disposal system for the discharge of concentrated brine from desalination plants, and for the drainage of irrigation return water and other saline groundwater.

In this context, we recommend a study to be conducted on the common brine discharge facility through the Jordan River Valley.

8.2.3 Modification of the Study

During the JICA Study, the Peace Treaty between Jordan and Israel was concluded and the situation surrounding the study was drastically changed. The Study Team incorporated the changes as far as possible but could not keep pace completely with the ever changing conditions.

Therefore a certain modification shall be required on the following points under the cooperation of Japan and Jordan.

- Water source allocation and implementation plan
- Water supply to the cities in West Bank
- Water demand by new development plans

8.2.4 Further Study on Brackish Groundwater Resources

There are some indications and information about the high potential of brackish groundwater not only in the JICA Study area, but also in various parts of Jordan.

This study has also indicated that the brackish groundwater in the Study area is not the most ideal water resource for water supply by desalination from a view point of water quality and the pre-treatment processes required. Therefore, further study is recommended on the potential and quality of brackish groundwater covering the whole country.