3. Alternative Development Plans

(1) Quality of brackish groundwater and desalination system

The quality of the brackish groundwater in the study area is shown in Table II-3.1. The salinity of the water in the South area is about 5,000 mg/L, and that in the North area is about 7,500 mg/L as TDS. Three methods which are commonly applied in sea water and brackish water - evaporation (MSF), electrodialysis (ED) and reverse osmosis (RO) - were reviewed, and RO was selected as the most suitable process for this project because of its better separation performance, lower energy consumption, lower construction and operation costs in accordance with the brackish groundwater quality. The general characteristics of these desalination methods are as follows.

Evaporation (MSF) is a method to remove salts by water distillation and condensation. By this method very high quality water can be obtained, but energy consumption is usually high and large quantity of cooling water is needed.

Electrodialysis (ED) is a method to separate salt ions by pairs of ion-permeable membranes under direct current. It is a method suitable for the desalination of brackish waters with a TDS lower than 2,000 mg/L.

Reverse Osmosis (RO) is a method to acquire dilute solution from a concentrated solution by utilizing semi-permeable membranes under a higher pressure than the osmotic pressure of the concentrated solution. With a remarkable development in membrane technology, RO is widely used in both sea water and brackish water desalination at lower cost. It is most suitable for desalination in the inland area.

Table II-3.1 Brackish Groundwater Quality

Items	Unit	North area	South area
pH	-	6.2 - 6.5	6.1 - 6.4
TDS	mg/L	about 7,500	about 5,000
SDI	-	5 - 6	4 - 5
Ca	mg/L	700 - 900	400 - 500
Mg	mg/L	100 - 150	100 - 150
Na	mg/L	1,100 - 1,300	1,000 - 1,200
Cl	mg/L	1,700 - 2,000	1,500 - 1,700
SO_4	mg/L	1,600 - 1,800	400 - 600
HCO_3	mg/L	1,000 - 1,200	1,000 - 1,200
Fe	mg/L	8 - 12	< 1
SiO_2	mg/L	15 - 25	5 - 15

According to the Jordanian Drinking Water Quality Standard, the permissible TDS is 500 mg/L. However, in the Jordan Valley region, TDS of the supplied drinking water is much higher than the standard value in many areas, because the abstraction of groundwater is almost at a marginal quantity which causes a deterioration in water quality. In order to improve the present condition and supply high quality drinking water to these area, the target quality of treated water was set at TDS 300 mg/L. This needs a salt rejection higher than 94 - 96% which is common for RO operation.

(2) Alternative Plans

Based on the previous hydrogeological analysis, water demand analysis, study on the existing water supply system and other studies, five (5) alternative development plans have been formulated for the development of brackish groundwater in the Study area (Table II-3.2, Fig. II-3.1) For the selection of alternatives, the following common components were considered and examined respectively for each development plan.

1) Supply areas and Quantity

- Supply to Amman (easing shortage in the five Northern governorates)	Full scale development
- Supply to Jordan Valley for the demand in 1998	5 MCM/year
- Supply to Jordan Valley for the demand in 2010	16 MCM/year

2) Development area and Quantity

- In Deir Alla for the production of 5MCM/year	6MCM/year
- In Deir Alla for the full scale development	30MCM/year
- In Kafrain for the production of 5MCM/year	6MCM/year
- In Kafrain for the full scale development	45MCM/year

3) Desalination process and quality of treated water

- Desalination process	Reverse osmosis
- Treated water quality	TDS less than 300 mg/L

4) Product water transfer/distribution

- Utilization of the existing Deir Alla - Zai transfer line
- Construction of a North - South trunk pipe line
- Construction of a Kafrain - National Park Pump Station high lift transfer line

5) Disposal of concentrated brine

- Discharge to the Dead Sea by a common brine discharge line which receives the concentrated brine from desalination plant, water from saline springs and irrigation return flows in the whole Jordan River Valley
- Discharge to the Dead Sea by an independent discharge line
- Discharge directly to the Dead Sea through the near-by wadi (in Kafrein/Hisban area)
- Evaporation pond

In any of the alternative plans, the concentrated brine shall not be discharged to the Jordan River or its tributaries in accordance with the related articles in the Peace Treaty between Jordan and Israel.

5) Electricity supply

- Supply from the existing 33KV line in the Jordan Valley
- Supply form the existing 132KV line in upland
- Construction of a power station with the desalination plant

Table II-3.2 Alternative Plans

Component \ Plan	Plan A	Plan B	Plan C	Plan D	Plan E
Development Area of Brackish Groundwater	Deir Alla	Deir Alla	Kafrein	Kafrein	Deir Alla/Kafrein
Development Volume	30 MCM/year	6 MCM/year	45 MCM/year	6 MCM/year	75 MCM/year
Quality of Brackish Groundwater	TDS 7,500 mg/L	TDS 7,500 mg/L	TDS 5,000 mg/L	TDS 5,000 mg/L	TDS 7,500/5,000 mg/L
Desalination Process	Reverse Osmosis (RO)	Reverse Osmosis (RO)	Reverse Osmosis (RO)	Reverse Osmosis (RO)	Reverse Osmosis (RO)
Product Water Supply Area	Amman Jordan Valley	Amman Jordan Valley	Amman Jordan Valley East bank of Dead Sea	Jordan Valley East bank of Dead Sea	Amman Jordan Valley East bank of Dead Sea
Supply Volume	24 MCM/year	5 MCM/year	36 MCM/year	5 MCM/year	60 MCM/year
Product Water Quality	TDS 300 mg/L	TDS 300 mg/L	TDS 300 mg/L	TDS 300 mg/L	TDS 300 mg/L
Water Distribution / Conveyance	Existing Network New North-South Line Existing Zai Transfer Line	Existing Network New North-South Line Existing Zai Transfer Line	New Transfer Line to Amman	Existing Network New North-South Line	New Transfer Line to Amman Existing Network New North-South Line Existing Zai Transfer
Electricity Supply by Power Generation	no	no	12,000 KW	no	12,000 KW
Connection to the Transmission Line	132 KV	33 KV	33 KV	33 KV	132 / 33 KV
Brine Disposal	Common Discharge Facility to Dead Sea	Common Discharge Facility to Dead Sea	Discharge Facility to Dead Sea	Wadi Ijarfa	Common Discharge Facility to Dead Sea
	Independent Discharge Facility to Dead Sea	Evaporation Pond			

Notes: 1) As an alternative plan to B and D, surface water purification from K.A.C. shall be examined.
2) As an alternative plan to E, Disi water conveyance scheme shall be examined.

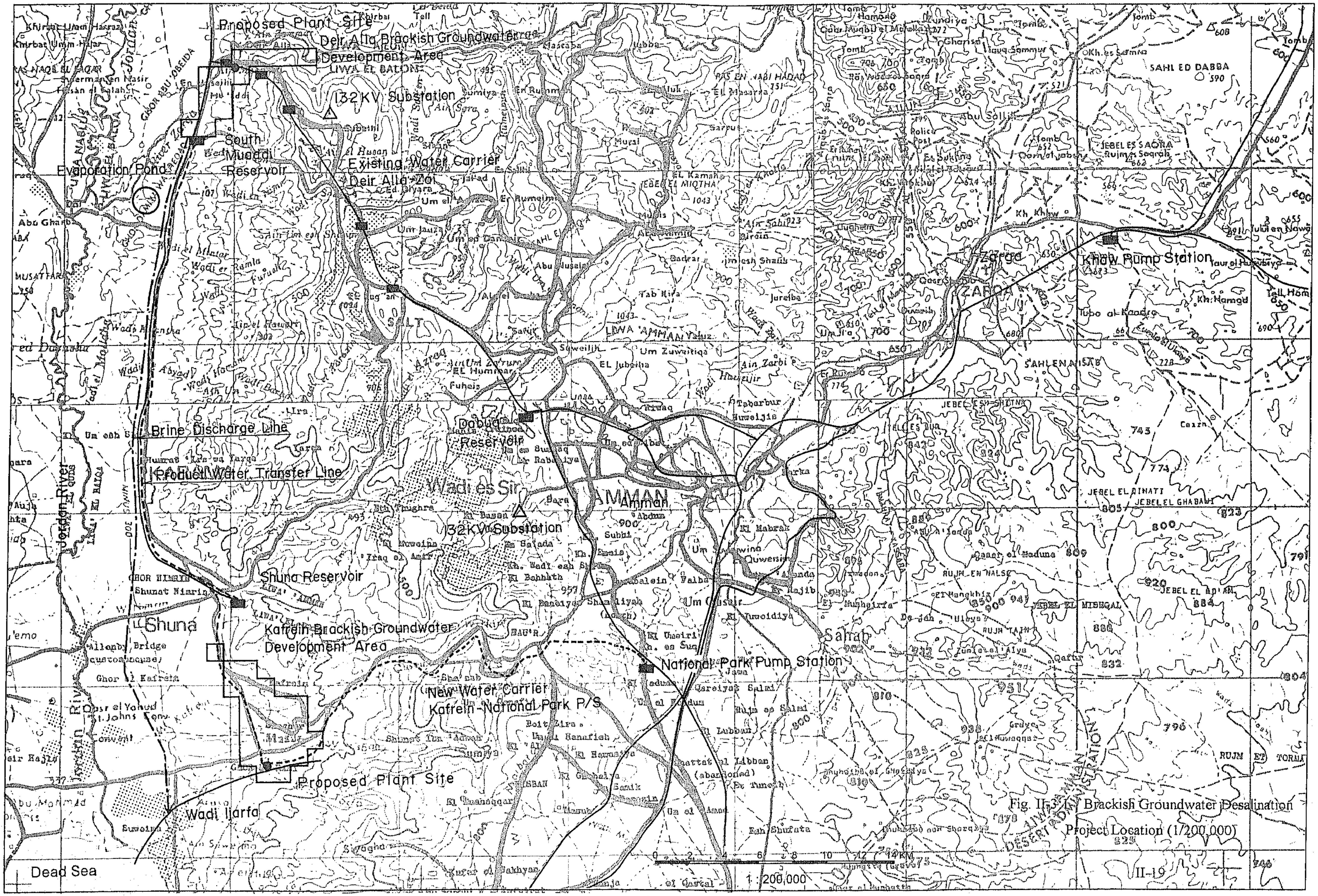


Fig. II-3.1 Brackish Groundwater Desalination Project Location (1/200,000)

(3) Initial Environmental Examination

According to JICA's policy on environmental examination for international cooperation projects, initial environmental examination (IEE) should follow the environmental guidelines of the host country as far as possible, and if there are no guidelines available in that country or the guidelines are insufficient, JICA Environmental Consideration Guidelines should be adopted. Considering the present conditions in Jordan, IEE for this project mainly followed JICA guidelines, and meanwhile, the particular environmental issues in the Study Area were considered.

An environmental examination matrix was applied for a brief screen of the impact of this project on the environment (Fig. II-3.2). 23 environmental elements which cover social environment, natural environment and hazards were examined and project activities to be involved in each of the alternative plans in both construction and operation phases were taken into considerations.

Consequently, the following environmental elements were selected and the impacts of project activities were examined in detail.

- Impacts on economic activities
- Impacts on traffic and public facilities
- Impacts on archaeological treasures
- Solid wastes, noise and vibration
- Impacts on groundwater aquifers
- Water or soil pollution by brine discharge

The results of examinations on the above mentioned items show that although some impacts of the project on the environment are envisaged, these impacts can be reduced to the minimum as certain countermeasures are taken.

Table II-3.2 Environmental Examination Matrix

Project Activities \ Environmental Elements			Hazards						Natural Environment								Social Environment								
			Offensive odor	Ground subsidence	Noise and vibration	Soil pollution	Water pollution	Air pollution	Landscape	Weather	Flora and Fauna	Coastal and sea area	Lake and rivers	Groundwater	Soil erosion	Topography/Geography	Risk of disaster	Solid waste	Public health	Water right	Archaeological treasures	Traffic/public facilities	Economic activities	Area separation	Resettlement
Desalination plants	North plant	Construction phase			O													O			O	O	O		
		Operation phase												O											
	South plant	Construction phase			O													O			O	O	O		
		Operation phase												O											
Brine disposal	North plant – Evaporation pond	Construction phase			O													O			O	O	O		
		Operation phase				O	O											O							
	North plant – Transfer line	Construction phase			O																O	O	O		
		Operation phase																							
	South plant	Wadi Ijarfa				O	O						O												
		Transfer																							
Common brine discharge line		Construction phase			O													O			O	O	O		
		Operation phase																							
Transfer pipeline between North and South plants		Construction phase			O													O			O	O	O		
		Operation phase																							
Transfer pipeline to National Park Pump Station		Construction phase			O													O			O	O	O		
		Operation phase																							

Shaded area: No impact is anticipated; Circle: Impact cannot be ignored and further examination is needed.

4. Project Evaluation

(1) Project Cost and Operation/Maintenance Cost

1) Project cost

The construction costs of the 5 alternative projects are shown in Table II-4.1. The principles of cost estimation are as follows:

(i) For production wells practical cost for test wells drilling in this Study was referred.

(ii) For RO equipment, international standard prices and the practical price level of existing projects were referred.

(iii) For materials, the practical purchasing prices in Jordan was referred

(iv) For construction work, the cost was at the local level based on the information provided by WAJ.

(v) For pipe line construction, the practical cost of some existing projects in Jordan were referred.

2) Operation and maintenance cost

The costs for the operation and Maintenance of the project are shown in Table II-4.2. Calculations of these costs are based on the following principles.

(i) The current electricity price of 0.03 JD/Kwh for WAJ's water supply was used.

(ii) The price of RO membrane modules was set on the international base and an annual replacement of 20% membrane modules was considered.

(iii) Consumption of chemicals was estimated according to the consultant's experience and the raw water quality, and both local purchasing prices and international standard prices were referred in setting the unit prices of chemicals.

(iv) Present salary of labors in Jordan was referred.

(v) Annual maintenance cost was estimated according the equipment level and the consultant's experience.

Table II-4.1 Construction Cost of Alternative Projects ('000 JD)

	Plan-A		Plan-B		Plan-C		Plan-D		Plan-E	
	Foreign	Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign	Local
I. Production Wells	**8,408**	**685**	**1,426**	**241**	**12,433**	**1,307**	**1,372**	**295**	**20,841**	**1,992**
a. Well Construction	1,716	484	832	235	2600	733	832	235	4,316	1,217
b. Well Pump	4224	176			6467	200			10,691	376
c. Collection Pipes	2468	25	594	6	3366	374	540	60	5,834	399
II. RO Desalination Plant	**24,003**	**13,133**	**6,107**	**2,953**	**32,787**	**17,366**	**6,511**	**3,206**	**56,790**	**30,499**
(1) Equipment	21,542	467	5,518	107	29,636	633	5,524	107	51,178	1,100
a. Machinery	17,775	467	4,451	107	24,569	633	4,457	107	42,344	1,100
b. Electrical & Instrumental	3,767		1,067		5,067		1,067		8,834	
(2) Material	1,306	1,266	332	313	1,611	1,533	730	566	2,917	2,799
a. Machinery	773	933	199	233	944	1,133	197	233	1,717	2,066
b. Electrical & Instrumental	533	333	133	80	667	400	533	333	1,200	733
(3) Construction Work	1,155	11,400	257	2,533	1,540	15,200	257	2,533	2,695	26,600
a. Mechanical	855		190		1,140		190		1,995	
b. Electrical & Instrumental	300		67		400		67		700	
c. Civil		11,400		2,533		15,200		2,533		26,600
III. Brine Discharge Line Construction	**12,000**		**1,153**		**2,167**		**33**		**14,167**	
IV. Electricity Power Supply	**3,653**		**860**		**8,207**		**613**		**11,860**	
V. Water Supply System	**10,618**	**2,349**	**4,933**	**1,333**	**27,860**	**9,189**	**4,666**	**1,600**	**38,478**	**11,538**
(1) Equipment	3,374		533		2,880		533		6,254	
a. Pump	1,587		333		1,587		333		3,174	
b. Electrical	1,787		200		1,293		200		3,080	
(2) Material	3,524	2,349	2,000	1,333	11,540	7,696	2,000	1,333	15,064	10,045
(3) Construction Work	3,720		2,400		13,440	1,493	2,133	267	17,160	1,493
a. Mechanical			300				300			
b. Piping	3,720		1,833				1,833		3,720	
c. Civil			267		13,440	1,493		267	13,440	1,493
VI. Design & Supervise	**5,055**		**1,288**		**7,316**		**1,256**		**12,371**	
Subtotal	*63,737*	*16,167*	*15,767*	*4,527*	*90,770*	*27,862*	*14,451*	*5,101*	*154,507*	*44,029*
	79,904		*20,294*		*118,632*		*19,552*		*198,536*	
Contingency* (10%)	7,990		2,029		11,863		1,955		19,854	
Total	*87,894*		*22,323*		*130,495*		*21,507*		*218,390*	

* Including physical contingency, price contingency and interest for working capital in the first year of construction.

Table II-4.2 Operation and Maintenance Cost of Alternative Projects

('000 JD)

Item	Plan-A	Plan-B	Plan-C	Plan-D	Plan-E
I. Desalination Plant	**5,610**	**1,096**	**7,897**	**972**	**13,507**
(1) Electricity	2,061	318	2,947	252	5,008
(2) RO membrane replacement	584	120	875	120	1,459
(3) Chemicals and consumable	2,556	509.5	3,477	451.5	6,033
a. H_2SO_4	1,603	310	2,392	310	3,995
b. NaClO	704	141	262	34	966
c. $FeCl_3$	0	0	383	49	383
d. Inhibitor	63	12	95	12	158
e. SBS ($NaHSO_3$)	31	6	46	6	77
f. NaOH	108	31	229	31	337
g. Citric acid	9.5	2	15	2	25
h. Safety filter	37.5	7.5	55	7.5	93
(4) Labor	86	76	112	76	198
(5) Maintenance	323	72	485.5	72	809
II. Water supply system	**1,323**	**115**	**4,568**	**115**	**5,891**
(1) Electricity	1,236	99.3	4,198	99.3	5,434
(2) Labor	0	0	0	0	0
(3) Maintenance	86.7	16	370	16	457
Total	***6,933***	***1,211***	***12,465***	***1,087***	***19,397***

(2) Water Cost

The study area is in short of water supply. This shortage will never be fulfilled by the all capacity of water supply in the region. This implies that projects of water development should be implemented as far as the finance is allowed. The priority of project will be determined at a least cost principle. Water production cost of desalination plan is calculated. The results are compared with that of Disi/Mudawarra project. (See Table II-4.3)

(i) Water production cost of desalination project ranges between 0.551 JD/m^3 to 0.600 JD/m^3. This is lower than the current production cost of WAJ water. Desalination projects may require the government contribution or grant for implementation. The government contribution or grant will ease a burden of capital cost and subsequently reduce the water production cost.

(ii) Among the development plans, Plan D is of lowest water production cost: 0.522 JD/m^3. This is because of several advantages that include direct discharge of the brine to the Dead Sea through Wadi Ijarfa and smaller scale construction of water transfer trunk line in the Jordan Valley than that to Amman.

(iii) However, the water production cost of Plan D stays higher than that of Disi/Mudawarra project.

(iv) For RO desalination, the electricity cost shares a large portion of the O & M cost. In this study, the unit water production cost has been calculated on the basis of a very low price of

Table II-4.3 Comparison of Water Production Cost

Items	A	B	C	D	E	Disi
Water Production (MCM)	24	5	36	5	60	50
Capital Cost (MJD)*	87.89	22.32	130.49	21.51	218.39	245.51
Adjusted Capital Cost (MJD)**	109.40	26.86	159.06	26.56	268.46	n.a.
O&M Cost (MJD)	6.93	1.21	12.47	1.09	19.40	5.59
Water Cost (JD/m3)						
Capital Cost***	0.262	0.308	0.254	0.305	0.257	0.282
O&M Cost	0.289	0.242	0.346	0.217	0.323	0.112
Total	0.551	0.551	0.600	0.522	0.580	0.394

Note 1: Capital cost does not include the capital cost for electricity power supply because electricity price each year is assumed to have already taken into account the depreciation of necessary equipment.

Note 2: Capital cost is adjusted by capital replacement cost during the project period.

Note 3: Calculation of water cost assumes a 3%-interest loan of which repayment period is 25 years.

The loan condition (low interest) in this analysis is in favor of the project of heavy initial investment such as Disi project.

If the government contribution or grant is introduced, capital cost will be substantially reduced.

30 fils/Kwh which is a special price provided by Jordan Electric Authority (JEA) for water pumping and is just a little lower than the economic cost of power generation in Jordan because of free oil import from Iraq. However, if an international price of oil is considered, the electricity cost will be higher. Under an assumption of an adjusted electricity cost of 50 fils/Kwh, the unit water production cost is calculated as 0.73 JD/m^3 for Plan-C and 0.57 JD/m^3 for Plan-D which are higher than the data shown in Table II-4.3.

(3) Economic and Financial Analysis

1) Financial internal rate of return

Financial internal rate of return (FIRR) is calculated. It is an approximate calculation that does not take into account the interest payment of loan scheme. None of plans becomes financially attractive under the current assumptions. This is because of large negative outlays in net benefit. An increase of sales revenues (+50 %) or subsidy (+100 %) will bring the positive FIRR, but their margins are still small. (See Table II-4.4)

The results imply that the desalination projects could require the substantial amount of government contribution or grant under the current price or sales revenue system. If we assume the level of subsidy that brings positive FIRR, the required amount of government subsidy will be JD 1.86 million to JD 22.32 million that is equivalent to 5 % to 59 % of currently subsidy received in WAJ.

2) Balance sheet analysis of priority project (Plan D)

(i) Total income never exceeds total expenditure throughout the project period. (See Figure II-4.1.)

Although the current level of government subsidy is assumed, total income does not cover the whole expenditure. Depreciation cost share the substantial part of total expenditure.

(ii) Total liability stays at a high level throughout the project period. An additional loan will be required at the year of replacement.

(iii) Operating cash stays at a low level, and will be substantially low when the replacement of plant equipment is needed. The cash level and liability level will never balance.

(iv) By any means, the priority project of brackish groundwater desalination needs a large volume of financial contribution or grant from the government. Otherwise, the project will not be feasible.

3) Contribution element

Contribution element such as a intra-government contribution or inter-government grant to the project is assumed, and the change of financial position of priority project is probed. (See Figure II-4.2.) The financial position has substantially improved as in a following manner:

(i) Government subsidy is reduced to half of the current subsidy level.

(ii) Although the net income says negative throughout the project period, the cash level will increase every year. The cash level and liability level will eventually balance in the 8th year.

(iii) A sum of total liability and own fund stays at a low level, and diminishes to zero in the 22nd year.

(iii) Cash will be accumulated so that the replacement cost is covered by its own cash.

(iv) As a result, the project will be sustained throughout the project period.

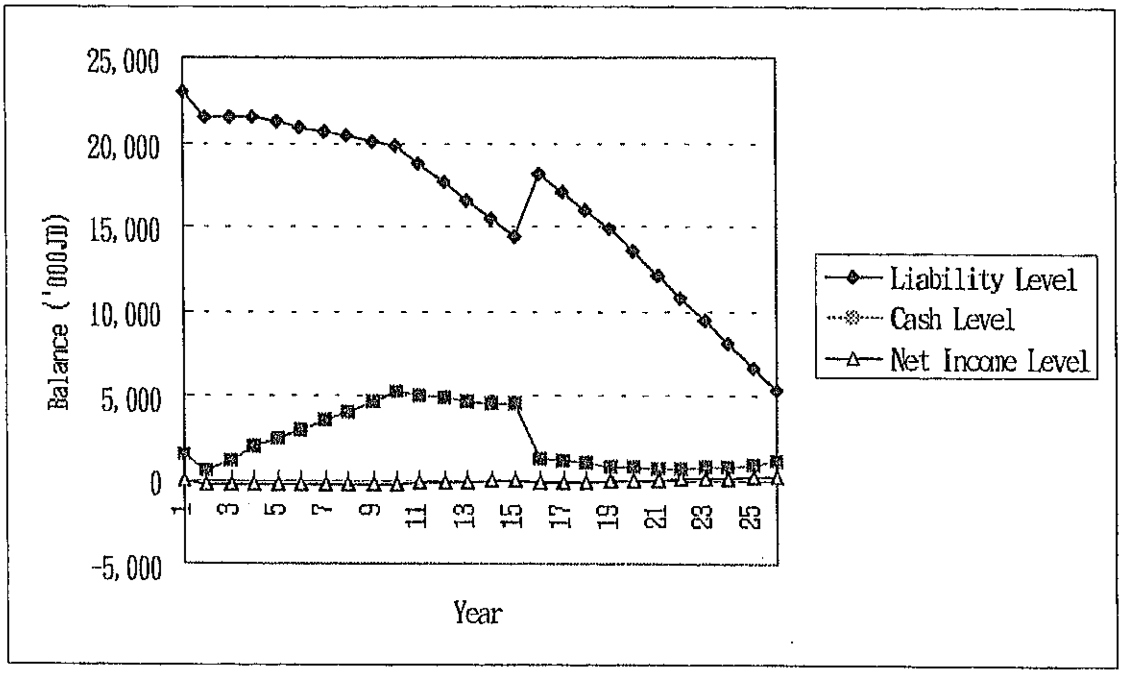


Fig. II-4.1 Financial Position of Priority Project (Plan D)

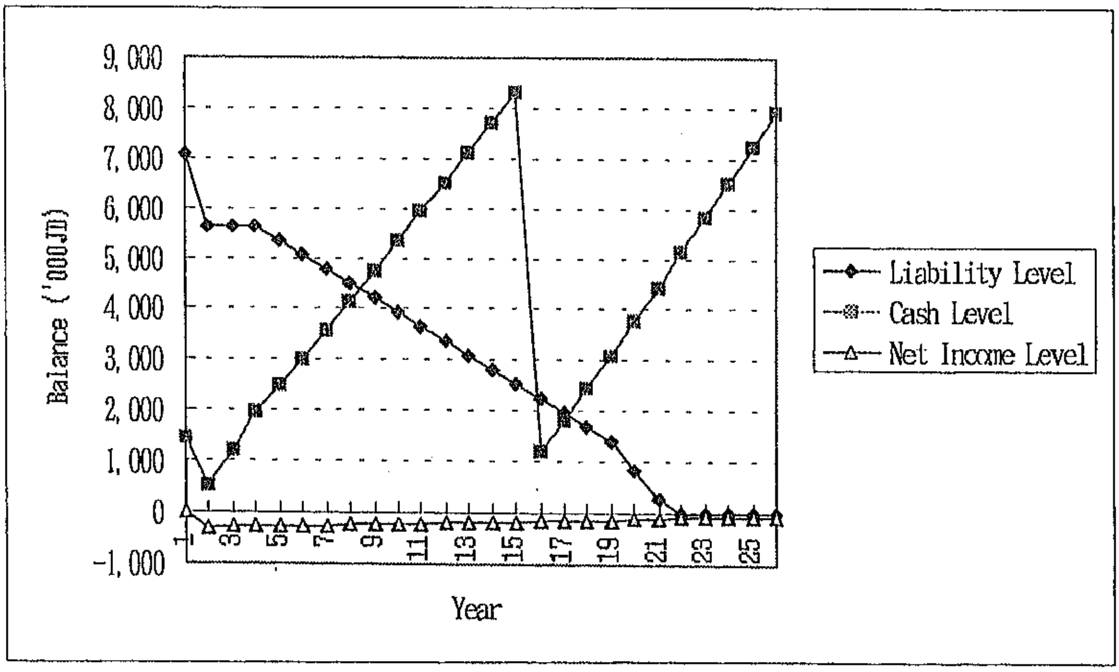


Fig. II-4.2 Financial Position of Priority Project with Grant Element and Reduced Government Subsidy (-50%)

5. Priority Project

(1) Selection of the First Priority Project

The first priority project is the 6 MCM/year brackish groundwater development in the Hisban/Kafrein area to provide 5 MCM/year product water to Jordan Valley area. The project includes the construction of a desalination plant and a water transfer pipeline from Kafrein to Deir Alla. Selection of the priority project is based on the results of the project evaluation regarding the five alternative development plans. The followings are a summary of the evaluation.

(i) 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 resource which has not been utilized is significant to the water sector.

(ii) 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 through the 6 MCM/year brackish groundwater development for the year of 1998 - 2000.

(iii) 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 water 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 to pump the product water up to more than 1,200 meter to Amman area. Government subsidy will be 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.

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

(v) The quality of concentrated brine from the desalination process is allowable to be discharged to the Dead Sea. For the priority project, 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) as shown in Supporting Report Chapter 15.

(2) Preliminary Design of the Project

The location of the priority project is shown in Fig. II-5.1. 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.

1) Design condition

- Raw water quantity: 18,000 m^3/day
- Raw water quality: TDS 5,000 mg/L
- 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 85%)
- Supply water quality: in accordance with Jordanian Standard for Drinking Water Quality

2) Facilities design

(i) Production wells (see Figs. II-5.2 for well location and profile)

- Number of wells: 6
- Well depth: 350 m
- Production capacity: 125 m^3/hour/well (1 MCM/year/well)
- Casing material: top zone (depth 0 - 50 m): stainless steel
  lower zone (depth 50 - 350 m): ordinary API steel
- Well pump: not required
- Layout of raw water collection pipes (see Fig. II-5.2)
- Pipe material: Polyvinyl Chloride (PVC)

(ii) RO desalination system

Figs. II-5.3, II-5.4 and II-5.5 show the RO process flow, the plant layout and plant view & section. The RO desalination system consists of (i) pre-treatment facility, (ii) RO unit, (iii) post-treatment facility and (iv) chemical cleaning and waste water treatment facility.

<u>Pre-treatment facility</u>

Pre-treatment is to remove the impurities which may cause membrane fouling. Selection of pre-treatment processes for this project was based on the general treatment methods (see Table II-5.1) and the brackish groundwater quality (see Table II-5.2). For this project, the pre-treatment aims mainly at removal and control of turbidity, Ca, HCO_3, Fe and excess free chlorine resulting from chlorination. The following facilities are designed 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
- In line-coagulation (coagulant dosing and dual-media filtration): for a removal of turbidity
- Dechlorination: for a removal of residual free chlorine
- Inhibitor dosing: for anti-scaling

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.

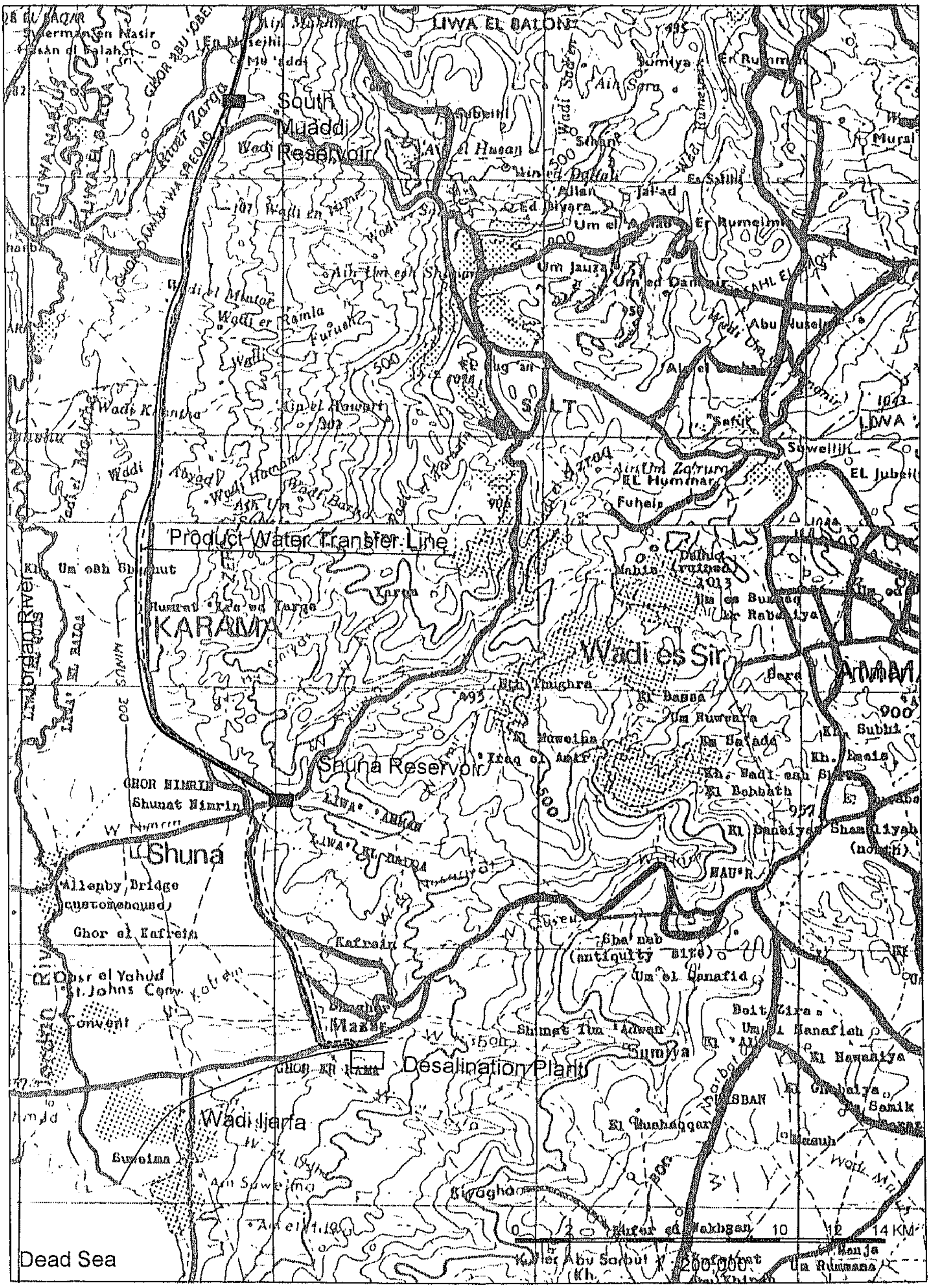


Fig. II-5.1 Location of the Priority Project

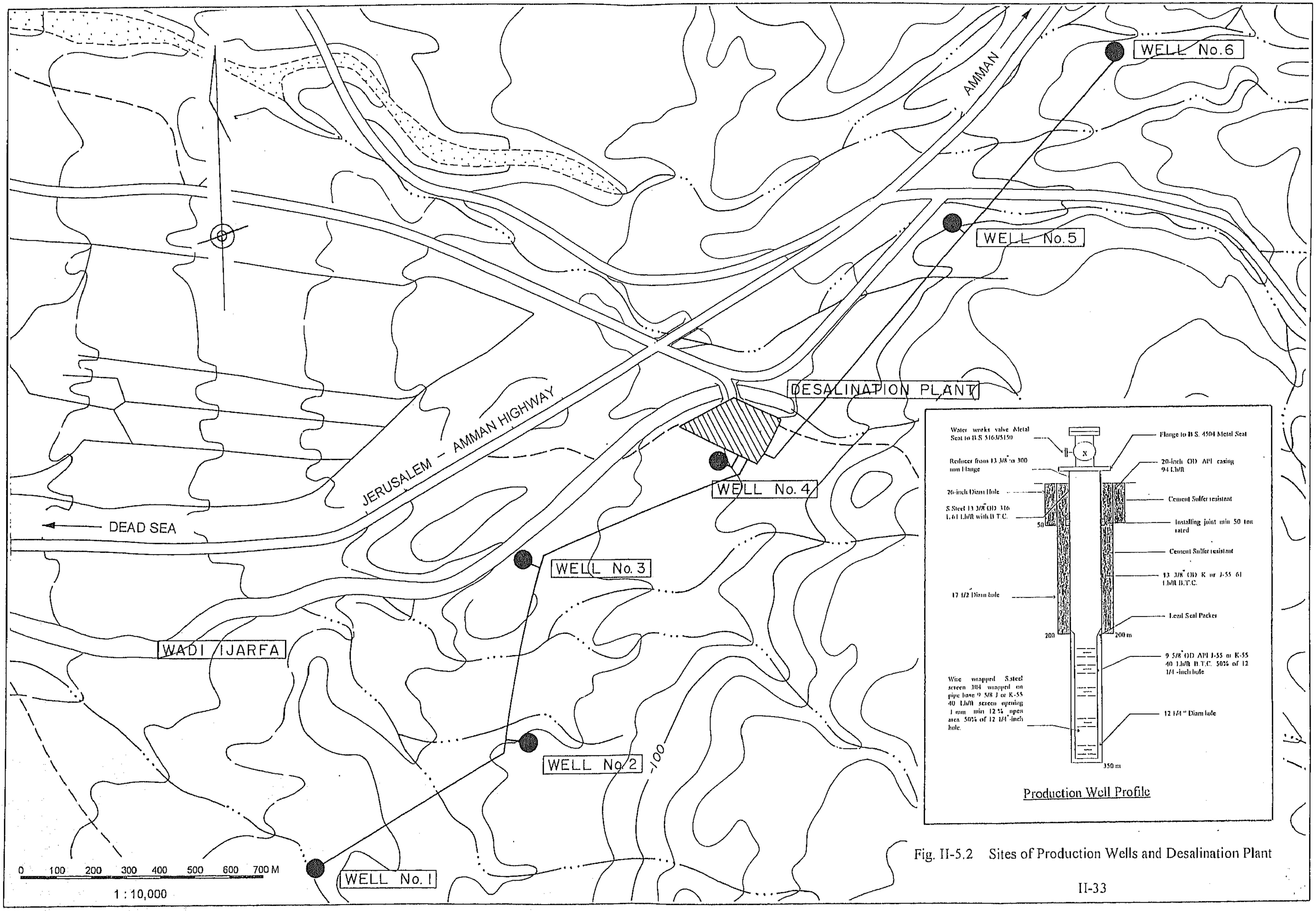


Fig. II-5.2 Sites of Production Wells and Desalination Plant

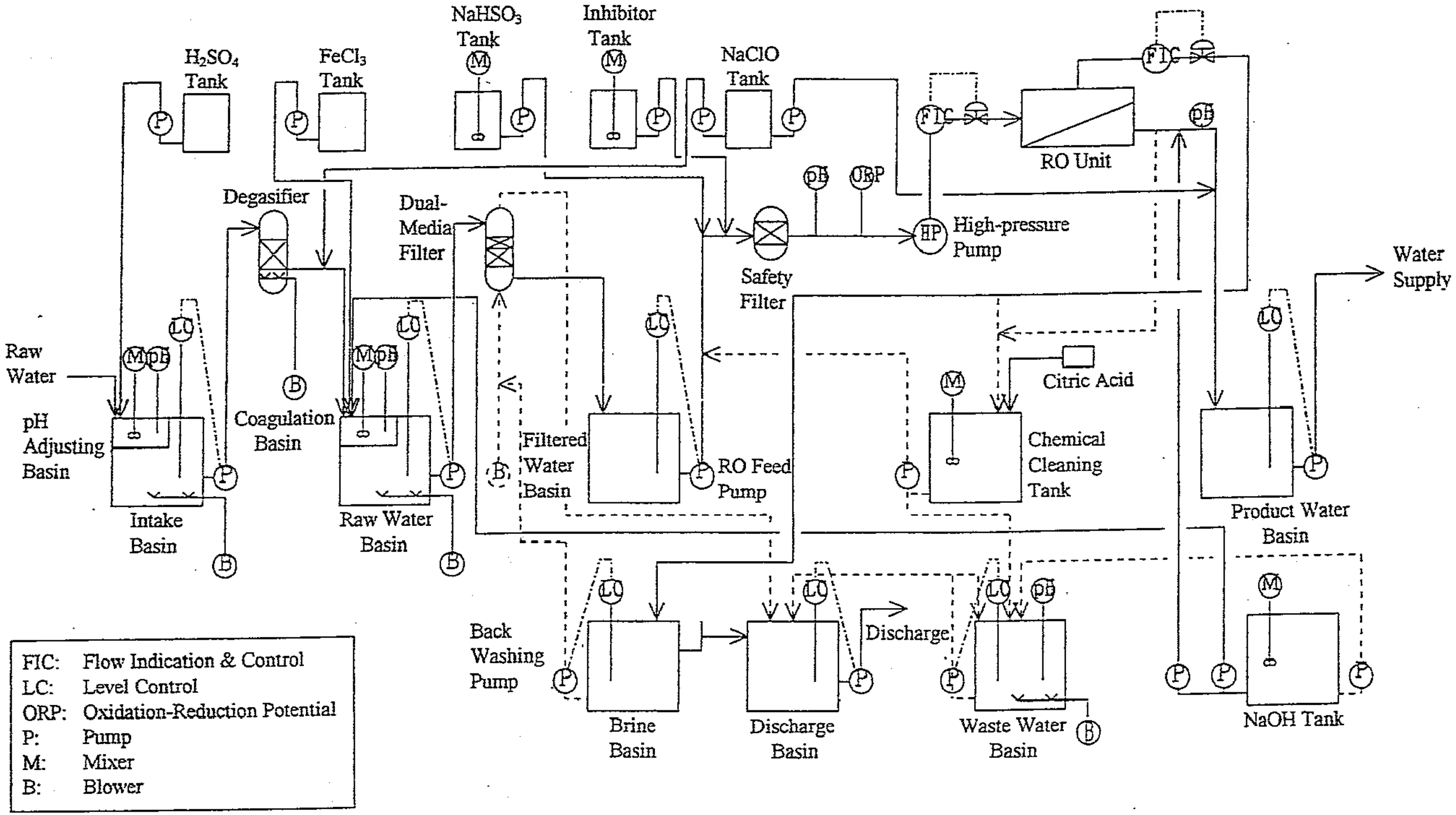


Fig. II-5.3 Process Flow of the RO Desalination System

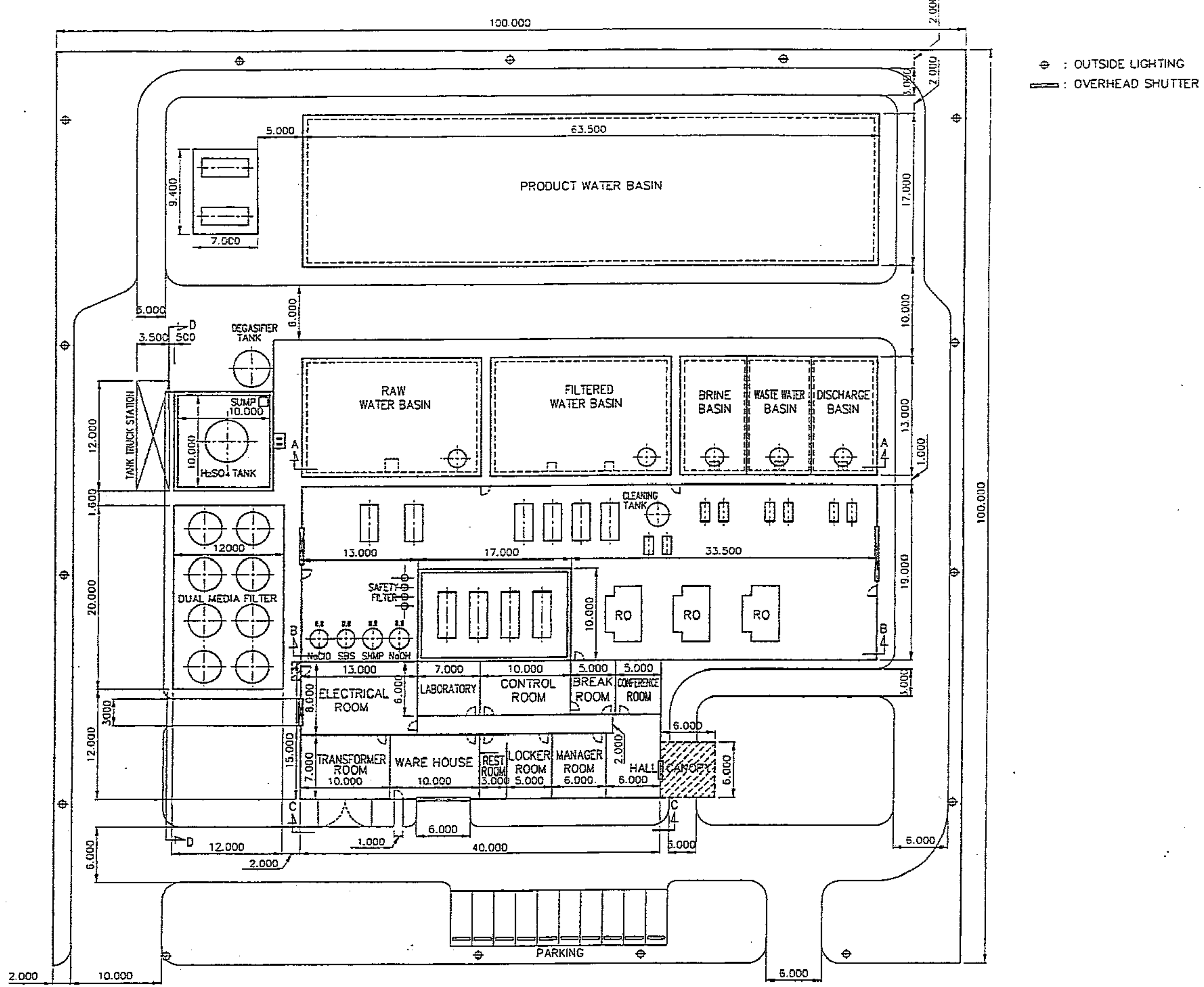
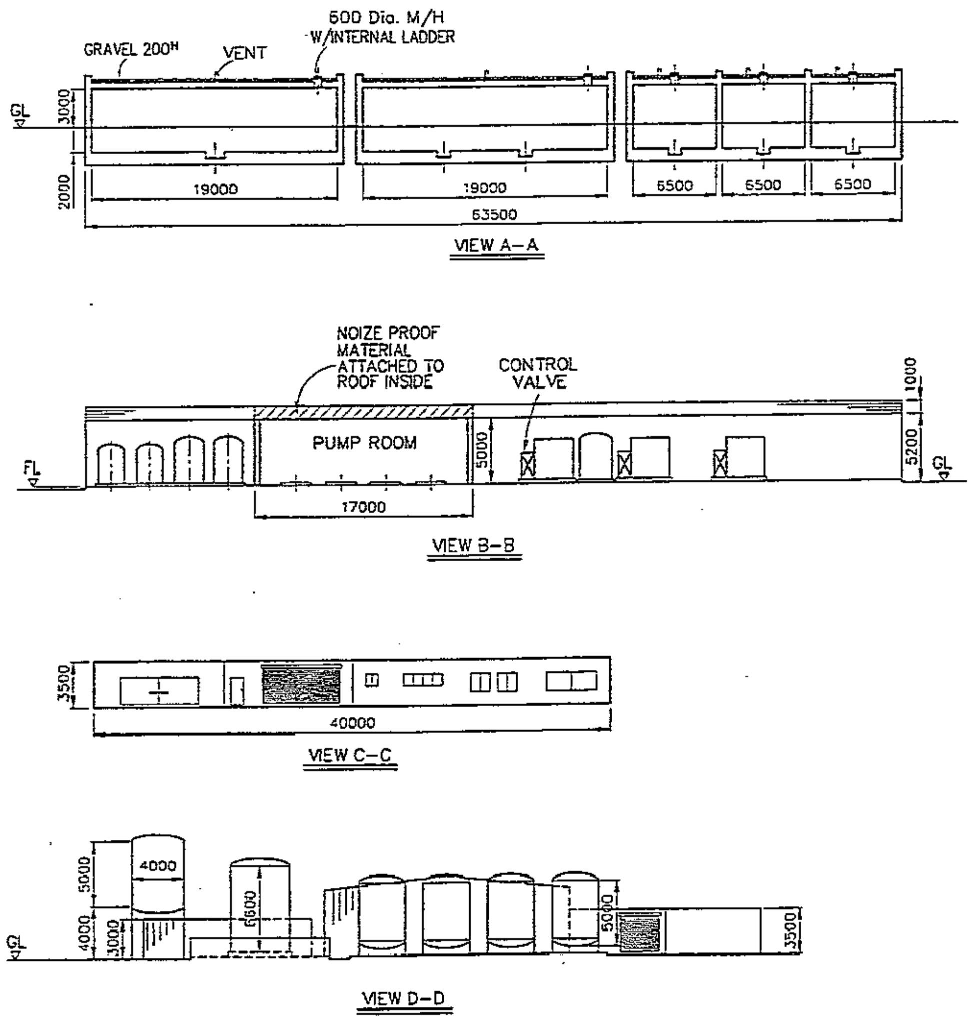


Fig. II-5.4 Layout of the RO Desalination Plant



NOTE :
(1) UNIT : MM

Fig. II-5.5 Views and Sections of the RO Desalination Plant

Table II-5.1 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.

Table II-5.2 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

RO Units

Selections of RO membrane modules are based on a comparison of the characteristics of the membranes widely used in water desalination and the specifications of the membrane modules to be used for this project are as follows:

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

Post-treatment

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

Chemical cleaning and wastewater treatment

- Chemical to be used: Citric acid
- Frequency of chemical cleaning: One time per 3 months for each membrane module
- Waste water treatment Neutralization by adding NaOH and aeration for biological degradation of organic matters

Brine discharge

- Brine quality:	TDS 25,000 - 33,500 mg/L
- Brine quantity:	about 2,700 m^3/day
- 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.)

(iii) Water supply facility

- Product water storage basin	4,000 m^3
- Product water pump	Capacity 5.7 m^3/min, pump head 70 m
- Water transfer pipelines	11 km to Shuna Nimrin Reservoir
(Dia. 300 mm)	41 km to Muaddi Reservoir (with 3 lift pumps)

(iv) Electricity supply system

By using the 33 kv transmission line available in the Jordan Valley near the project site.

3) Operation and Maintenance

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

Daily inspection items

- Operating data: water temperature, raw water flow rate, product water flow rate, operating pressure, chemical dosing rate
- Water quality: pH, redox potential (ORP), silt density index (SDI), electric conductivity (EC)
- 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) and product water basin and product water pumps

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)

Maintenance work

- Small scale repair (to be involved in the daily work) and regular maintenance (to be involved in the regular work)

(ii) Plant organization (see Table II-5.3)

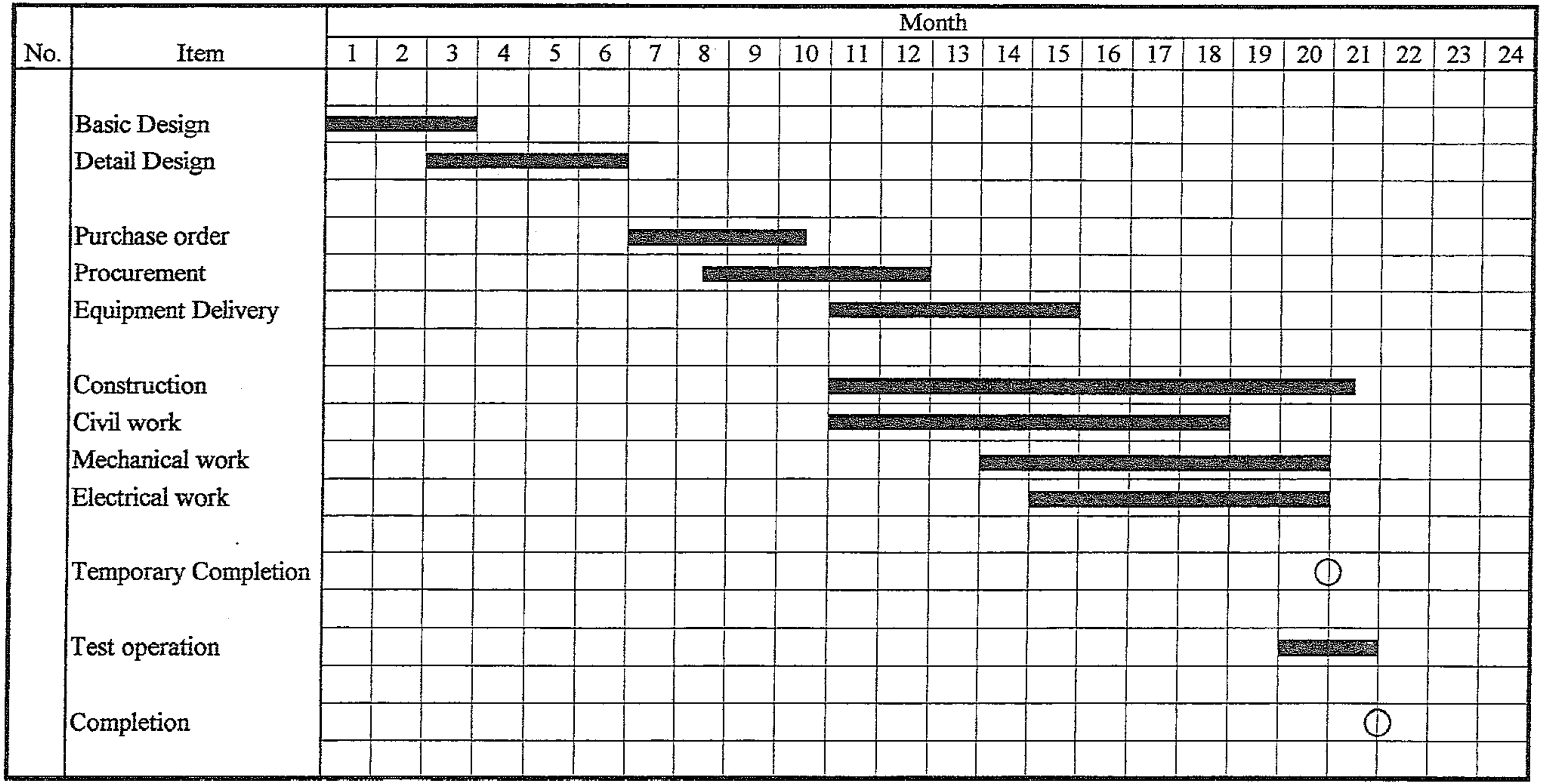
Table II-5.3 Organization of the RO Desalination Plant

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 x 4
	Guard man	1 x 4
Total		21

4) Time Schedule for Project Construction

The estimated time schedule for the construction of the priority project is shown in Fig. II-5.6. A period of 21 months is scheduled from the beginning of basic design to the completion of the project.

Fig. II-5.6 Time Schedule for RO Plant Construction (6 MCM/Year)



6. Implementation Plan

(1) Development Strategy of the Brackish Groundwater in the Study Area

1) Water sources derived from the Peace Treaty

Utilization of water sources derived from the Peace Treaty shall be given a top priority.

2) Utilization and Water supply areas

The development of the brackish groundwater by desalination shall be utilized for domestic and industrial water but not for irrigation water because of economical considerations.

Water supply areas shall be the Jordan River Valley and Amman City. Supply to the Northern four governorates will be considered through the supply to Amman City.

3) Development areas and Quantities

(i) Hisban/Kafrain in the Southern part of the study area

Development of 6 MCM/year of brackish groundwater by desalination at Hisban/Kafrain for the purpose of domestic and industrial supply in Jordan Valley shall be given a top priority in the development strategy.

Development of remaining 39 MCM/year of brackish groundwater by desalination at Hisban/Kafrain for the purpose of supplying domestic and industrial water to Amman City should be given a detailed feasibility study in comparison with the competing Disi fossil groundwater development plan. As far as examined in the study, full scale development of pumping to Amman should be considered after the Disi project.

(ii) Deir Alla in the Northern part of the study area

Development of 13 MCM/year of brackish groundwater by desalination at Deir Alla for the purpose of domestic and industrial supply in Jordan Valley should be considered for satisfying the demand increase from 1998 to 2010. In this development plan, the establishment of an appropriate disposal method for the concentrated brine will be essential because the cost of an independent discharge facility to the Dead Sea impedes the feasibility of the plan. A common brine discharge facility, covering all the concentrated brine from the expected desalination plants, saline springs and irrigation returns discharged in the Jordan River Valley, from the North Lake Taberias to the North of the Dead Sea may be the best solution to minimize the cost of brine disposal. This could be one of the most effective methods of water quality conservation for the Jordan River.

Development of remaining 17 MCM/year of brackish groundwater by desalination at Deir Alla for the purpose of supplying domestic and industrial water to Amman City should be considered in the comprehensive plan for water allocation and conveyance of the Peace Treaty water to Amman City and the other four governorates, including the utilization of the existing King Abudulla Canal and Deir Alla - Zai water transfer pipe line.

(2) Implementation Plan and Financial Plan

Implementation and timing of the brackish groundwater development based on the development strategy will vary depending on the allocation of the Peace Treaty water to the domestic and industrial sectors. The progress of the existing large scale water resources development, especially Disi fossil groundwater development plan, will also affect the master plan of water resources development. However, according to the bold assumptions of the study team, an implementation plan until the target year of 2010 and a corresponding financial plan has been prepared for reference in Table II-6.1.

Table II-6.1 Development Strategy of Brackish Groundwater Desalination

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
(Deir Alla)															
Common Waste Water Line															
24 MCM/yr. Desalination (Plan A)															
(Kafrain)															
5 MCM/yr. Desali. (Plan D)															
31 MCM/yr. Desali. (Plan C)															
(Disi)															
75 MCM/yr. extraction															
Attained Water Supply (MCM)			5	5	5	80	80	80	80	80	80	111	111	111	111
Required Capital (MJD)	10.8	10.8	81.8	81.8	81.8	18.2	18.2	18.2	66.2	66.2	66.2	14.6	14.6	14.6	14.6
O&M Cost (MJD)	0	0	1.1	1.1	1.1	6.7	6.7	6.7	6.7	6.7	6.7	18.1	18.1	18.1	18.1
Water Production Cost (JD/m3)*			0.52	0.52	0.52	0.40	0.40	0.40	0.40	0.40	0.40	0.46	0.46	0.46	0.46

Note* : Current water production cost in WAJ is 0.307 JD/m3. If the grant element is introduced, water production cost of desalination as well as required capital will be reduced.

Source: JICA Study Team.

7. Recommendation

(1) Recommendation for Implementation of the Priority Project

(i) Technical preparation for RO desalination plant management

Since water supply by brackish groundwater desalination will be a new practice in Jordan, WAJ shall have to be prepared to administer and manage the project while undertaking the operation and maintenance responsibilities. It is recommended that WAJ shall start studies on desalination technology and the techniques of RO plant management, operation and maintenance from the beginning of project construction, and couple such studies with personnel training.

(ii) Water quality study and monitoring

As the brackish groundwater in the study area contains certain membrane fouling substances which should be removed or controlled by pre-treatment, further study and long term monitoring of water quality is required. It is recommended that a study group shall be organized by WAJ to carry out the above mentioned work and to provide long term water quality monitoring record as the basis for water quality control of the RO desalination plant.

(2) Other Recommendations

(i) Long term hydrogeological observation

A long term hydrogeological observation of the Zerqa Group Aquifers is important for providing more reliable information for the stepwise implementation of the brackish groundwater development projects. A brackish groundwater monitoring network is recommended to be built by utilizing the 6 test wells drilled in this study.

(ii) Common brine discharge line

Construction of a common brine discharge line is indispensable for the full scale development of the brackish groundwater in the Zerqa Aquifers, and a development of the other saline groundwater and spring waters near Lake Taberias and in the East and West banks of the Jordan Valley. Therefore, it is recommended that a study to be conducted on the construction of the common brine discharge line through the Jordan Valley.

(iii) Modification of the water resource development strategy

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 the West Bank
- Water demand by new development plans

(iv) 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. Further study is recommended to be conducted on the potential and quality of brackish groundwater covering the whole country.