WATER AUTHORITY OF JORDAN
MINISTRY OF WATER AND IRRIGATION
HASHEMITE KINGDOM OF JORDAN

STUDY REPORT FOR THE IMPLEMENTATION REVIEW OF THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY SYSTEM TO GREATER AMMAN PHASE II IN THE HASHEMITE KINGDOM OF JORDAM

DECEMBER 1997

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO ENGINEERING CONSULTANTS CO., LTD
NIPPON KOEI CO., LTD.

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PREFACE

In response to a request from the Government of the Hahsemite Kingdom of Jordan, the Government of Japan decided to conduct a study for the implementation review of the project for improvement water supply system to greater Amman, phase II in the Hashemite Kingdom of Jordan and entrusted the study to the Japan International Cooperation Agency (JICA)

JICA sent Jordan a study team from October 12 to October 30, 1997.

The team held discussions with the officials concerned of the Government of Jordan, and conducted a field study at the study area. After the team returned to Japan, further studies were made and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Hashemite Kingdom of Jordan for their close cooperation extended to the teams.

December 1997

Kimio Fujita
President
Japan International
Cooperation Agency

December 1997

Letter of Transmittal

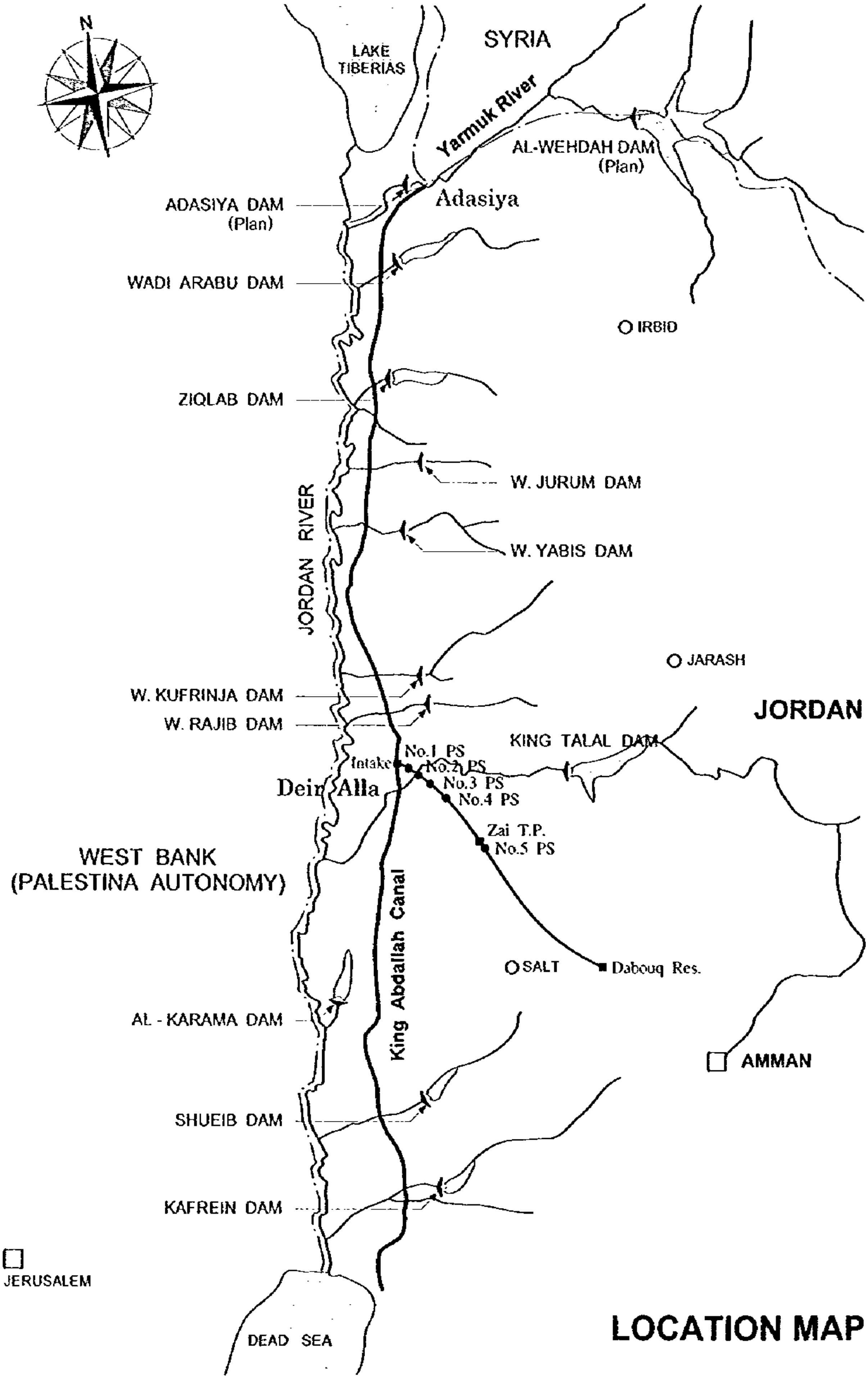
We are pleased to submit to you the report of the study for the implementation review of the project for the improvement of water supply system to greater Amman, Phase II in the Hashemite Kingdom of Jordan.

This study was conducted by Tokyo Engineering Consultants Co., Ltd. in association with Nippon Koei Co., Ltd., under a contract to JICA, during the period from October 7 December 15, 1997. In conducting the study, we have examined the feasibility and rationale of the project with due to consideration to the present situation of the Hashemite Kingdom of Jordan and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

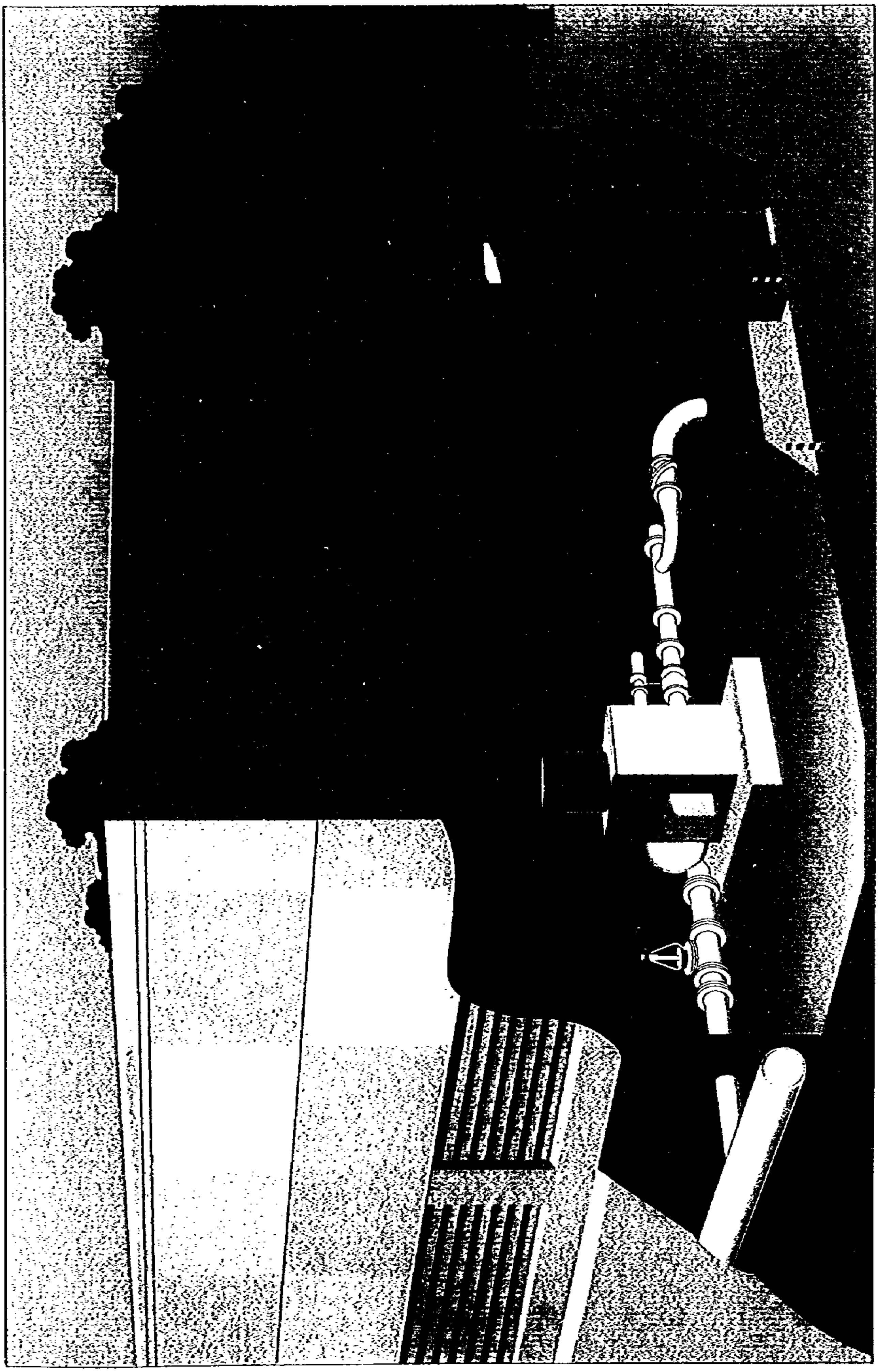
Very truly yours,

Kazufumi Momonse
Project manager, Study team for
the implementation review of
water supply system to
greater Amman
Tokyo Engineering Consultants Co., Ltd.
in association with
Nippon Koei Co., Ltd.

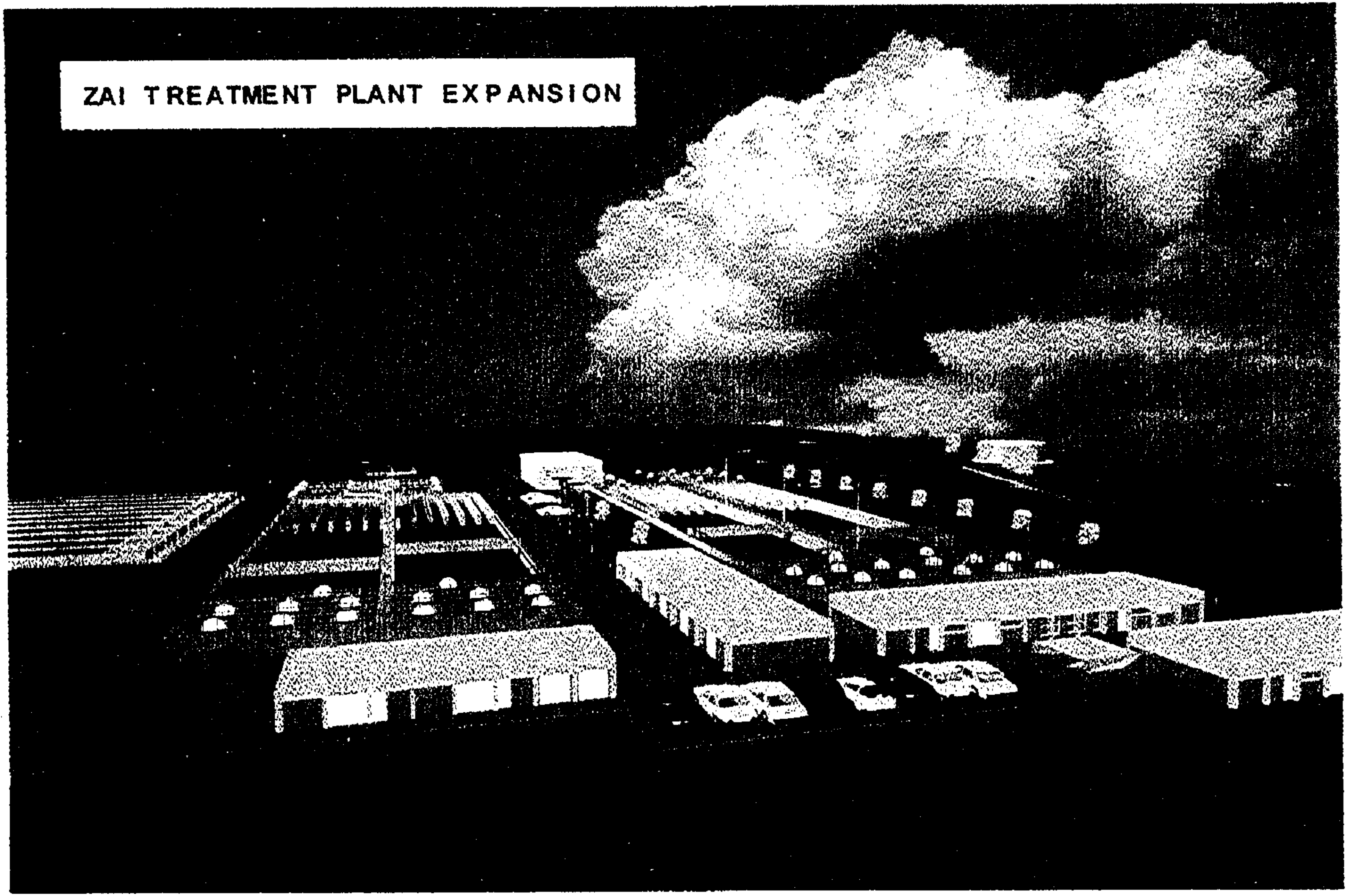


LOCATION MAP

ZAI SYSTEM AND DAMS IN JORDAN VALLEY



PUMP HOUSE BIRDS-EYE VIEW


ZAI TREATMENT PLANT EXPANSION

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ABBREVIATION

GTZ	Deutsche Gesellchaft fur Technishe Zusammenareit
JVA	Jordan Valley Authority
JICA	Japan International Cooperation Agency
KAC	King Abdullah Canal
KfW	Kreditanstalt fur Wiederaufbau
MOP	Ministry of Planning
MWI	Ministry of Water and Irrigation
WAJ	Water Authority of Jordan

Chapter 1
Background of the Project

Chapter 1 Background of the Project

The Hashemite Kingdom of Jordan with her land of 98 thousand km² and her population of 4,212 thousand in 1995, is bordered with Egypt, Israel, Syria, Iraq and Saudi Arabia. Her per capita GNP was 1,510 US dollars in 1995. Her economy with deep relation with her neighboring oil-producing countries, had long been suffered from trade deficits. After the gulf crisis, her economy has further worsened because of stagnant trade with the neighboring countries, shrinkage of export markets, increase of population due to many returnees from the gulf countries, decrease of remittance inflow. As a result, her financial situation is now in a severe situation.

The population increased at high growth rate of 4.7% in 1995. With the increase of the population, water demand for domestic as well as agriculture increased as well and reached to 1,400 MCM in 1995. On the other hand, water supply volume is only 950 MCM in the same year, less than the water demand. Groundwater which accounts for 50% of the water supply has been over-extracted to try to meet the water demand. As a result, water tables are lowered and contents of water have lots of minerals so that further water supply from the groundwater is difficult.

Water to Amman comes, in addition to groundwater, from the King Abdul Canal (KAC). The water is taken at Deir Alla in the KAC and boosted with intake pumps and four booster pumps to the Zai water treatment plant. After treatment, water is again pumped to Amman. The difference in elevation is 1,100 m between Deir Alla and Amman. This Deir Alla - Zai system (DAZS) had never fulfilled its 45 MCM/year capacity since its inauguration of 1985 due to insufficient raw water at Deir Alla. The water supply situation is, therefore, severe with supplying only two days per week during summer periods.

However, the Peace Treaty concluded in October 1994 between Jordan and Israel has brought Jordan with additional water which has come from the Yarmouk river, Tiberias lake etc. As a result, available raw water is sufficient at Deir Alla for the DAZS. Its 45 MCM capacity is, however, lowered to about 37 MCM capacity now due to abrasion of pump impellers etc. Therefore, in order to utilize the available water at Deir Alla to the fullest, the DAZS needs rehabilitation as well as expansion.

The government of Jordan has requested the government of Japan rehabilitation of the intake pumping station and four booster stations as well as expansion of the Zai treatment plant. In response, the government of Japan sent a JICA preliminary study mission to Jordan in January 1996, to evaluate the request. The mission found that the request was reasonable to conduct the "basic design study", further step towards appraising Japanese grant-aid project. The mission also found that the contents of the requested project would be too large for the Japanese grant-aid project so that the contents of the basic design study is limited to four booster stations and Zai water treatment plant.

As a result of the basic design study, the rehabilitation of the four booster stations are being implemented, scheduled to be completed in March, 1998. The expansion of the four booster stations and the treatment plant has been suspended for implementation because the related project (from No.5 booster station to Dabuk reservoir etc.) had not yet financed. Now it could be financed by KfW so that the study for the implementation review of the project for improvement of water supply system to greater Amman, phase II was initiated. The study team was dispatched to Jordan between October 12, 1997 and October 30, 1997, followed by home work in Japan until December, 1997.

Chapter 2
Contents of the Project

[illegible]

[illegible]

Chapter 2 Contents of the Project

2.1 Objectives of the Project

The annual rainfall around Amman is only about 300 mm, and is concentrated in the months between November and March. Accordingly, there is no stream flow in the rivers during the dry months and the surface water cannot be used as a stable water source for the water supply systems in Jordan. The water supply systems depend entirely on ground water, excepting the Zai water supply system, which is the topic of this Study. Originally, spring water and ground water in Amman were used as water sources, but since the amount of water from these sources was limited, water was fetched from remote wells outside the city. All renewable ground water sources in Jordan were developed so that today the ground water level has decreased and the quality of water has deteriorated. As a result, the water supply situation in Jordan (including areas around Amman) is very severe, with water being rationed frequently especially during the dry period when the demand is high.

As a result of the Peace Treaty signed in October 1994 between Jordan and Israel, surface water was shared from the Yarmouk river and Lake Tiberias in Israel, which mitigated the severe water supply situation in Jordan to some extent. However, the water supply is limited, and the severe situation continues today. Rehabilitation and expansion of existing facilities for mitigating the severe water supply situation in Amman has become an urgent topic. The government of Jordan prepared two plans, described below, for dealing with the problem of inadequate drinking water supply.

1) Plan for renewing the deteriorated raw water pumps and transmission pumps in the Zai system (between Deir Alla and Amman), procuring and installing materials and equipment required for restoring the planned water supply of 45 million m^3/year for the Zai system. (Rehabilitation Portion)
2) Plan for expanding the water supply of the Zai system from 45 million m^3/year to 90 million m^3/year. (Expansion Portion)

The rehabilitation portion is being implemented, to be completed in March 1998, Therefore, the present Study has the objectives of expanding the rehabilitated Zai system to 90 million m^3/year (250,000 m^3/day), and to convey and supply this water to the Amman city area by procuring and installing the necessary materials and equipment and constructing facilities for the same. The No. 1 to No. 4 pumping stations in the Zai system, the raw water main between the No. 1 pumping station to the Zai treatment plant, and the Zai treatment plant fall in the scope of this Study; the conveyance facilities between the Zai treatment plant and the Dabuk distribution reservoir and between Deir Alla intake and No.1 pumping station do not fall within the scope of this Study.

2.2 Basic Concept of the Project

2.2.1 Ensuring Water Sources

The minister of planning confirmed, in the letter on September 7, 1997 to the Ambassador of Japan in Amman, that the Government of the Hashemite Kingdom of Jordan shall secure 90 MCM/Year i. e. 250,000 Ton/Day of water at the Deir Alla Intake Pumping Station of the King Abdullah Canal to allocate to the municipal purpose (drinking water) for the Greater Amman area. The above is further confirmed by the Study Team in the following from a point of view of water balance at Adasiya in KAC.

The KAC was constructed for irrigating lands in the Jordan valley. Its water is taken not only from the Yarmouk river but also from side wadis. The Tiberias lake started supply water to the KAC after the peace treaty. At Deir Alla in the middle of the KAC, the Zai system takes water from the KAC. Among the above, water from the Zarqa river, the largest river in the side wadis comes mainly from treated waste water in Amman and its water is directed used for irrigation not through the KAC. As a result, the Yarmouk river and the Tiberias lake constitute the water source for the Zai system. These water is inflowed at and near the Adasiya. Water flow at Adasiya is shown in Table 1.

The quantity of water running in the KAC was 120 million m^3/year before the peace treaty. It increased by 75 to 80 million m^3/year at the peace treaty, due to increase of the allocated water from the Yarmouk river and the Tiberias lake. Further, construction of Adasiya diversion dam by JVA will increase available water for the KAC by 37 million m^3/year . The increased quantity of water will total to 112 to 117 million m^3/year. Accordingly, 90 million m^3/year of water can be used for the Zai system.

The 268 million m^3/year of water in Table 1 is almost equal to the measured water flows. The flows for the Adasiya are measured at the two points; one at KAC and another at downstream just after branching off the KAC. The former flow was 127 million m^3/year (average between 1982 and 1995) and the latter flow was 138 million m^3/year (average between 1981 and 1995).

Table 1 Water Allocation at Adasiya of KAC

(Unit : million m^3/year)

Term / Water Source	Before Peace Treaty (~1994)	After Peace Treaty (1995~)	After Adasiya Dam Construction
Yarmouk river			
Total	268	268	268
Ineffective	148	83	46
to Israel		25	25
to KAC	120	140	177
From Tiberias lake			
Desalinated or from Deganya	-	10	10
Seasonal adjustment	-	20	20
Agreement on May, 1997	-	25 to 30	25 to 30
Sub-Total		55 to 60	55 to 60
Running KAC	120	195 to 200	232 to 237
for Zai	45	90	90
for irrigation	75	105 to 110	142 to 147

2.2.2 Water Balance in Amman

Water balance is planned for Amman by "the hydraulic analysis of Greater Amman Water supply system, April, 1997".

(1) Water Demand

Water demand of 113 million m^3/year in 1995 is estimated to reach 221 million m^3/year in 2025 as shown in Table 2. The increase in demand is mainly due to increase in population.

Table 2 Water Demand in Amman

(Unit : million m^3/year)

Item	Unit	1995	2000	2005	2010	2015	2025
Population	thousand	1,583	1,853	1,913	2,481	2,839	3,637
Per capita consumption	l/c/d	130	135	140	145	150	150
Consumption	million m^3/year	75.1	91.3	110.0	131.3	155.4	199.1
Leakage Ratio	%	30	20	10	10	10	10
Demand for leakage	million m^3/year	33.9	23.8	12.7	15.0	17.3	22.1
large consumer demand	ditto	4.0	4.0	4.0	4.0	4.0	4.0
Total demand	million m^3/year	113.0	119.1	126.7	150.3	172.7	221.2

(2) Water Supply

Water supply is planned as shown in Table 3.

Table 3 Water Supply for Amman

(Unit : million m^3/year)

Name		1995	2000	2005	2010	2015	2025
Other than Zai System	Existing	57.4	47.6	46.6	45.6	45.6	45.6
Zai System	Existing	45.0	45.0	45.0	45.0	45.0	45.0
	Expansion	-	-	45.0	45.0	45.0	45.0
	Sub total	45.0	45.0	90.0	90.0	90.0	90.0
Disi ground water	Planning	-	-	90.0	90.0	150.0	150.0
Total		102.4	92.6	226.6	225.6	285.6	285.6

According to the plan, supply from many over-extracted wells other than Zai system is reduced. Although the plan envisages the supply from the Zai system starts operation in 2000, this Study assumes its supply starts in 2002.

(3) Water Balance

After the expansion of the Zai system and the Disi system, water demand can be met with water supply as is shown in Table 4.

Table 4 Water Balance in Amman

(Unit : million m^3/year)

	1995	2000	2005	2010	2015	2025
Demand	113.0	119.1	126.7	150.3	172.7	221.2
Branch to Balqa	-	-	4.4	4.4	4.4	4.4
Supply	102.4	92.6	226.6	225.6	285.6	285.6
Balance	-10.6	-26.5	95.5	70.9	108.5	60.0

2.2.3 Design Flow Rate of Facilities

The design flow rate of the Zai system is increased to 250,000 m^3/day from 125,000 m^3/day, taking into account of the following:

(1) To utilize the water of 90 million m^3/year, available in the KAC.
Out of 90 million m^3/year, 45 million m^3/year water is for expansion.

(2) The facilities in Jordan is usually designed against daily average demand.

2.2.4 Expansion Plan for Treatment Plant

It is physically possible to modify existing treatment plants and increase their capacities, but this will lead to prolonged water supply stoppages during modification and will have adverse effects on the residents of Amman, and is therefore impractical. In principle, the number of treatment plants similar to existing plants, should be increased. However, as described later, a part of the facilities such as raw water regulating basins and clean water reservoirs that can be shared, should not be increased.

2.2.5 Expansion Plan for Conveyance pipelines and conveyance pumps

The plans for conveyance pipelines in response to the doubling of flow rate (design flow rate) include the method of installing additional conveyance pipelines (Alternative H), and the method of utilizing existing conveyance pipelines without laying additional pipelines (Alternative I). With the doubling of the flow rate, the power consumption for pumps will increase in Alternative I, while the cost for laying additional conveyance pipelines can be economized. In this case, the head of the pump to be installed additionally will be the actual head of existing pump (difference in altitudes of the pumping stations) plus the friction losses (due to doubling of flow rate). The increase in head for this case is shown in Table 5.

Table 5 Head When Using Existing Conveyance Pipelines and Doubling The Flow Rate

	45 million m^3/year	90 million m^3/year	Increase in head
No. 1 conveyance pump	286m	300m	4%
No. 2 conveyance pump	286m	300m	4%
No. 3 conveyance pump	286m	308m	6%
No. 4 conveyance pump	286m	314m	9%
Transmission pump	198m	257m	30%

As seen in the table above, the percentage increase in head for pump stations No. 1 to No. 4 is comparatively small at 4 to 9%. This shows that the head in most cases is only the actual head and friction loss is negligible. If the percentage increase in head is as small as the figures indicate, there is a high possibility that the conveyance pipelines of existing facilities can withstand the increased flow rate. As explained later, detailed studies were carried out on the ability of conveyance pipelines to withstand pressure. The results of the studied showed that excluding a part of the pipelines, the existing pipelines can withstand the increased pressure due to the doubling of the flow rate.

While construction costs are incurred and operating and maintenance costs economized for Alternative H, the construction costs can be economized and operating and maintenance costs are incurred for Alternative I. To determine the Alternative that is most beneficial, the "net present value" of both alternatives were calculated. The results of the studies showed that Alternative I was more beneficial, and thus this alternative was selected (Refer to Appendix 8). That is, existing conveyance pipelines will be utilized in the expansion stage.

2.2.6 Expansion Plan for Pump

(1) Plan considering expansion

For the expansion plan (to increase the capacity of the pumping stations) four alternatives listed below can be considered using the existing pipelines even during the expansion stage. (The field survey confirmed that the existing pipeline can be used except for a partial section.)

Alternative A: Replace the four existing pumps with four new pumps (58.0 m^3/min., three duty pumps and one standby pump)

Alternative B: Replace the four existing pumps with four new pumps (43.5 m^3/min., procuring the required number of standby pumps separately)

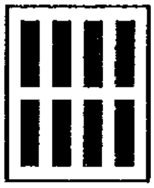
Alternative C: Replace the four existing pumps with five new pumps (43.5 m^3/min., Four duty pumps and one standby pump)

Alternative D: Add four new pumps of the same capacity (25.0 m^3/min.) as the existing pumps.

(2) Comparison of Alternatives

Table 6 shows the comparison of the Alternatives.

Table 6 Comparison of Alternative for Expansion

Alternative	A	B	C	D
Salient feature	The existing four pumps (4 duty and no stand-by pump) in each pumping station in No.1 to No.4 are replaced with the new four pumps (3 duty and 1 stand-by).	The existing four pumps (no stand-by pump) in each pumping station in No.1 to No.4 are replaced with the new four pumps (4 duty). In addition, one stand-by pump are procured and stored in storage.	The existing four pumps (no stand-by pump) in each pumping station in No.1 to No.4 are replaced with the new five pumps (4 duty and 1 stand-by).	Four new pumps with the same capacity as the existing pumps are added.
 Duty  Stand-by				
Pump specification				
Diameter (mm)	ϕ 550× ϕ 450	ϕ 450× ϕ 300	ϕ 450× ϕ 300	ϕ 350× ϕ 250
Discharge (m^3/min.)	58.0	43.5	43.5	25.0
Total head (m)	300～314	300～314	300～314	300～314
Number	4 (including 1 stand-by)	4 *	5 (including 1 stand-by)	8 (including 1 stand-by)
Suction velocity (m/s)	4.07	4.56	4.56	4.33
Other works				
Existing 4 pump	Remove	Remove	Remove	Utilize
Existing header pipe	Replace (existing diameter is ϕ 450)	Utilize	Utilize	Utilize
Pump house expansion	No necessary	No necessary	Necessary for 1 pump	Necessary for 4 pumps
Others	Suction velocity is too large, 6.08 m/s when existing header pipe is used	—	—	No space for pump house expansion
Cost	Second largest	Smallest	Second smallest	Largest
Technical Aspect			◎	
Selected alternative		◎		

* In addition, two pumps are procured for stand-by for four pumping stations.

(3) Selection of Alternative

Alternative B is selected because of the following reasons:

For Alternative A, the pump diameter becomes very large necessitating the complete replacement of header pipes on the suction and discharge sides. This requires water supply stoppage for prolonged periods, therefore this Alternative is not acceptable. Moreover the header and suction pumps cannot be accommodated in the existing pump house.

Alternative D requires the same space as the space of the existing pumping station and this additional space is not available in the existing pumping station. The cost for this Alternative is higher than the cost for Alternatives B and C.

Comparing Alternatives B and C, the duty pump capacities for both Alternatives are the same. Considering maintenance aspects, C is superior to B because a standby pump is permanently available. However, in the existing facility, a system similar to B is being implemented, therefore no additional problems are expected if B is selected. Considering cost, C requires expansion of pump house, and an additional set of distribution pipelines and valves. Alternative B satisfies the various conditions of this Study, and is the most economical, therefore Alternative B is selected.

For the expansion stage, four existing pumps of dia. 350 x dia. 250 x 21.95 m^3/min. x 286 m x 1,850 HP each will be replaced by four pumps of dia. 450 x dia. 300 x 43.5 m^3/min. x 300 - 314 m x 3200 - 3500 kW each, and the required number of standby pumps will be procured and stored.

2.2.7 Main Pump Motor and Its Starting Method

Shortening the water stoppage period as far as possible during the work of the pumping station is a very important factor that needs to be considered. In addition to considerations of efficiency and safety during operation, there should be no significant changes to header pipes in and around the existing pump house, and the construction period should be shortened to the maximum extent possible. In view of the above points, the starting method of the squirrel-cage rotor type induction motor, which has the same starting method as that of the existing pump motor, should be changed to the reactor starting method for this Project.

(1) Selection of motor

Based on the results of comparison shown in the table below, the squirrel cage rotor type induction motor, which is the same as the existing motor, is selected.

Table 7 Comparison of Induction Motor

Type	Characteristic on operation	Space for installation
Squirrel-cage rotor type	Generally, starting current is large. But, it can be suppressed by starting equipment.	· Can be installed on the same arrangement with the existing motor location. · Dimension of motor foundation must be expanded.
Wound rotor type	Can be started without excessive starting current.	· Dimension is larger than the squirrel-cage rotor type · Cannot be installed on the existing motor location. · Starting register needs expansion of pump house to install it.

(2) Selection of starting method

Since the motor used for this Project is a large motor of the 3000-kW class, the starting current needs to be suppressed. From the results of comparison of various starting methods shown in Table 8, the reactor starting method is selected.

Table 8 Comparison of Starting Method for Induction Motor

Starting Method	Characteristics
Direct (Line) starting	· On starting time, the current is as large as about 8～10 times of normal operative condition flows to motor. This starting current on the induction motor of large capacity gives large shock to power transmission system. Therefore, this starting method cannot be recommended to this Project.
Star-Delta starting	· This method is not applied to H.T. motor because its terminal structure is complex. (Generally, this method is applied to L.T. motor of capacity less than 100 KW.)
Reactor starting	· Starting current can be suppressed to about 5～7 times of current on normal operative condition. · Starting reactor can be installed in the existing pump house.
Kondrfer-system starting	· Starting current can be suppressed to about 4～5 times of current on normal operative condition. · Dimension of starting system is large, therefore it cannot be installed in the existing pump house.

2.2.8 Main Transformer for Power Receiving

By using the reactor starting method for the pump motor, the starting current can be suppressed to 1.5 times the starting current in the existing pump motor. To suppress the drop in voltage due to this starting current within a suitable range (less than 8 to 10% of the rated voltage approximately) and to start the motor correctly, each pump house requires the main transformer to have a capacity of approximately 20 MVA in the expansion stage. Transformers with a rated capacity of 10 MVA were already added to each pumping station during the rehabilitation, and these transformers should be run in parallel with the existing transformers to balance the current flow.

2.3 Basic Design

2.3.1 Design Concept

(1) Design concept considering natural conditions

1) Temperature

The four-month period from June to September in Jordan is dry and the temperature is high. Direct sunlight is not conducive to the placing of concrete. The months from October to May is suitable for the placing of concrete. If concrete is placed during the summer season, it should preferably be done in the evening and night time. A large quantity of water should be dispersed for the concrete to harden in order to prevent evaporation due to the dry atmosphere and high temperatures, if concrete is placed in the day time in the presence of direct sunlight.

2) Rainfall

Rainfall is maximum in the period from January to March, and the maximum rainfall is about 90 mm. Snow also falls two to three times in the vicinity of the Zai treatment plant. Work may have to be stopped because of these snows.

3) Wind

Assembly of reinforcing bars and form works should be avoided in strong winds. Strong and adequate supports are needed for reinforcing bars and formworks to be assembled. In general, winds will not affect the progress of the construction work.

4) Topography and geology

The existing pumping stations are located on steep gradients and careful considerations are necessary when carrying heavy objects such as transformers and pumps to the stations. Roads from Deir Alla to the Zai treatment plant through various pumping stations are paved, but the roads have steep slopes in places.

The foundation ground of pumping stations and treatment plants consists of sandstone. The pumping stations are constructed on cut out rock beds. The sandstone foundation of treatment plants (for expansion facilities) is considered to reach to 6 to 7 m, but if it does not reach up to the foundation substrate of settling basins and filter basins, the said part needs to be replaced with lean-mix concrete, and the construction of the settling basin needs to be changed from the retaining wall construction to rigid frame construction.

5) Earthquakes

Seismic loads should be considered in the design loads of structures because Jordan experiences earthquakes.

(2) Design concept considering social conditions

The main religion in Jordan is Islam, therefore the implementation plans should consider religious aspects, such as Ramadan.

Since there are no residential areas in the vicinity of the pumping stations, there are no water supply and sewage facilities. Generators, water supply tanks, and purification tanks need to be provided at the construction sites.

(3) Design concept considering special circumstances related to construction and the construction industry

Many types of construction machinery can be procured within the country. Automation is common and the level of construction is comparatively high. Most construction machinery can be purchased locally.

Surplus soil can be used from the soil disposal site at Zarqa (approx. 30 km) east of Amman.

Most of the equipment and machinery required for construction are locally available in Jordan. Value added tax (VAT) is applicable to construction equipment and machinery in Jordan, but VAT is exempted for projects receiving foreign aid (borne by the implementing organization).

(4) Design concept considering utilization of local contractors (construction companies and consultants) and local machinery and equipment

Trained local contractors are available in civil, mechanical, electrical, architectural fields and can be utilized as sub-contractors for the work enabling the project cost to be reduced.

(5) Design concept considering operation and management ability of implementing organizations

WAJ has built up its experience with the Zai system over a long period, and the expansion facilities for this Project are similar to those in the existing system, therefore WAJ is considered to have operating and maintenance skills that are adequate for the expansion facilities. On the other hand, the balance of current account for WAJ shows a deficit. If such deficit situation will continue, operation and maintenance of the facilities improved might become weak. In order to avoid such situation, WAJ should take initiatives for achieving better financial balance by tariff modification, decreasing unaccounted-for-water etc.

(6) Design concept considering the establishment of grades and scope of facilities, equipment and machinery

WAJ's level of technology for operations and management for existing facilities is adequate. Therefore, the grade for facilities during expansion is kept the same as the grade for existing facilities.

(7) Design concept considering implementation period

The schedule for implementation is given below.

May 1998	Approval by the Japanese government
June 1998	Exchange of notes
July 1998	Contracts with consultants
July '98 to January '99	Detailed design
February 1999	Tenders, evaluation, selection of contractors, signing contracts
March '99 to November 2001	Construction period

2.3.2 Basic Plan

(1) Overall Plan

Three of the four pumps and motors (excluding one pump and one motor already rehabilitated) in each of the pumping stations No. 1 to No. 4 of the Zai system are to be renewed, and one surge tank in each pumping station is to be additionally installed to increase the planned capacity after rehabilitation from 45 million m^3/year to 90 million m^3/year (250 thousand m^3/day) in the expansion stage. The items below form the basic concept.

* Formulate the basic plan utilizing the existing facilities effectively (conveyance pipelines, pump houses, pump wells, transformers, surge tanks, chemical dosing equipment, raw water regulating basins, etc.)
* 660 m of conveyance pipeline from the No. 4 pump to the Zai treatment plan cannot withstand the internal water pressure and need to be replaced. However, to bring down the overall project costs, this replacement is not included in the Project. This work should be carried out independently by Jordan.
* After expansion, the Zai system will supply treated water to the Amman city area with the other facilities constructed in the separate Projects, the "Adasiya - Deir Alla" project, and the "No. 5 pumping station to Dabouk service reservoir" project. Accordingly, the control of flow rate of raw water, treated water, and delivered water is very important, and the control equipment for the Zai treatment plant is considered to be the most equipment for the three projects mentioned above.
* No problems in particular are found in the design concept and functions of existing treatment plant. Consequently, the same process as in the existing treatment plant will be used, in principle.

Pump Expansion

(2) Facilities Plan

Each pumping station consists of the pump house (pumps, motors, electrical equipment, etc.), transformer, storage tank(s), and surge tank. The pump house and transformer are installed on level ground after filling up the depression. On the other hand, storage tank(s) is/are installed about 20 m above the pump house (after cutting off the apex of the mountain) to match the pump characteristics.

Pumps and motors are replaceable equipment and are to be installed in the existing pump house. However, the surge tanks will be added in the future. This is because one more surge tank of the same size as the existing one needs to be installed in the pump house when the design flow rate is increased. After expansion, the capacity of the surge tank should be doubled. The surge tank can be installed at any arbitrary position, and the frequency of maintenance is also comparatively small, therefore the position should be considered based on the condition of the soil, foundation, laying of special H.T. lines, and buried pipes.

Additionally, the topographical and geological conditions given below need to be considered when installing the No. 1 pump.

* Since the surge tank is installed south of the existing conveyance pipelines, it would be preferable to install it by the side of existing surge tank, but there is no space. Therefore, the surge tank is to be installed on the gentle slope on the north side of the existing tank near the storage tank and rainwater drain.
* The ground has a rising gradient from the eastern side of the pump house toward the north, and a part of the surface has been cut away. Backfill can also be observed at some locations (an area of about 10 m x 35 m at the pump suction header pipe part north of the pump house). Excluding the above-mentioned parts, no problems are anticipated in the ground. The bearing ability of the ground was also confirmed from the results of checks by boring the ground.

(3) Machinery and Equipment Plans

1) Pump, motor and transformer for receiving power
After rehabilitation, the pumping capacity of each pumping station will be: dia. 350 mm x dia. 250 mm x 21.95 m^3/min. x 286 m x 1850 HP x 3 sets plus, dia. 450 mm x dia. 300 mm x 43.5 m^3/min. x 300 - 314 m x 3000 - 3500 kW x 1 set. The total capacity of the pumping station will be 45 million m^3/year (approximately 123 thousand m^3/day).

During the expansion stage, the pumps in each pumping station together with the three existing non-renewed pumps are to be replaced with dia. 450 mm x dia. 300 mm x 43.5 m^3/min. x 300 - 314 m x 3000 - 3500 kW specifications, same as the pumps renewed during the rehabilitation stage. Accordingly, all pumping stations after the expansion will operate four pumps of the same capacity. With the expansion of these pumps, the following facilities will become necessary:

* Two standby pump (kept in the store) is available at each pumping station which were procured in the rehabilitation stage and no standby pumps are procured in the expansion stage.
* One additional surge tank to be installed in each pumping station for preventing the water hammering.
* Three motors to be provided at each pumping station (same specifications as during the rehabilitation stage - reactor starting squirrel cage induction motors)(no standby motor)

The transformer capacity required for each pumping station is 20 MVA but since 20 MVA has been provided at the rehabilitation stage, no expansion is necessary.

2) Control and telemetry equipment

Since the operators have been using the monitoring and control system through graphic panels currently without any problems, the same system can be adopted in future, but because of the reasons below an overall renewal needs to be carried out.

* Existing capacity per pump (before rehabilitation) is the same at all pumping stations, and it has been designed so that the same flow rate is used at all pumping stations. In practice, however, the discharge rate of each pump is not the same at all stations. To regulate this rate, storage tanks (regulating reservoirs) were installed at all pumping stations. For this Project, however, existing tanks are to be used even after expansion to reduce costs. This will result in a reduction in the regulating capacity of the tanks. To compensate this, the degree of opening of the delivery valves should be controlled in addition to controlling the number of pumps on the pump side, which is done conventionally. Large-scale changes in the automatic control functions (software for built-in programmable controller) are needed, but the manufacturer (Bristol-Babcock of the USA) has already stopped manufacture of similar types of equipment, therefore changes in program are not possible. Moreover, procurement of spare parts for electronic equipment being used is likely to become difficult in the near future.

* The existing equipment have been manufactured in the first half of the eighties, and do not have the automatic function of generating operation and maintenance reports (daily reports).

3) Description of machinery and equipment

The machinery and equipment in each pumping station after expansion is shown in Table 12.

1. Pumps

Equipment name and items	Existing equipment 1	Existing equipment 2 (at rehabilitation)	Equipment at expansion (per pumping station)	Overall equipment after expansion (per pumping station)
Number	3 pumps (removal)	1 pump (+ 2 standby for 4 PS)	3 pumps (installation)	4 pumps (+2 standby for 4 PS)
Diameter (mm)	ϕ 350× ϕ 250	ϕ 450× ϕ 300	Same as left	Same as left
Discharge rate (per pump)	21.95m³/min.	43.5m³/min.	Same as left	Same as left
Total head (No.1 PS)	286m	300m	Same as left	Same as left
Total head (No.2 PS)	286m	300m	Same as left	Same as left
Total head (No.3 PS)	286m	308m	Same as left	Same as left
Total head (No.4 PS)	286m	314m	Same as left	Same as left
Standby pump		300 m	None	1
Standby pump		314 m	None	1
Speed of rotation	2,980 rpm	1,490 rpm	Same as left	Same as left
Impeller material	Stainless cast steel (SCS1)	Stainless cast steel (SCS1)	Same as left	Same as left
Body material	Cast steel (SC46)	Cast steel (SC46)	Same as left	Same as left
Shaft seal	Gland packing	Gland packing	Same as left	Same as left
Bearing cooling method	Oil bath + cooling water	Same as left	Same as left	Same as left
- Pump accessories				
Suction pressure gauge Number Type	 3(removal) Bourdon tube	 1 Diaphragm type	 3(installation) Same as left	 4 Same as left
Delivery pressure gauge Number Type	 3(removal) Bourdon tube	 1 Diaphragm type	 3(installation) Same as left	 4 Same as left
Other Pipes and Valves			1 set	

2. Motor

Equipment name and items	Existing equipment 1	Existing equipment 2 (at rehabilitation)	Equipment at expansion (per pumping station)	Overall equipment after expansion (per pumping station)
Number	3 (removal)	1	3	4
Type	Horizontal shaft, squirrel cage 3-phase induction motor	Same as left	Same as left	Same as left
Protection and cooling	Open type drip-proof, forced air cooling	Same as left	Same as left	Same as left
No. of poles	2 P	4 P	Same as left	Same as left
Voltage, frequency	6,600v、50Hz	6,600v、50Hz	Same as left	Same as left
Motor output (No. 1 PS)	1,850HP	3,200KW	Same as left	Same as left
Motor output (No. 2 PS)	1,850HP	3,200KW	Same as left	Same as left
Motor output (No. 3 PS)	1,850HP	3,300KW	Same as left	Same as left
Motor output (No. 4 PS)	1,850HP	3,500KW	Same as left	Same as left
Starting method	Direct line	Reactor starting	Same as left	Same as left

3. High Tension and Low Tension Facilities

Equipment name and items	Existing equipment 1	Existing equipment 2 (at rehabilitation)	Equipment at expansion (per pumping station)	Overall equipment after expansion (per pumping station)
H.T. receiving panel	Metal-enclosed, self-standing type	1 no. (removal)	Same as left, 1 no.	Same as left, 2 no.
H.T. motor panel	Same as above (including direct line starter), 3 no. (removal)	Same as left (including starting reactor), 1 no.	Same as left, 3 no.	Same as left, 4 no.
Ventilation panel	Same as above, 1 no. removal	Same as left, 1 no.	Same as left, 3 no.	Same as left, 4 no.
Modification of existing panel	- (removal)	-	1 set	-
Wires, cables	-	-	1 set	-

4. Control and Telemetry Equipment (Pumping Station)

Equipment name and items	Existing equipment 1	Existing equipment 2 (at rehabilitation)	Equipment at expansion (per pumping station)	Overall equipment after expansion (per pumping station)
Monitoring and operation panel (including graphic panel)	Metal-enclosed, self-standing type, 1 no. (removal)	-	Metal-enclosed, self-standing type, 1 no.	Same as left, 1 no.
Signal I/O panel	Same as above, 1 no. (removal)	-	Same as above, 1 no.	Same as left, 1 no.
Control telemetry equipment	1 no.	-	1 no.*	1 no.
Battery and battery charger	1 no.	-	1 no.*	1 no.
Flow meter	Ultrasonic type, 1 no. (removal in Nos. 1 and 4 PS)	-	Ultrasonic type, 1 no. (installation in Nos. 1 and 4 PS)	Ultrasonic type, 1 no.
Modification of existing VHF telephone equipment	-	-	1 set	-
Wires, cables	-	-	1 set	-

* One number of each to be installed in the Dabouk service reservoir also.

5. Delivery Valves

Equipment name and items	Existing equipment 1	Existing equipment 2 (at rehabilitation)	Equipment at expansion (per pumping station)	Overall equipment after expansion (per pumping station)
Number	3	1	3	4
Diameter (mm)	ϕ 300	ϕ 450	Same as left	Same as left
Type	Ball valve	Ball valve	Same as left	Same as left
Drive mechanism	Hydraulic	Motor driven	Same as left	Same as left
Pressure class	ANSI300	ANSI300	Same as left	Same as left

6. Delivery Side Joints

Equipment name and items	Existing equipment 1	Existing equipment 2 (at rehabilitation)	Equipment at expansion (per pumping station)	Overall equipment after expansion (per pumping station)
Number	3	1	3	4
Diameter (mm)	ϕ 300	ϕ 450	Same as left	Same as left
Material	Steel pipe	Steel pipe	Same as left	Same as left
Pressure class	ANSI300	ANSI300	Same as left	Same as left

7. Suction and Delivery Pipes

Equipment name and items	Existing equipment 1	Existing equipment 2 (at rehabilitation)	Equipment at expansion (per pumping station)	Overall equipment after expansion (per pumping station)
No. of sets	3	1	3	4
Diameter (mm)	ϕ 300	ϕ 450	Same as left	Same as left
Material	Steel pipe	Steel pipe	Same as left	Same as left
Pressure class	ANSI300	ANSI300	Same as left	Same as left

8. Surge Tank

Equipment name and items	Existing equipment 1	Existing equipment 2 (at rehabilitation)	Equipment at expansion (per pumping station)	Overall equipment after expansion (per pumping station)
Type	Horizontal		Horizontal	Horizontal
Size(cm)	D 1,900x10,700		D 1,900x10,700	D 1,900x10,700
Pressure class	ANSI300		ANSI300	ANSI300
Number	1		1	2

(4) Basic Design Drawings

Fig. 1 Plan view of No. 1 pumping station

Fig. 2 Plan view of No. 2 pumping station

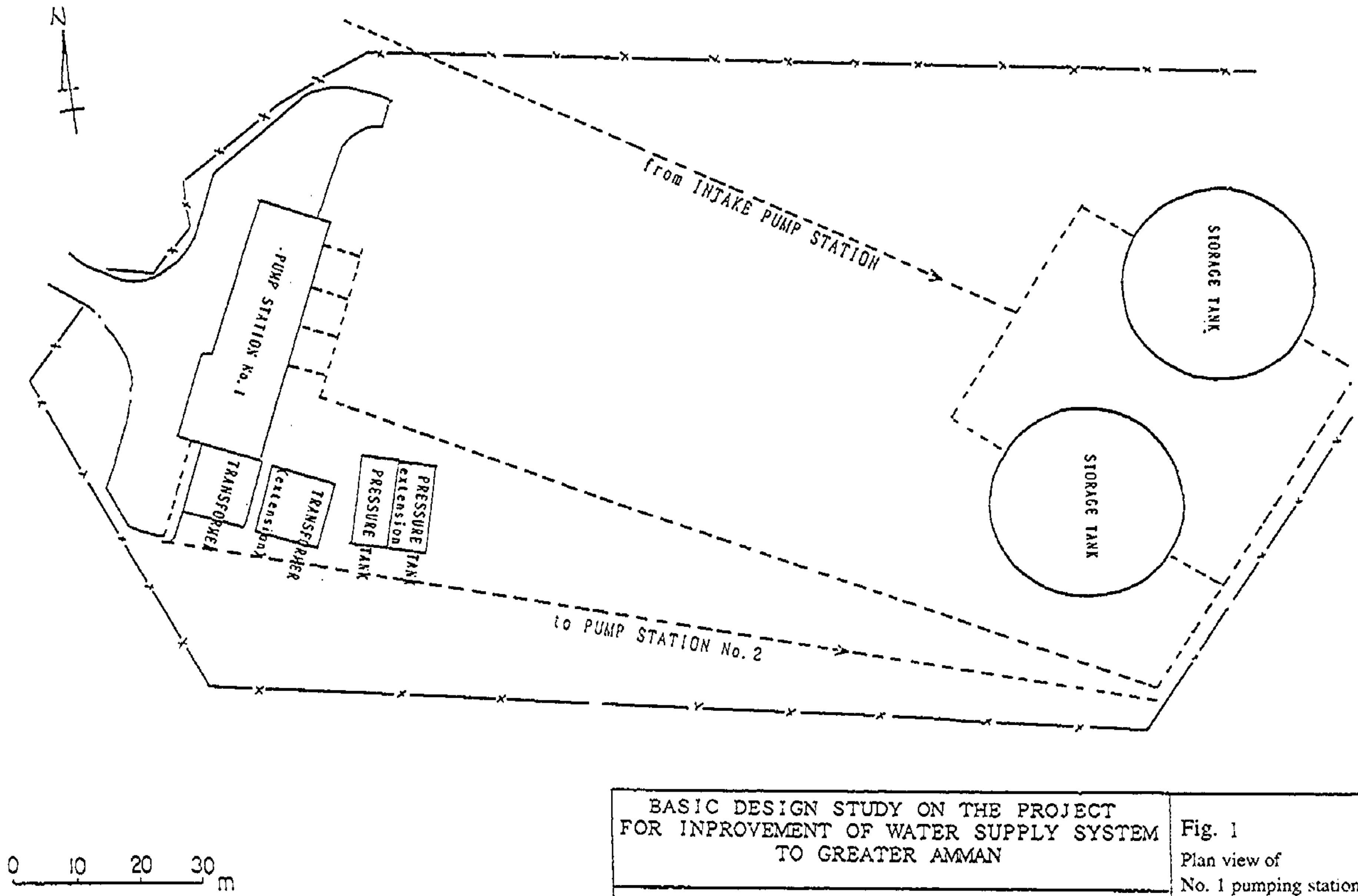
Fig. 3 Plan view of No. 3 pumping station

Fig. 4 Plan view of No. 4 pumping station

Fig. 5 Layout of equipment in pumping station (No. 1 to No. 4)

Fig. 6 Wiring diagram of pumping station

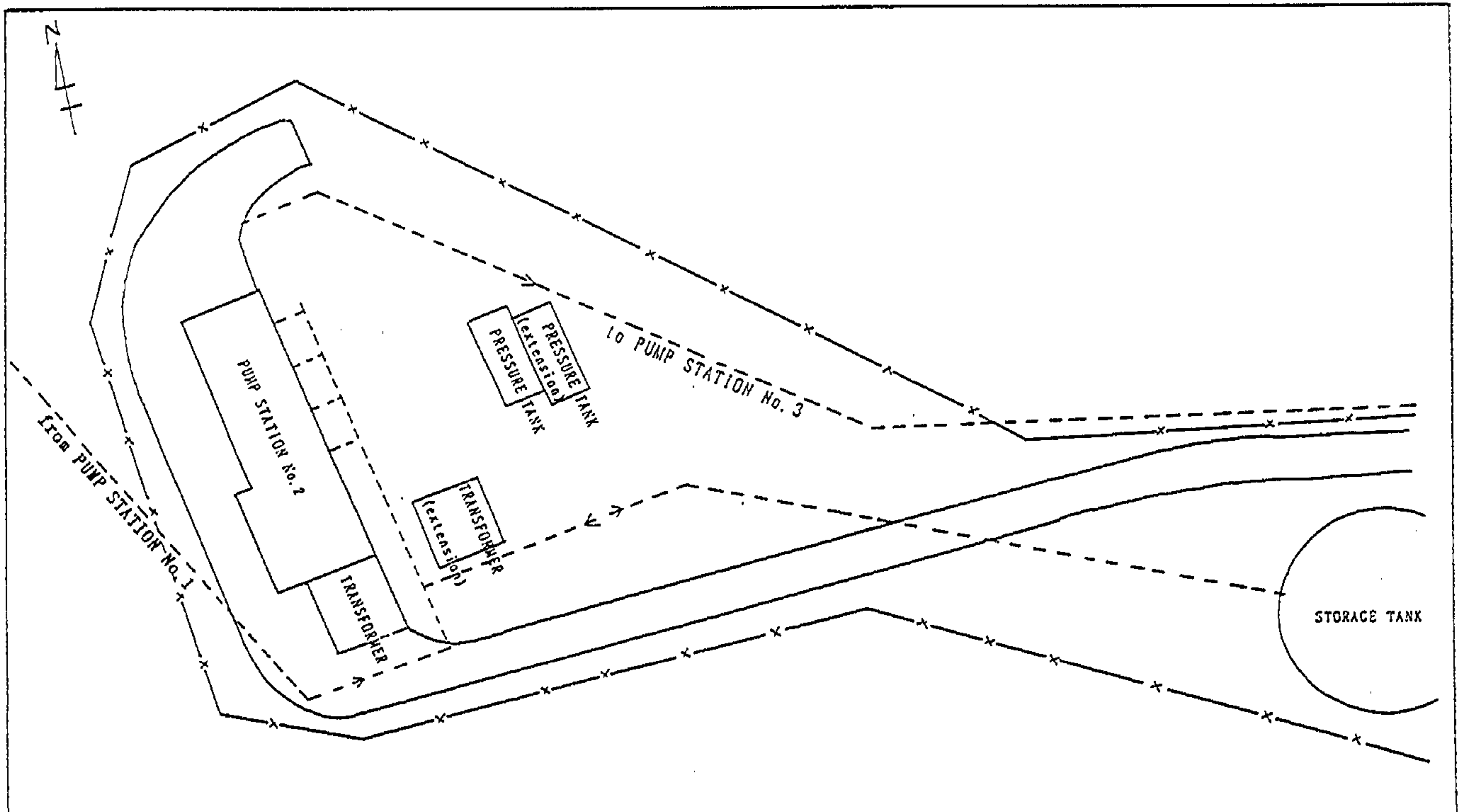
Fig. 7 Single line diagram of pumping station



BASIC DESIGN STUDY ON THE PROJECT
FOR INPROVEMENT OF WATER SUPPLY SYSTEM
TO GREATER AMMAN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 1
Plan view of
No. 1 pumping station



BASIC DESIGN STUDY ON THE PROJECT FOR INPROVEMENT OF WATER SUPPLY SYSTEM TO GREATER AMMAN

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Fig. 2
Plan view of
No. 2 pumping station

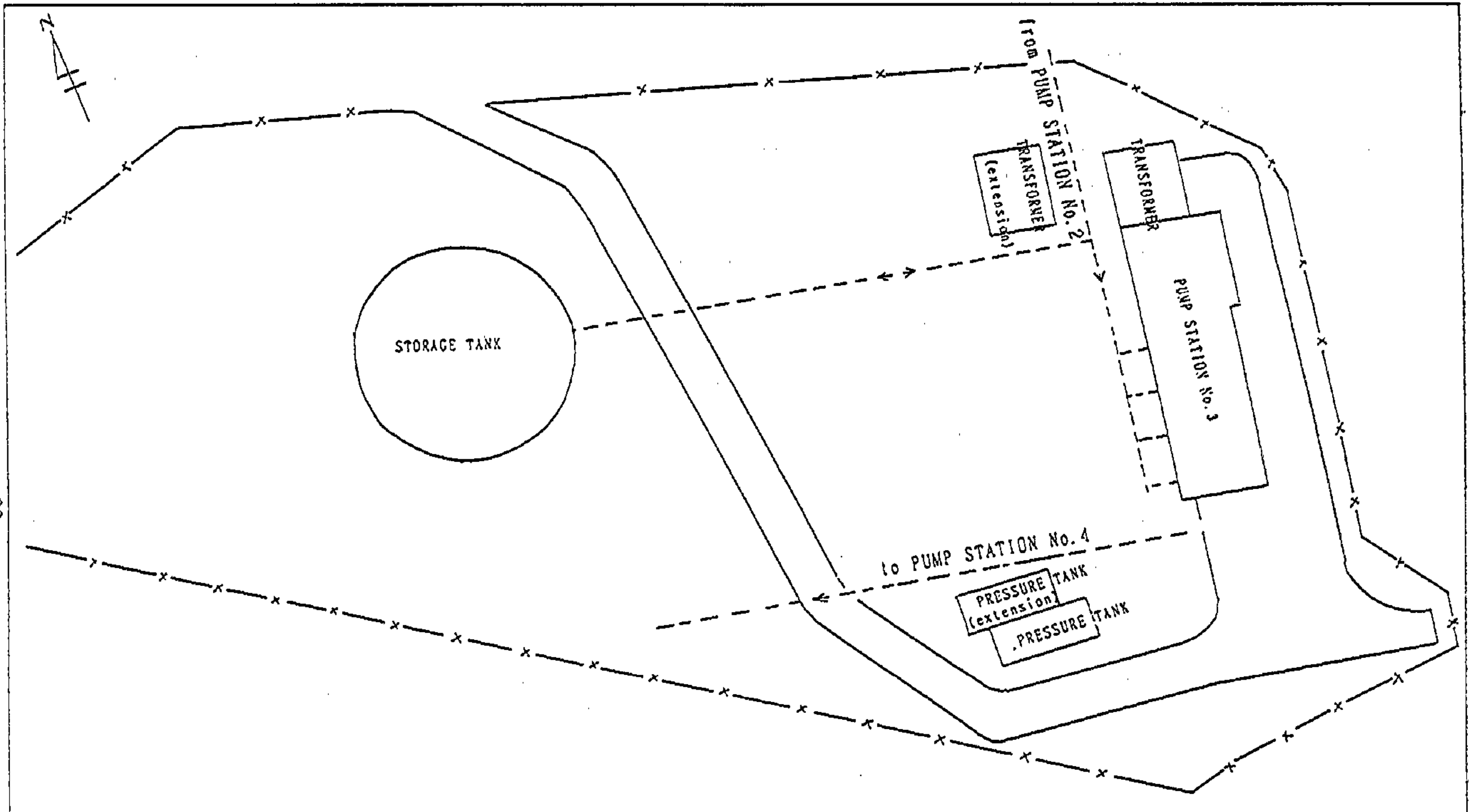

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Fig. 3
Plan view of
No. 3 pumping station

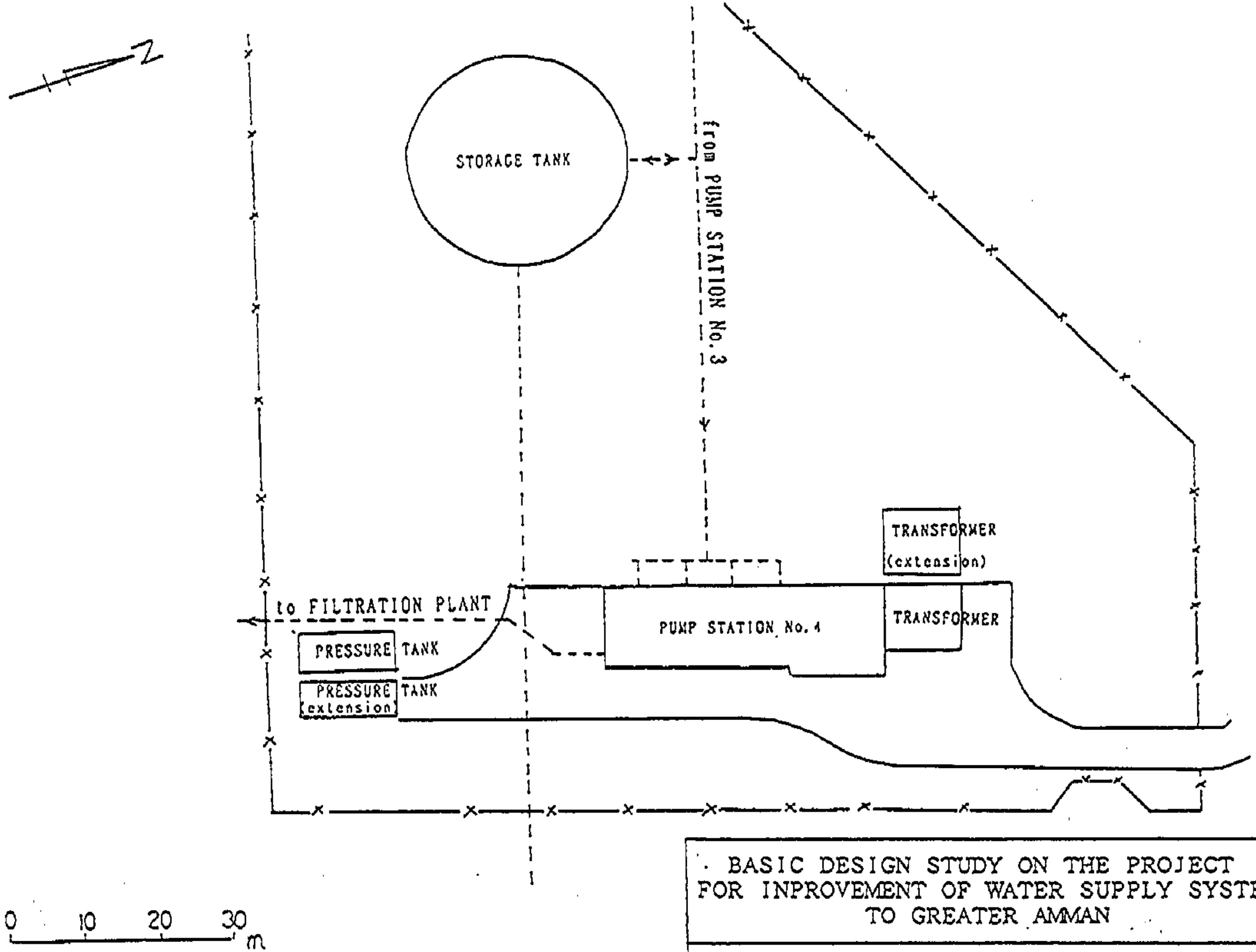

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Fig. 4
Plan view of
No. 4 pumping station

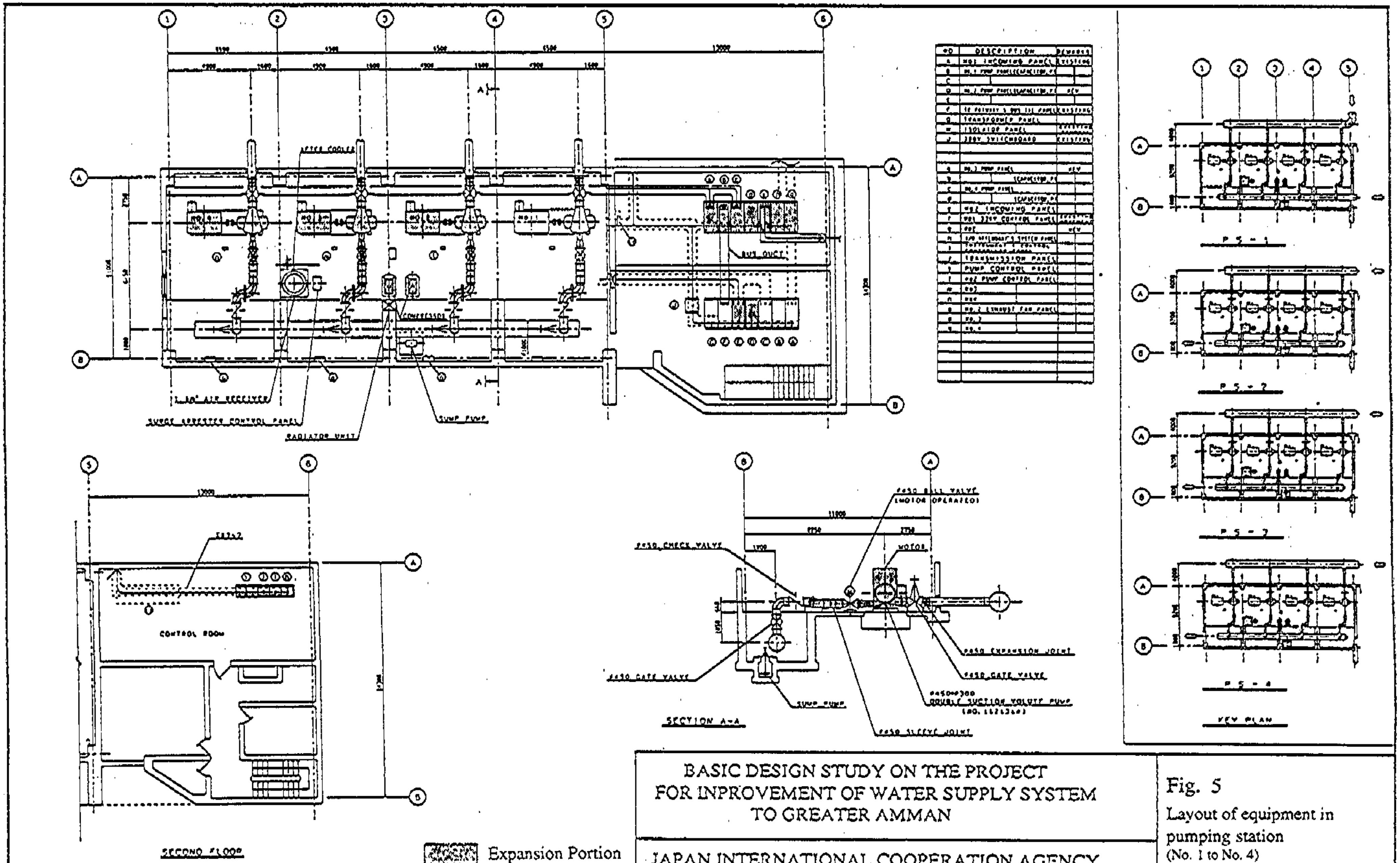

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Fig. 5
Layout of equipment in pumping station
(No. 1 to No. 4)

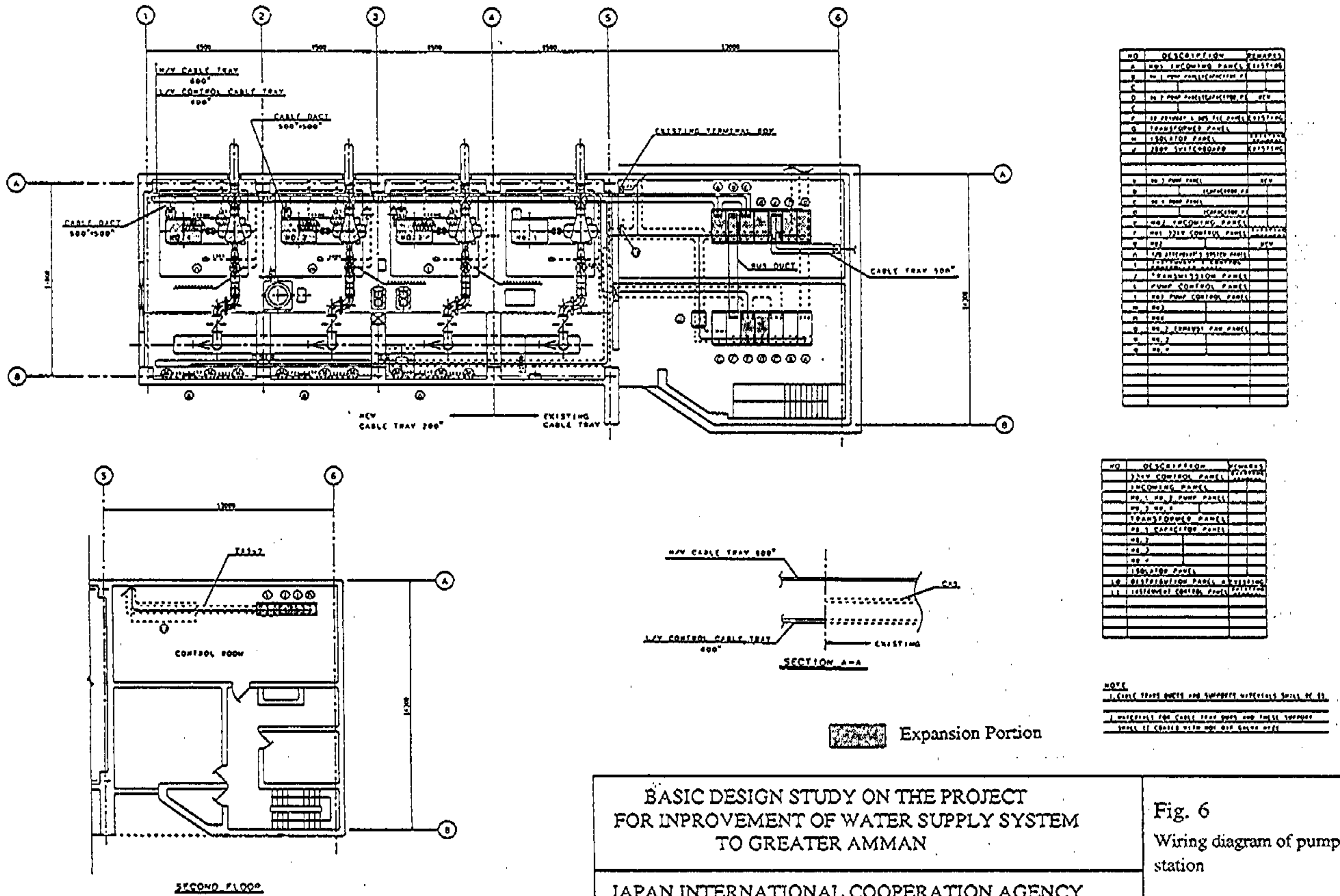

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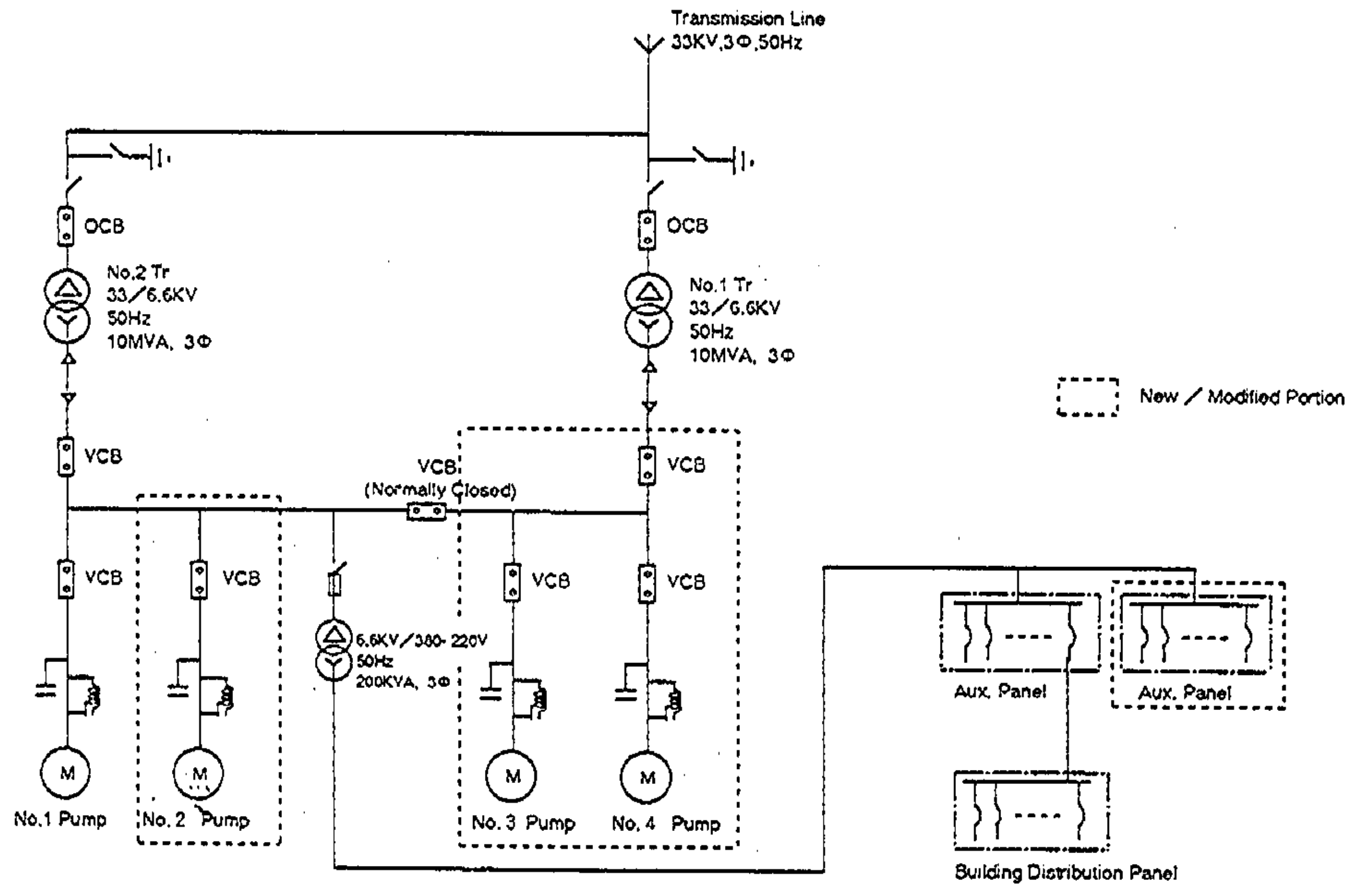
Fig. 6
Wiring diagram of pumping station



No.1 PS	3,200KW	3,200KW	3,200KW	3,200KW
No.2 PS	〃	〃	〃	〃
No.3 PS	3,300KW	3,300KW	3,300KW	3,300KW
No.4 PS	3,500KW	3,500KW	3,500KW	3,500KW

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Fig. 7
Single line diagram of pumping station

(2) Status of Water Quality in Zai Treatment Plant

For the expansion of treatment plant, the current status of quality of water in the Zai treatment plant are investigated together with treatment methods using dosing devices.

The monthly average values of main properties of raw and treated water in the Zai treatment plant for the months from January 1994 to September 1997 are given in the table below.

Table 9 Average Properties of Water in the Zai Treatment Plant

Water properties	Raw water	Treated water
Alkalinity (mg/l)	157 - 264	152 - 221
pH value	8.06 - 8.50	7.74 - 8.10
Hardness (mg/l)	248 - 316	246 - 314
Electric conductivity (us/cm)	589 - 989	591 - 996
Turbidity (NTU)	4.9 - 207	0.00 - 0.17
Total suspended solid (mg/l)	554 - 981	484 - 631
Total trihalomethane T-THMs (mg/l)	-	0.032 - 0.091
Fecal coliform(MPN/100ml)	142 - 4,940	0.0

(* According to individual values from January 1995 to September 1997)

From the table above, the main water properties are as follows:

* The concentration of soluble inorganic salts of calcium, magnesium etc. is high, therefore the alkalinity, pH value, hardness, electric conductivity, and TDS are all at a high level. However, all the treated water properties satisfy the water quality standards for drinking water in Jordan and are within the permissible limits.
* The variation in turbidity of raw water is large, and rather high values are attained, but the turbidity of treated water is stable and at a low level.
* The level of THM is quite high. The properties of tap water have not been measured but if the retention time is prolonged, there is a high possibility that the standards (tentative) for tap water of 0.1 mg/l will be exceeded.
* The level of fecal coliform in raw water is quite high, but almost negligible in treated water. Disinfection is adequate.
* For detecting heavy metals, tests were carried out from January 1996 to detect the presence of zinc, chrome, cadmium, cobalt and copper, but the levels of all these elements were quite low and did not pose any problem. However, compared to the maximum value of cadmium of 0.0005 mg/l according to the water quality standards, the detection limit is about 0.02 mg/l, therefore, a modification of the analytical method is recommended.

The main properties of raw water in the Zai treatment plant and of the water in the Deir Alla for the months from January 1996 to September 1997 are given in the table below.

Table 10 Main Properties of Zai and Deir Alla

Water Properties	Unit	Deir Alla			Raw Water at Zai		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Alkalinity	mg/l	243.87	157.44	203.34	252.23	166.29	208.12
pH value	-	8.35	8.19	8.25	8.43	8.27	8.36
Hardness	mg/l	215.89	248.48	277.64	315.68	247.92	278.73
Corrosion index	-	12.91	12.41	12.75	13.00	12.71	12.87
Turbidity	mg/l	60.90	4.85	18.50	102.28	9.04	31.28
Color	mg/l	612.73	42.97	252.86	500.73	60.33	285.03
Electric conductivity	us/cm	988.57	700.45	856.41	982.86	714.80	853.79

The ratio of the average water properties at the both sites and their correlation factors are given in the table below.

Water Properties	Deir Alla / Zai	Correlation Factor
Alkalinity	0.977	0.9806
pH value	0.987	0.0766
Hardness	0.996	0.9966
Corrosion index	0.991	0.8630
Turbidity	0.591	0.9768
Color	0.887	0.9403
Electric conductivity	1.003	0.9951

The water properties at Deir Alla are almost equal to those at Zai except turbidity and color. The turbidity and color at Deir Alla are lower than those at Zai. However, the difference will not affect the dosing ratios of coagulant and coagulant aid because the turbidity does not have any linkage with dosing ratios of coagulant and coagulant aid.

The correlation factors of the water properties show high value except pH value. The pH values show similar values although the correlation factor is small.

Accordingly, from the above results, the dosing ratios of chemicals will be the same ratios of the past.

However, TOC and COD data for organic substances is very meager, and analysis is very difficult more so because the sampling points are not consistent, therefore the main sources of THM precursor substances are not known. However, if activated carbon is used as a measure against THM, dosing devices that inject a larger percentage of chemicals than now should be used. The judgment on the need for such equipment and expansion is entrusted to the Jordanian authorities, and is not considered in this Project. (Refer to Appendix 7)

(3) Current Status of Dosing Devices

Dosing devices installed currently in the Zai treatment plant are as given in the table below.

Table 11 Existing Dosing Devices

	Average dosage (mg/l)	Maximum dosage (mg/l)
Pre-chlorination	3	6
Intermediate chlorination	1	3
Post chlorination	0.5	1
Aluminum sulfate	10	40
Caustic soda (25% solution)	5	10
Activated carbon (powder)	2	10
Potassium permanganate	2	5
Polymer (cation)	1	2
Polymer (anion)	0.02	0.04

The monthly average dosage during January 1994 to September 1997 is given in the table below.

Table 12 Average Dosage of Chemicals

Dosing device	Average dosage (mg/l)
Post chlorination	2.27 - 4.00
Aluminum sulfate	16.24 - 22.71
Activated carbon (powder)	0.58 - 2.97
Potassium permanganate	0.77 - 3.05
Polymer (cation)	0.00 - 1.99

* Pre-chlorination and post chlorination are not being used to prevent from forming THM.

* Caustic soda is not used because the pH value and alkalinity levels of raw water are high.

* Organic polymer (anion) is not used because it is not required for coagulation.
* Softening agents are not used because the TDS and total hardness of treated water are considerably less than the maximum values of 1500 mg/l and 500 mg/l respectively, required by the water quality standards.
* Activated carbon is being used to eliminate foul odors.
* Potassium permanganate is used because it oxidizes organic substances and reduces the precursors of THM. The dosage is set so that a faint red color remains during jar test.
* The dosages of aluminum sulfate and polymer (cation) are set by the jar test carried out three times a day.
* In addition to the chemicals mentioned above, copper sulfate is also used for eliminating algae etc.

(4) Dosage of Chemicals in Future

a) Caustic soda and organic polymer (anion)

Considering the raw water quality and the high coagulation effect currently, these chemicals are not likely to become necessary in the future. Consequently, it is not necessary to install dosing devices for these chemicals.

b) Softening agent

If the target values of TDS and total hardness are to be less than the maximum values according to water quality standards in the future, it is not necessary to install dosing devices.

c) Aluminum sulfate and organic polymer (cation)

Turbidity is being kept at an adequately low level by water treatment currently. The dosages of aluminum sulfate and polymer cation was 17.10 to 27.20 mg/l and 0.35 to 1.07 mg/l respectively on days when the raw water turbidity indicated the maximum or minimum value in 1995. Almost no correlation of these chemicals was observed with raw water turbidity. Consequently, it is not necessary to change the dosage of aluminum sulfate and polymer (cation) appreciably in the future.

d) Chlorination

Since the THM in treated water may reach a considerably high level, chlorination should be only post chlorination.

Presently, disinfection against fecal coliform, which are indicators of disease-causing germs, is adequate. However, according to test results until 1995, some counts of heterotrophic bacteria/ml have been detected in the treated water, therefore reducing the existing chlorination dosage against THM is not recommended.

e) Potassium permanganate

It is likely that potassium permanganate is dosed with the purpose of oxidizing organic substances and reducing the amount of THM generated, but since tests on items that become indices of organic substances are not being carried out, the effects of reduced THM cannot be quantitatively studied.

The dosage is set so that a slight red color remains during the jar test. If the dosage is increased above this level, the permanganate ions are likely to break through during treatment, therefore the dosage should not be increased above the current level.

f) Activated carbon (powder)

Activated carbon is currently introduced for eliminating foul odors, and the average maximum monthly dosage is less than 3 mg/l, therefore, it does not have an appreciable effect on reducing THM. If activated carbon (powder) is to be used for reducing THM, it is necessary to install equipment that doses a larger amount of carbon. However, the existing dosage is maintained in this Project. (Refer to Appendix 7)

(5) Treatment Process

If the treated quantity of water is to be increased by modifying the existing facilities, extensive modifications over a long period are necessary, and the stoppage time of existing facilities become prolonged. It is impractical to stop the existing water treatment plant for modifications because nearly half the demand of Amman city is being satisfied by the treatment plant. Therefore, conventional facilities should be expanded, additional facilities similar to existing facilities installed by the concept described below.

1) Design concept

a) The existing water treatment process (coagulation, settlement, rapid filtration) gives satisfactory results, and satisfactory results are anticipated for water quality in future. Moreover, the staff have become proficient in the operating the existing treatment plant, therefore, the water treatment process during the expansion stage should be the same as the existing process.

b) Changes to the dosing devices below, should be carried out as mentioned previously.

* Anion-based polymer dosing device, caustic soda dosing device and water softening equipment are not being used, and are not likely to be used in the future. They should be discarded.
* Six types of chemicals - for intermediate chlorination (dosage 3 mg/l, same units hereafter),

for post-chlorination (1), aluminum sulfate (40), activated carbon powder (10), potassium permanganate (5) and cation-based polymer (2) are being used and need to be used in the future. The additional dosing devices for the six types of chemicals should be installed in the spaces of equipment that have been discarded, as mentioned above.

* Activated carbon dosing devices installed for eliminating foul odors are considered to be effective when used for preventing from forming THM, but are not considered for this Project. (Refer to Appendix 7)

c) Raw water regulating basins, wash water basins, clean water reservoirs and clean water tanks have adequate capacity for the Project, hence no expansion is necessary.

d) Design standards of the existing facilities should be used for all expansion facilities, buildings, machinery and equipment (mixing basins, flocculation basin, settling basin, rapid filter basin, generator building, chemicals storage building, water lift pumps, etc.) and same facilities should be added. However, the capacity of wash water pump should be at least 10.4 m^3/min., larger than the capacity of the existing pump (7.2 m^3/min.) and two of these pumps should be installed.

2) Facilities to be expanded

Based on the result of the investigations above, the facilities to be expanded in the Project are shown in Table 13.

Table 13 Water Treatment Facilities to be Expanded

Facility	Description
Dosing devices	Cation-based polymer dosing pump, chlorinator and dosing devices, pumps for dosing aluminum sulfate
Coagulation/settlement equipment	Mixing basin - 1, flocculation basin - 2, settling basins 2, rapid mixers - 2, flocculators - 18, sludge extractors - 2
Rapid filtration equipment	Filter basin (dual media) - 6, Filter effluent weir - 1, Wash water pump - 2, Drain recovery pump - 2
Sludge drying bed	2 Existing drying floors removed and relocated
Connection pipes and drain pipes in pumping station	Additional connection pipes between raw water regulating basins to rapid mixing basins and between filter basins and clean water reservoir, additional drain pipes for sludge and wash water from settling basin and filter basin
Generators and generator building	Diesel generator (250 kVA) as minimum standby power source for emergency and additional generator building
Chemicals storage building	Relocation and expansion of existing chemicals storage building
Electrical, monitoring and control panel equipment	Additional electrical equipment for receiving and distributing power, and new operation control equipment for dosing devices and water treatment equipment

(6) Facilities Plan

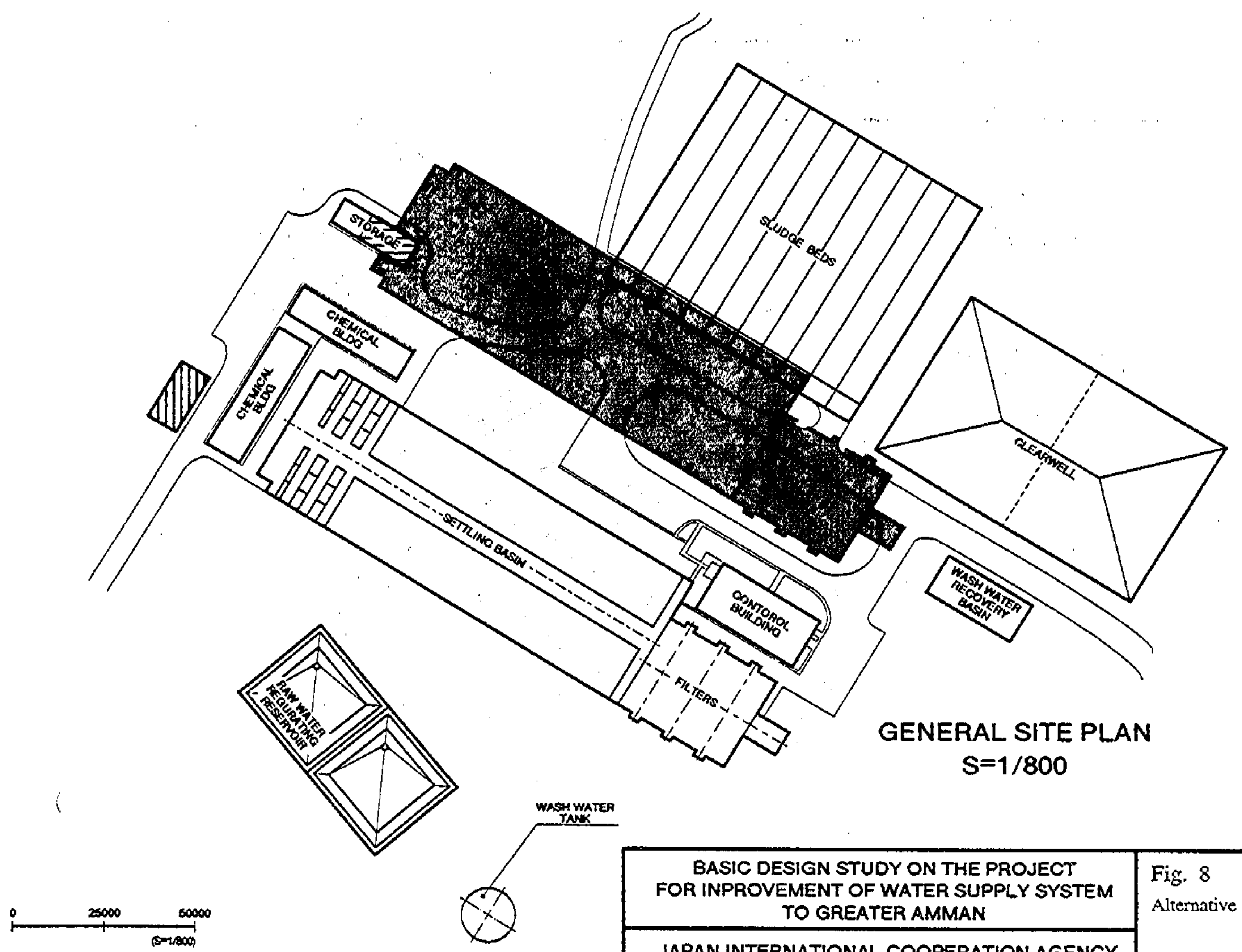
1) Layout plan

After studying the layout of expansion facilities given in Table 14 to further accommodate facilities in the empty spaces of existing treatment plant using the treatment process described above, Alternative 1 was selected because of the reasons below.

* The management staff of the treatment plant are proficient in the operations of the existing plant.
* Removal/modification of the dosing building is not necessary.
* Adequate space for road for inspection and maintenance even after expansion is available.
* Construction cost of expansion facilities is economical.

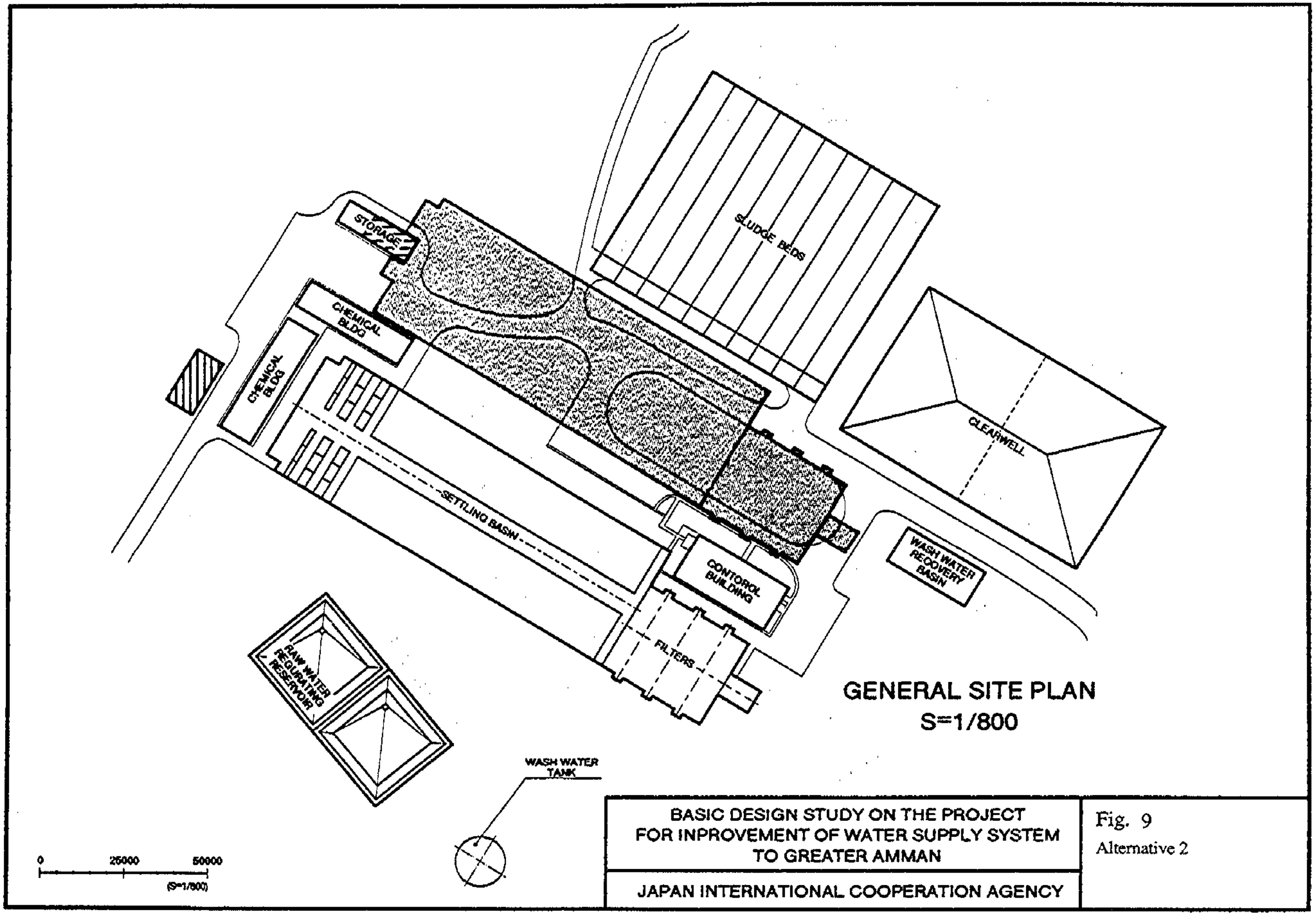
Table 14 Comparison Table of Arrangement Plans for Treatment Facilities

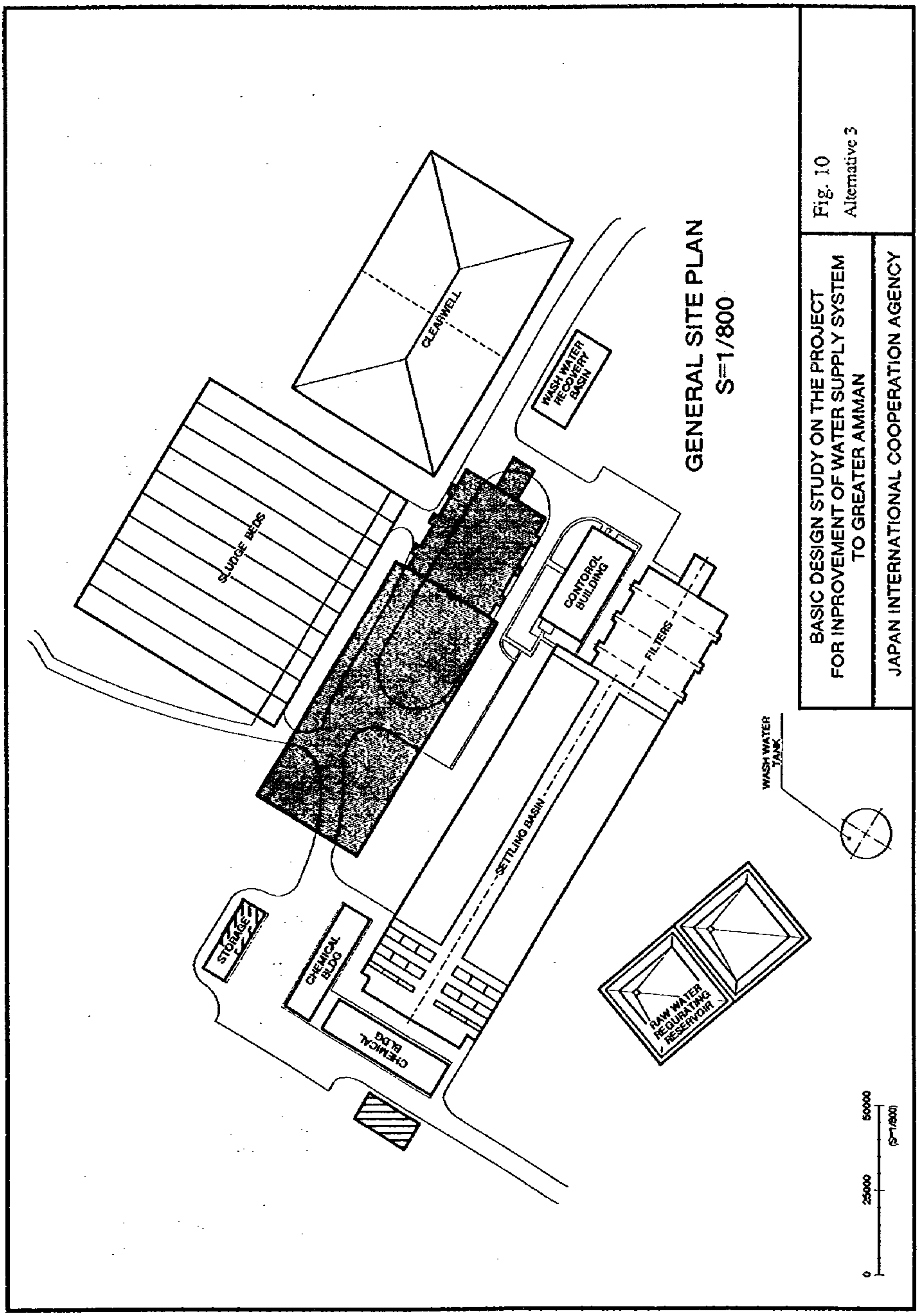
Item	Alternative 1	Alternative 2	Alternative 3
Conditions of arrangement plan	1) Same facilities as existing settling basin and filter basin 2) Tear down the chemicals storage building	1) Same as left 2) Locate the expansion facilities adjacent to the existing facilities	1) Decrease the volume of settling basin by using inclined plates
Operations and maintenance	1) Same as existing facilities, maintenance is easier	1) Same as left	1) Operating method of settling basin is complex compared to existing settling basin
Structures to be relocated	1) Relocation of control cables to sludge drying floor / filter basin, wash water drainage basin 2) Remove part of sludge drying floor and install two new basins in its place	1) Same as left 2) Relocation of electric room, generator room, workshop in the dosing building	1) Same as left
Stoppage period due to work	1) For a short period	1) Long period stoppage of water treatment plant necessary for moving electric panels in the dosing building	1) For a short period
Maintenance and inspection road	1) Adequate space for road for maintenance and inspection available 2) Clean water reservoir covers need to be reinforced for modifying road for maintenance and inspection by the side of the clean water reservoir	1) Difficult to construct a motorable road between main building and filter basin 2) Maintenance of settling basins is not possible because space for large vehicles to pass between basins is not available	1) Almost no space for a road between the main building and the filter basin building
Construction cost	Small	Large	Large
Maintenance cost	Small	Small	Large
Selected	O		



GENERAL SITE PLAN
S=1/800

BASIC DESIGN STUDY ON THE PROJECT FOR INPROVEMENT OF WATER SUPPLY SYSTEM TO GREATER AMMAN	Fig. 8 Alternative 1
JAPAN INTERNATIONAL COOPERATION AGENCY	


STORAGE
CHEMICAL BLDG
CHEMICAL BLDG
SLUDGE BEDS
CLEARWELL
SETTLING BASIN
CONTOROL BUILDING
WASH WATER RECOVERY BASIN
FILTERS
RAW WATER REGURATING RESERVOIR
WASH WATER TANK
GENERAL SITE PLAN
S=1/800
0
25000
50000
(S=1/800)
BASIC DESIGN STUDY ON THE PROJECT
FOR INPROVEMENT OF WATER SUPPLY SYSTEM
TO GREATER AMMAN
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 9
Alternative 2


GENERAL SITE PLAN
S=1/800
CLEARWELL
WASH WATER RECOVERY BASIN
SLUDGE BEDS
CONTOROL BUILDING
FILTERS
SETTLING BASIN
WASH WATER TANK
STORAGE
CHEMICAL BLDG
CHEMICAL BLDG
RAW WATER REGURATING RESERVOIR
0
25000
50000
(S=1/800)
BASIC DESIGN STUDY ON THE PROJECT
FOR INPROVEMENT OF WATER SUPPLY SYSTEM
TO GREATER AMMAN
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 10
Alternative 3

2) Facilities plan

Following the existing treatment process, water treatment facilities are expanded on a similar scale. All structures are arranged to present a good balance, and roads of adequate width provided for easy access to repairs and also for easy access to large vehicles for transporting materials for maintenance. Mixing basins, flocculation basins, settling basins and rapid filter basins of the same type and size are arranged.

Table 15 shows the number, size and scale of basins, structures to be expanded.

Table 15 Expansion of Water Treatment Facilities

Structure		Existing facility	Expanded facility
Raw water regulating basin	No. of basin	2	Not expanded. Existing one used
	Size	32 m x 32 m x 5 m	
	Volume	10,240 m^3	
	Retention time	2 hours	1 hour
Mixing basin	No. of basin	1	Same as left
	Size	17.7 m x 2.5 m x 1.8 m	Same as left
	Volume	80 m^3	Same as left
	Retention time	1 minute	Same as left
Flocculation basin	No. of basin	2 basins x 3 sections (per basin)	Same as left
	Size	5.8 m x 18.0 m x 4.5 m	Same as left
	Volume	1,410 m^3	Same as left
	Retention time	33分	Same as left
	Average flow rate	53 cm/min.	Same as left
Settling basin	No. of basin	2	Same as left
	Size	95 m x 18 m x 4.5 m	Same as left
	Surface load ratio	1.5 m/hour	Same as left
	Average flow rate	53 cm/min.	Same as left
Filter basin	No. of basin	6 (dual filter)	Same as left
	Size	9.6 m x 4.6 m x 2 filter media	Same as left
	Filtration area	88.32 m^3	Same as left
	Anthracite	600 mm	Same as left
	Sand	300 mm	Same as left
	Gravel	300 mm	Same as left
	Collection equipment	Nozzle-type, 868 m3/min.	Same as left
	Filtering speed	232 m/day	Same as left
Filter effluent weir	No.	1	Same as left
	Size	5.2 m x 7.5 m x 3.9 m	Same as left
	Volume	152 m^3	Same as left
	Retention time	1.83 min.	Same as left
Filter wash water basin	No.	1	Not expanded. Existing one used
	Size	26 m x 12 m x 3.95 ~5.3 m	—
	Volume	1,440 m^3	—

	Quantity from 1 filter	894 m^3	—
	Wash water return time	120 min.	60 min.
Wash water tank	No.	1	Not expanded. Existing one used
	Size	16 m x 7 m	—
	Effective volume	1,410 m^3	—
	Wash water pumping	43 min. (spare pump is also	44 min.
Clean water basin	No.	2	Not expanded. Existing one used
	Size	50 m x 40 m x 5 m	
	Volume	20,000 m^3	
	Retention time	3.9 hours	1.9 hours
Sludge drying bed	No.	10	Two beds relocated
	Volume	605 m^2 x 10 m= 6,050 m^3	605 m^2 x 2 = 1,310m^3
Generator, electric equipment and store house	No.	1	1
	Size	35.7 x 9.6 m	32 m x 8 m
	Area	343 m^2	256 m^2 RC
Chlorination, chemical store building	No.	1	1
	Size	39.6 x 9.6m	25m x 8 m = 200m^2
	Area	380 m^2	184 m^2 Store
			64 m^2 Chlorination

3) Structure plan

The existing walls of the settling basin has a retaining-wall structure and the base has a very thin structure (bedrock of the saddle between mountains has been excavated to a depth of about 10 m, grouted with cement and the structure placed thereon). Results of soil surveys showed that the supporting bedrock for the settling basin to be expanded, is 6.5 m above the ground surface at the upstream end of the settling basin, and 7m at the downstream end. The base of the settling basin is 5.3 m from the ground surface, and does not reach the bedrock. Consequently, the base foundation is to be stabilized by broken stones and by using rigid frame construction for the settling basin in order to prevent chafing and unequal settlement of the bedrock.

The treatment plant (and the pumping station) is located in the Jordanian fault zone, therefore the seismic forces need to be considered. The settling basin and the filter basin are underground structures, therefore the effect of the seismic forces is small, but buildings are above-ground structures and the effect of the seismic forces is large. The existing buildings of the pumping station and the treatment plant comply with the Uniform Building Code, Zone 4, seismic coefficient 0.4, therefore the columns and beams are massive structures. Accordingly, for the design, the standard design level seismic coefficient is taken as 0.2, based on Japanese Road and Bridge Construction Standards, and the conditions of the foundation, and other important correction coefficients are considered separately for seismic design.

(7) Machinery and Equipment Plan

Water treatment machinery and equipment for this Project can be broadly divided into dosing devices, water treatment equipment and electric/monitoring and control equipment. The description of machinery and equipment for the Project is given below.

1) Dosing devices

Since there are chemicals not currently used and some dosing points have been changed, plans for equipment and pipelines for this Project are based on the conditions below, after considering automatic dosing methods proportional to the flow rate.

a) Aluminum sulfate

Introduced in the mixing basin. Two dosing devices are used presently; two new dosing devices and two new pumps are to be installed.

b) Cation-based polymer

Pipelines are to be installed so that the polymer can be introduced as a coagulant aid before dosing aluminum sulfate, and for micro-flocculation of fine particles in the settling basin effluent weir. Only two new pumps are to be installed for dosing the settling basin effluent weir.

c) Chlorination

Intermediate chlorination (settling basin effluent weir), post chlorination (filter basin discharge pipe) and supplementary chlorination (clean water basin discharge pipe) are to be carried out but not pre-chlorination. Three chlorinators are used presently; these should be used for intermediate chlorination and post chlorination/ supplementary chlorination for one system. New facilities will include two dosing devices and vaporizers. Dosing for intermediate chlorination and post chlorination will be carried out.

Based on the plan above, the equipment to be newly installed are listed in Table 16.

Table 16 Dosing Equipment Provision Plan

Dosing equipment	Existing Equipment	Expanded Equipment
Potassium permanganate for raw water regulation basin 1 each	Hopper, feeder, dosing pump	-
Activated carbon for raw water regulation basin, prior to 1 each mixing basin, settled water	Hopper, feeder, dosing pump	-
Aluminum sulfate for mixing basin 2 each	Hopper, feeder, dosing pump	Same as left
Polymer coagulant (cation) prior to mixing basin	Solution tank 1, Storage tank 1 Dosing pump 2	Dosing pump 2
Polymer coagulant (Anion) for settled water	Solution tank 1, Storage tank 1 Dosing pump 2	Used for cation
Caustic soda	Softener, Dosing pump 2 Nos. each Storage tank 1 No.	No use
Chlorination	Chlorinator (37.5kg/h), 3 Nos. Vaporizer, 2 Nos.	Chlorinator (40kg/h), 2 Nos. Vaporizer, 2 Nos.

2) Water treatment machinery and equipment

New machinery and equipment (rapid mixer, flocculator and settling basin sludge extractor) to be installed in the mixing basin, the flocculating basin, settling basin and rapid filter basin will be of the same grade as the existing machinery and equipment.

The existing flocculator is a vertical-axis type but generally, the mixing effect is not always satisfactory compared to the horizontal-axis type flocculator. However, the settling effects are currently satisfactory, and considering the convenience of the operators and maintenance staff, vertical-axis type flocculators, same as the existing ones will be used.

Existing sludge extractors are pump suction type extractors. Since the turbidity of raw water is low, the amount of aluminum sulfate used is about half the independent dosage of aluminum sulfate by dosing polymer coagulant. Consequently, the sludge generated is reduced, and a pump suction type sludge extractor can be used. This situation is not expected to change in the future, therefore the same type of sludge extractor should be used in the future.

The dual-layer filtering method using anthracite and sand can filter water at high speed, developed in the USA. In most cases, the filtering speed is 15 m per hour (single layer filtering method using sand gives about 5 to 6.25 m/hour in Japan). For the same continuous filtration time, the particle diameter in the filter layer should be increased and the filter layer should have a larger thickness in order to maintain the high filtering speed. The table below shows the comparison of the US facility and the Zai water treatment plant.

Table 17 Comparison of Filtering Materials

Item		US example	Zai treatment plant
Anthracite	Particle diameter	1.1 - 1.2mm	0.99m
	Layer thickness	760mm	600mm
Sand layer	Particle diameter	0.6mm	0.55mm
	Layer thickness	300mm	300mm
Filtering speed		15m/hour	9.83m/hour

The capacities of the wash water pump and wash water drain recovery pump are determined based on the operating conditions of the filter basin.

Table 18 shows the machinery and equipment to be newly installed according to the plan described above.

Table 18 Water Treatment Machinery and Equipment Plan

Equipment	Specifications of equipment	Quantity
Rapid mixer	No.1 : Vertical paddle type, made of stainless steel	1
	No.2 : Vertical paddle type, made of stainless steel	1
Flocculator	No.1 : Vertical vortex type, made of stainless steel	6
	No.2 : Vertical vortex type, made of stainless steel	6
	No.3 : Vertical vortex type, made of stainless steel	6
Sludge extractor	Type : Moving sludge pump, max. speed: 3 m/min., minimum speed: 0.3 m/min. Sludge pump 340 l/min. x 5 m Cable winding method: Drum type	2
Filter basin wash water pump	Type: Vertical type pump, diameter 300 mm x pumping capacity 8.4 m^3/min. x head 20 m	2
Filter basin wash water drain recovery pump	Type: Vertical type pump, diameter 300 mm x pumping capacity 10.5 m^3/min. x head 22 m	2
Sampling pump	At 4 locations - raw water, filtered water (collector), post chlorination and treated water Pump type: Centrifugal, diameter 25 mm x capacity 80 l/min. x head 15 m	4

3) Electric/ monitoring and control equipment

Existing water treatment facilities have been constructed with US aid, and the entire water treatment plant is built according to the US style, adopting the central monitoring and remote operation system. The intake/conveyance pumping stations are remotely operated/ controlled from the treatment plant while monitoring the water level in the raw water regulating reservoir. Changes in dosage in the treatment plant, changeover of pump operations in the plant, and operation of sludge extractors are also controlled from the control panel of the central control room. The washing of the filtering basin is incorporated in the wash process sequence and is carried out automatically every 12 hours.

These equipment are sophisticated, but considering the balance of existing facilities and technical level of the staff, maintenance of the equipment can be carried out by the staff, therefore, equipment with the same concepts should be used for the expansion portion.

Plans for electric power receiving and distribution equipment for operating the dosing devices, treatment equipment, pumps and filter basin power valves, operation monitoring and control panel equipment for various pumping stations and treatment plants, and diesel generators used as standby power sources for operation monitoring and control equipment and filter basin operation panels are based on the conditions given below.

Power is currently being received at two locations - dosage and coagulation/ sedimentation basin equipment system and filter basin equipment /maintenance building system, and each system supplies power after reducing the voltage to various machinery and equipment. For the expansion facilities, the dosage and coagulation/ sedimentation basin equipment system and filter basin equipment /maintenance building system should be integrated to a single system for receiving power.

The control and telemetry equipment for pumps installed in the Zai system should be renewed because the automatic control functions of pumps need to be changed. The operators have become proficient in operating the monitoring and control system of the water treatment plant using the currently installed graphic panels therefore, the existing system should be incorporated in the expansion facilities. However, the function of generating automatic operation reports (daily reports) should be incorporated and existing equipment used during the expansion stage.

As minimum safeguards against power failure, a diesel generator (capacity 250 kVA, together with fuel tank and hoist crane as accessories) should be newly installed. The generator loads are rapid mixers, flocculators, filter basin valves, dosing devices (aluminum sulfate, polymer, chlorination), control equipment and emergency power supply.

Based on the plan above, the equipment to be newly installed are given in Table 19.

Table 19 Electric / Monitoring and Control Equipment Provision Plans

1. Special High Power Receiving Equipment

Equipment	Specifications	Quantity
Disconnecting switch	Outdoor type, manually operated, 36 kV, 400 A	1 set
Power fuses	36 kV, 400A	1 set
Lightning arrestor	Outdoor type	1 set
Transformer	Oil immersed, outdoor type, 500 kVA, 3-phase, 33 kV/ 380-220 V	1
L.T. main panel	Metal-enclosed, self-standing outdoor type	1
Wire, cables		1 set

2. Emergency Generator Equipment

Equipment	Specifications	Quantity
Diesel engine-driven generator	Air cooled, 250 kVA, 380-220 V, 50 Hz	1
Automatic starter panel	Metal-enclosed self-standing outdoor type	1
Fuel tank	Underground type, 2000 liters	1
Small fuel tank	Indoor type, 195 liters	1
Fuel oil pipes		1 set
Wires, cables		1 set

3. L.T. Power Equipment (For System 1)

Equipment	Specifications	Quantity
Power panel	Metal-enclosed, self-standing outdoor type	1 set
Control center	〃	1 set
Distribution panel	〃	1 set
Auxiliary relay panel	〃	1 set
Site operation panel (for pumps)	Metal enclosed, stand-type	1 set
Wires, cables		1 set

4. L.T. Power Equipment (For System 2)

Equipment	Specifications	Quantity
Power panel	Metal-enclosed, self-standing outdoor type	1 set
Control center	〃	1 set
Distribution panel	〃	1 set
Auxiliary relay panel	〃	1 set
Site operation panel (for pumps)	Metal enclosed, stand-type	1 set
Wires, cables		1 set

5. L.T. Power Equipment (Others)

Equipment	Specifications	Quantity
Filter basin operation panel	Metal enclosed, indoor, desk type	1
Filter basin site operation panel	Metal enclosed, outdoor, self-standing type	1 set
Dosing device site operation panel	Metal-enclosed, stand-type	1 set
Flow regulating valve site operation panel	〃	1 set
Uninterrupted power equipment	Metal-enclosed, self-standing, outdoor type	1
Wires, cables		1 set

6. Control Equipment

Equipment	Specifications	Quantity
Central monitoring and control panel	metal-enclosed self-standing type with graphic panel	1 set
Instrumentation	detector, signal transmitter, indicator, regulator, integrator, and warning devices for expanded treatment plant	1 set
Wires, cables		1 set

7. Illumination Equipment

Equipment	Specifications	Quantity
Distribution panel	Metal enclosed, indoor, hanging type	1
Lighting devices	Fluorescent lamps	1 set
Lighting devices	Mercury lamps, outdoor ball-shaped	1 set
Wires, cables		1 set

8. Electric Corrosion-Preventing Equipment

Equipment	Specifications	Quantity
Rectifier panel	Metal-enclosed, outdoor, self-standing type	1
Anodes		1 set
Wires, cables		1 set

9. Control And Telemetry Equipment For Pumping Station (Zai Control Room) Equipment

Equipment	Specifications	Quantity
Graphic control panel	Metal-enclosed, indoor, self-standing type	1 set
Control and telemetry equipment (with automatic control functions)	〃	1 set
Signal I/O panel	〃	1
Data logger	Preparation of daily reports, desk-type (with functions for water treatment plant)	1 set
Modified existing VHF telephone		1 set
Wires, cables		1 set

(8) Building Plan

Building facilities include those already mentioned in the facilities plan of (6), and include generator/ electric/ store buildings in the water treatment plant, chlorination room and chemicals store building. From these, the store building is to be relocated to the store building that has been torn down, and other buildings are to be newly constructed as expanded facilities. The grade of buildings to be relocated or newly built should be the same as the grade of existing buildings.

	Function	Dimensions (m)	Area (m^2)	Basis for size and area
Generator/ electric / store building		32 x 8	256	
Generator room	Room for additional generator	7 x 8	56	Equipment size, maintenance and inspection space (same area as existing generator room)
Electric room	Room for additional electric equipment	10 x 8	80	Equipment size, maintenance and inspection space
Store building	Relocation of existing store	15 x 8	120	Same as the existing one
Chlorination room / chemicals store building		25 x 8	200	
Chlorination room	For additional chlorination equipment	10 x 8	80	Equipment size, maintenance and inspection space (same area as existing room)
Chemicals store building	For additional chemicals store	15 x 8	120	Same area as existing facility

2) Cross section area plan

Since no functional problems have been found in the cross section dimensions in the existing electric/ chemicals building, the cross section dimensions should be the same as the existing dimensions (height 3.5 m, 4.6 m).

3) Structural plan

Design loads should be estimated based on self weight, loading weight, and wind loads according to the Japanese Construction Standards. Earthquakes are likely to occur in Jordan. Existing structures are based on the seismic coefficient (0.4) of the USA, however this figure is too high. For the buildings under study, the coefficient should be based on the building standards of Japan. The foundation should be a reverse-T independent mat foundation, and the foundation, columns, walls, slabs should be made of reinforced concrete.

4) Equipment plan

General illumination equipment, water supply equipment, and ventilation equipment should suit the shape and functions of each room.

5) Building material plan

Member	Finishing plan	Reasons for selection
Roof	Waterproof asphalt	Commonly used in Jordan
Inside and outside walls	Emulsion paint finish	Same as existing buildings
Floor	Concrete with trowel finish	Generally used in chemicals store, storehouse, electric room
Fittings	Aluminum sash windows, steel doors	Same as existing buildings

(9) Basic Drawings

Fig. 11 Treatment plant plan

Fig. 12 Treatment plant equipment systems diagram (Treatment facilities)

Fig. 13 Treatment plan equipment systems diagram (Dosing devices)

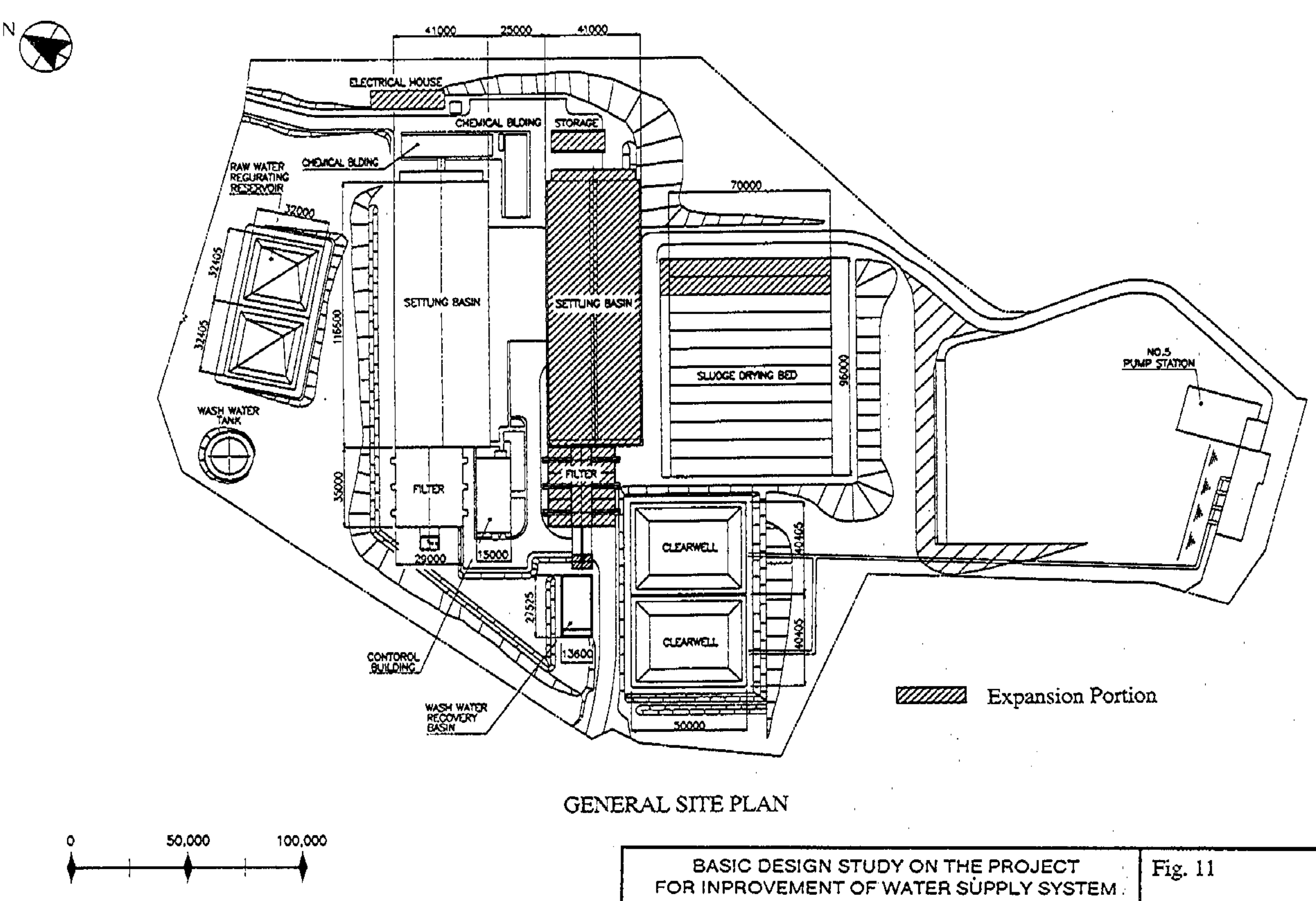
Fig. 14 Treatment plant equipment systems diagram (Chlorination equipment)

Fig. 15 Treatment plant dosing building

Fig. 16 Treatment plant single line wiring diagram

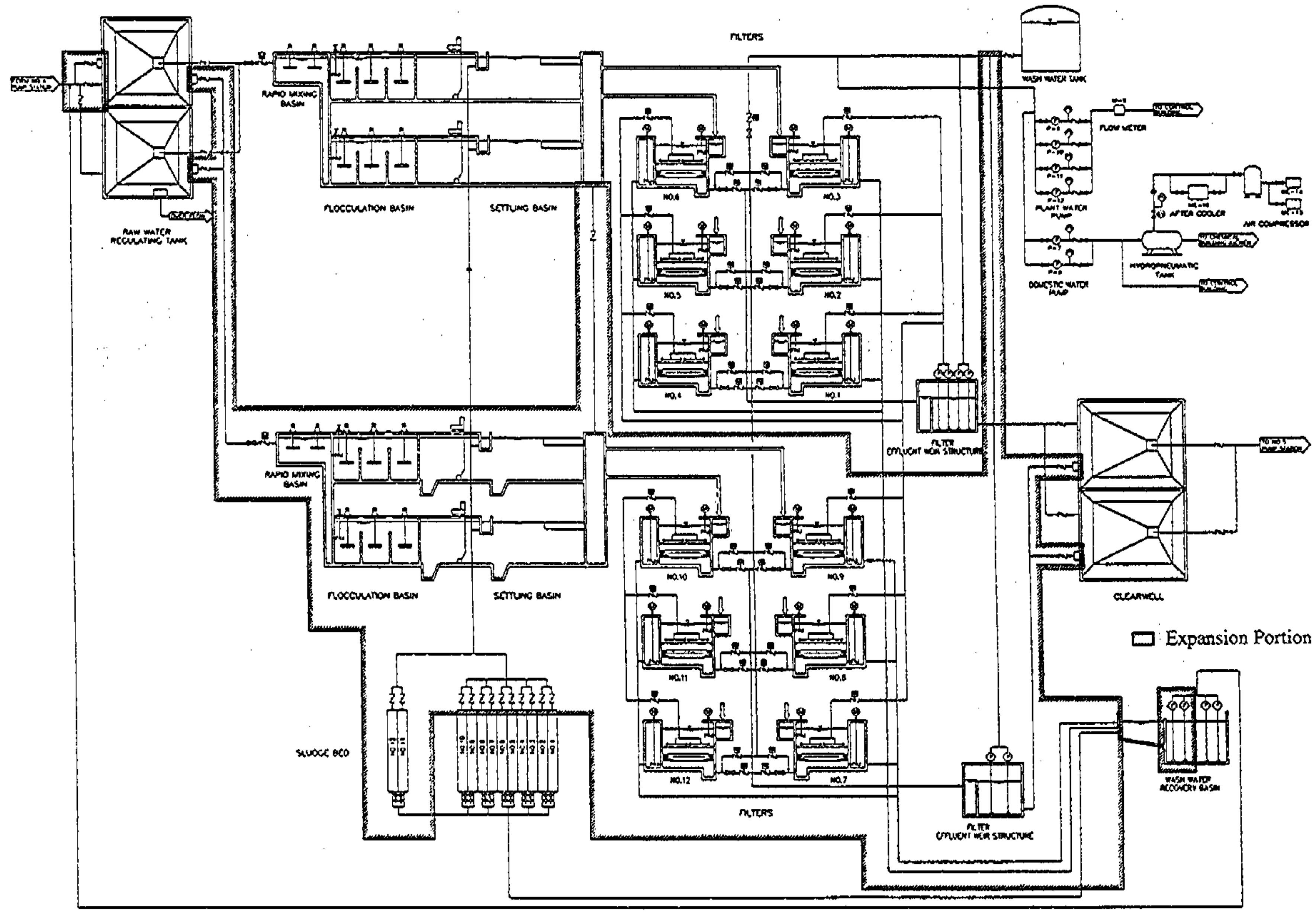
Fig. 17 Treatment plant central control room panel arrangement

Fig. 18 Control and monitoring equipment for conveyance/ delivery system



GENERAL SITE PLAN

BASIC DESIGN STUDY ON THE PROJECT FOR INPROVEMENT OF WATER SUPPLY SYSTEM TO GREATER AMMAN	Fig. 11 Treatment Plant Plan
JAPAN INTERNATIONAL COOPERATION AGENCY	



BASIC DESIGN STUDY ON THE PROJECT
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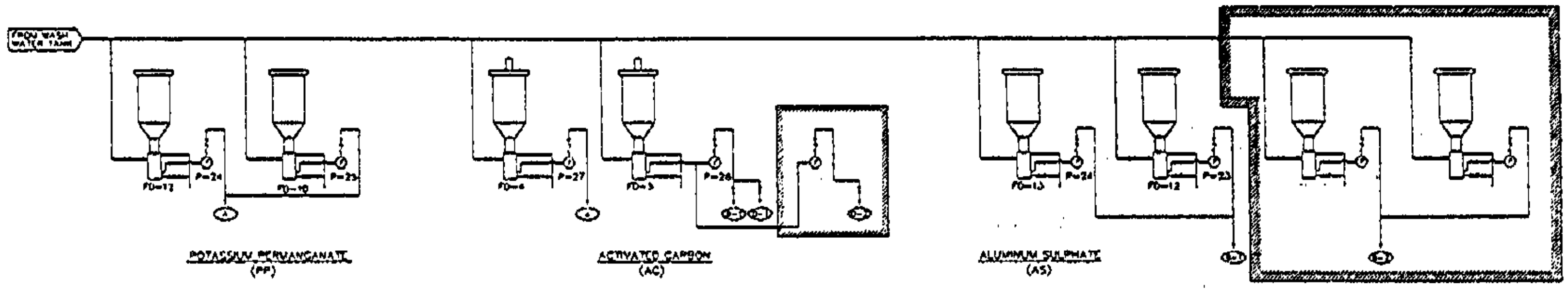
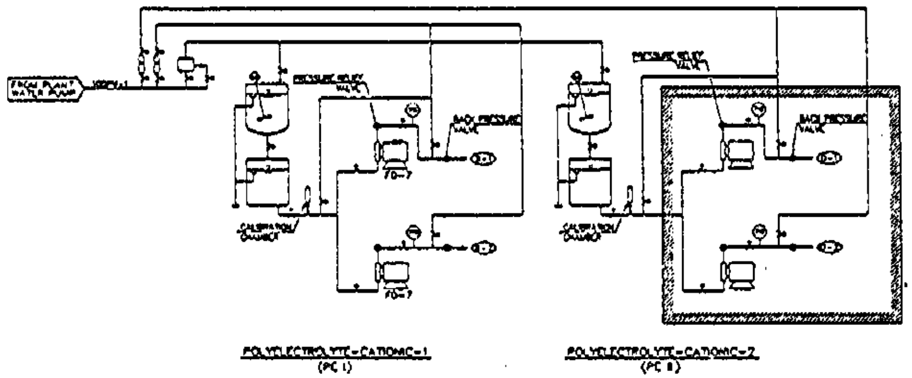
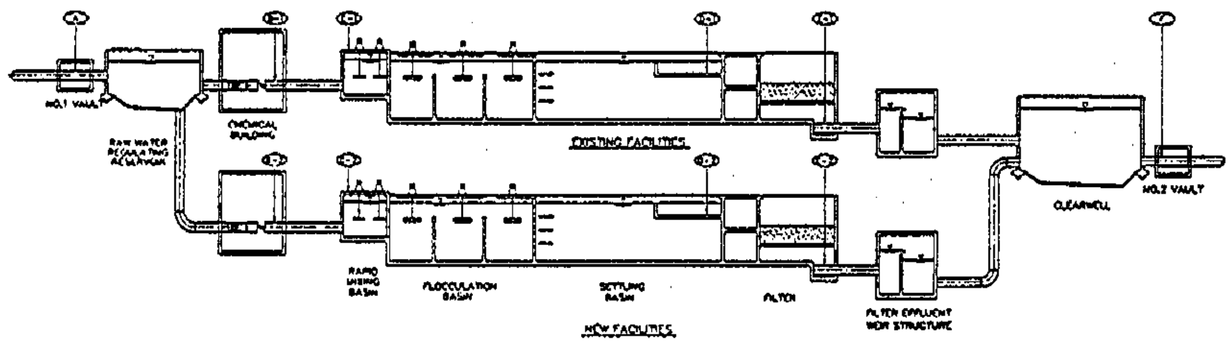
Fig. 12
Treatment plant equipment systems diagram
(Treatment facilities)





DOSING POINT

CHEMICAL	DOSING POINT					
	PRE-TREATMENT			INTER-MEDIATE	POST-TREATMENT	
	(A)	(B)	(C)	(D)	(E)	(F)
	NO.1 VAULT	CHEMICAL BUILDING	RAPID MIXING BASIN	SETTLING BASIN LAUNDER	AFTER FILTERS	NO.2 VAULT
PP	○	–	–	–	–	–
AC	–	–	–	○	–	–
AS	–	–	○	–	–	–
PC-1	–	○	–	–	–	–
PC-2	–	–	–	○	–	–



Expansion Portion

BASIC DESIGN STUDY ON THE PROJECT
FOR INPROVEMENT OF WATER SUPPLY SYSTEM
TO GREATER AMMAN

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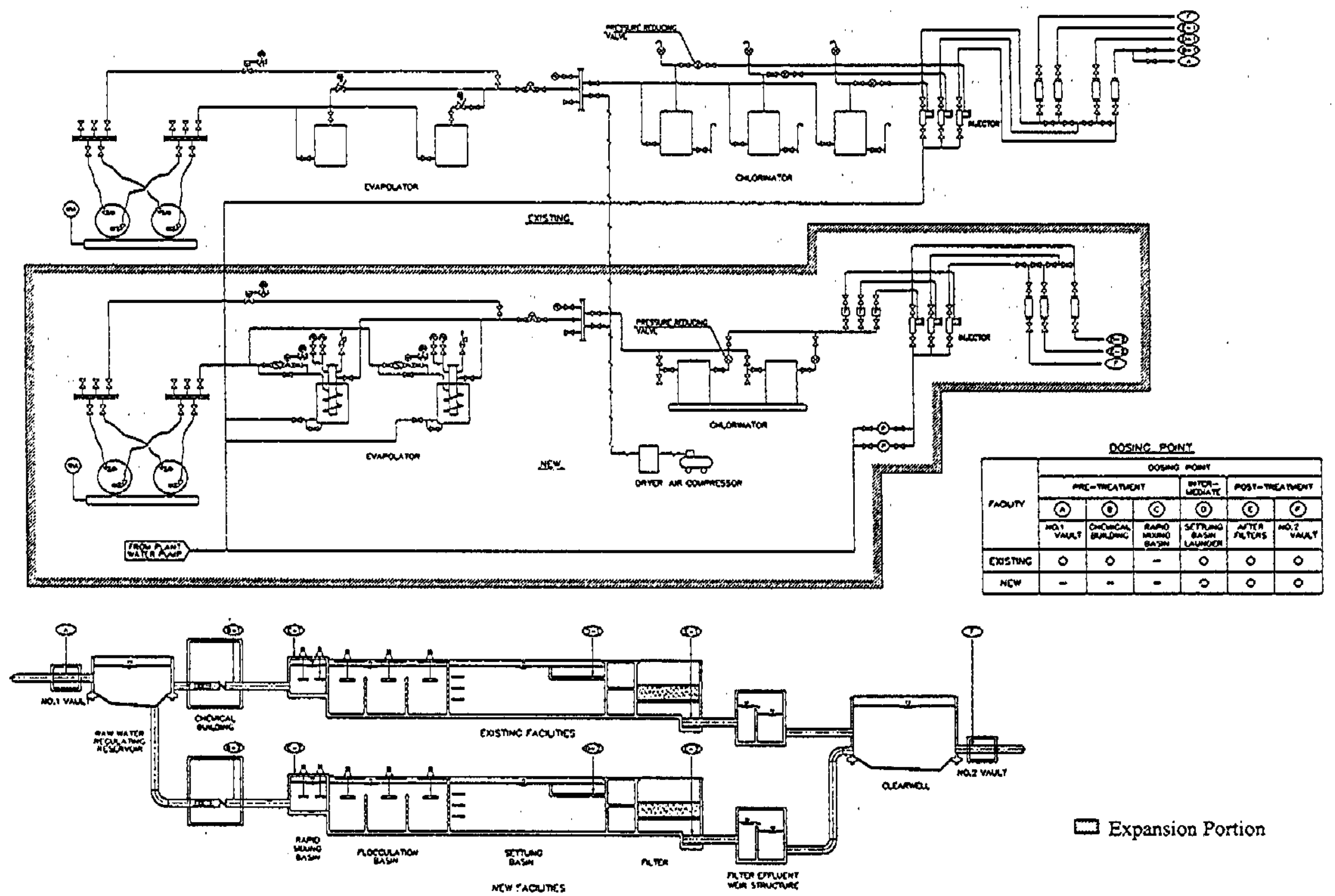
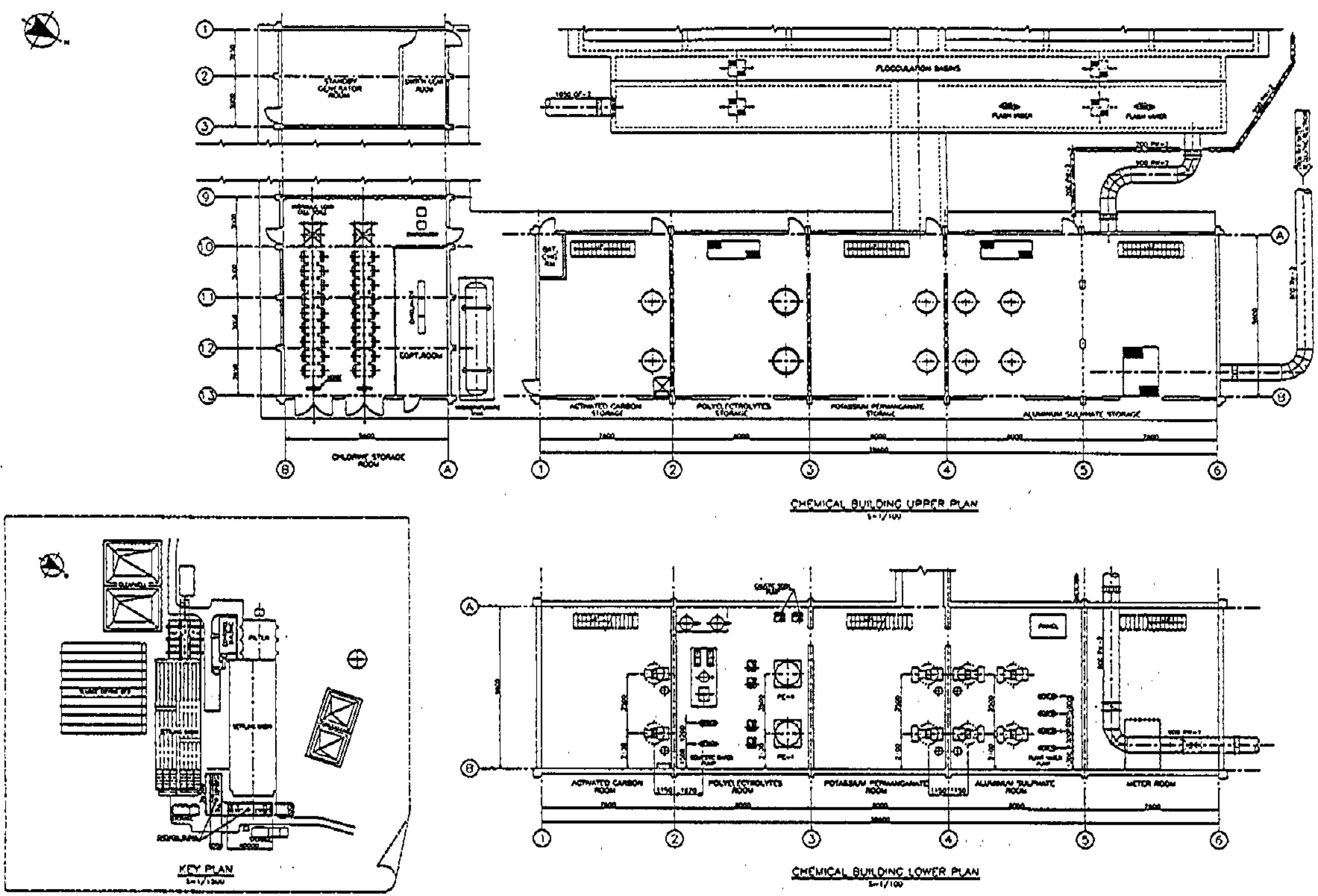
Fig. 13
Treatment plan equipment systems diagram
(Dosing devices)



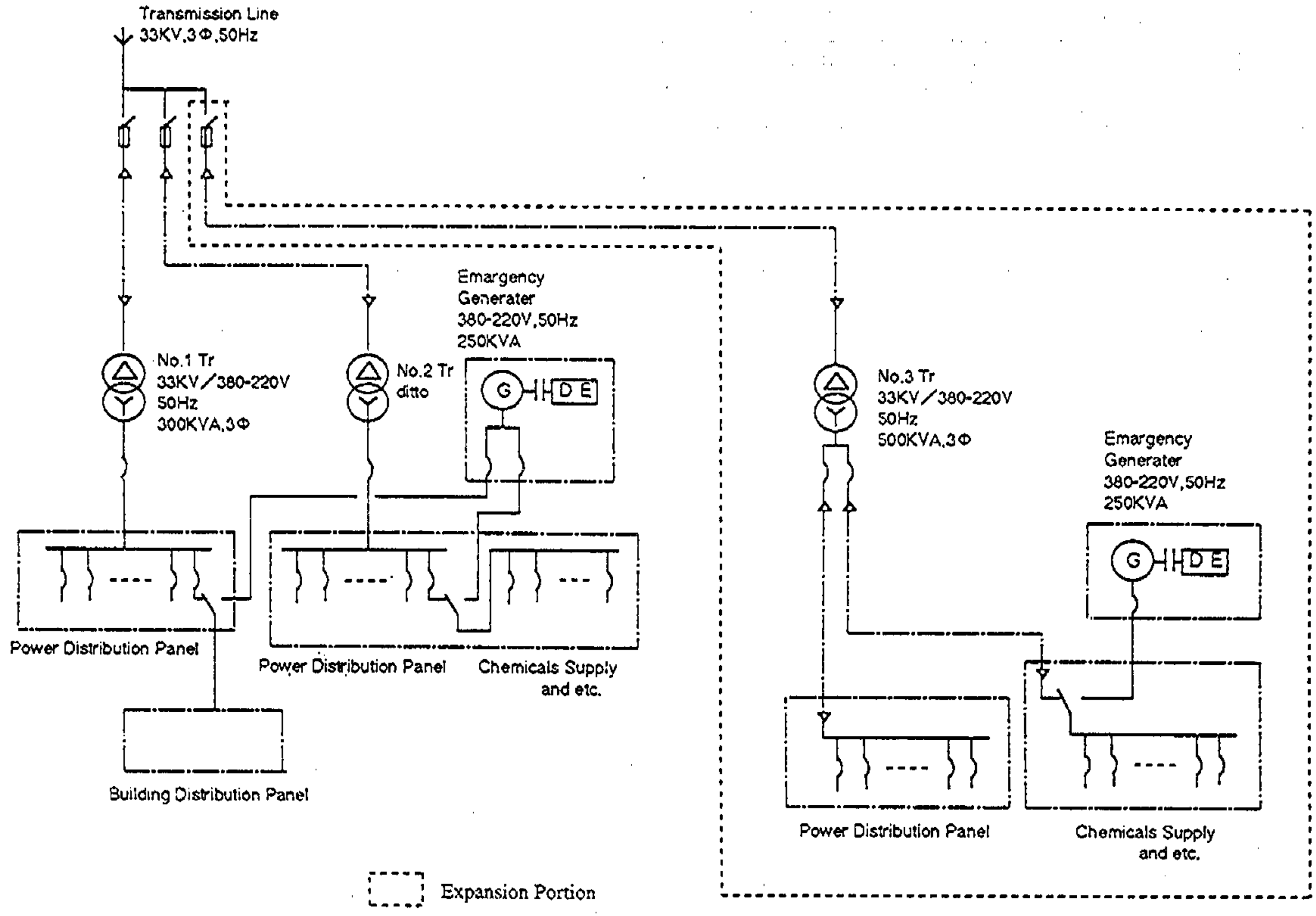
DOSING POINT

FACILITY	DOSING POINT					
	PRE-TREATMENT			INTER-MEDIATE	POST-TREATMENT	
	(A) NO.1 VAULT	(B) CHEMICAL BUILDING	(C) RAPID MIXING BASIN	(D) SETTLING BASIN LAUNDER	(E) AFTER FILTERS	(F) NO.2 VAULT
EXISTING	O	O	–	O	O	O
NEW	–	–	–	O	O	O

BASIC DESIGN STUDY ON THE PROJECT FOR INPROVEMENT OF WATER SUPPLY SYSTEM TO GREATER AMMAN	Fig. 14
JAPAN INTERNATIONAL COOPERATION AGENCY	Treatment plant equipment systems diagram (Chlorination equipment)



BASIC DESIGN STUDY ON THE PROJECT FOR INPROVEMENT OF WATER SUPPLY SYSTEM TO GREATER AMMAN	Fig. 15 Treatment plant dosing building
JAPAN INTERNATIONAL COOPERATION AGENCY	



BASIC DESIGN STUDY ON THE PROJECT
FOR INPROVEMENT OF WATER SUPPLY SYSTEM
TO GREATER AMMAN

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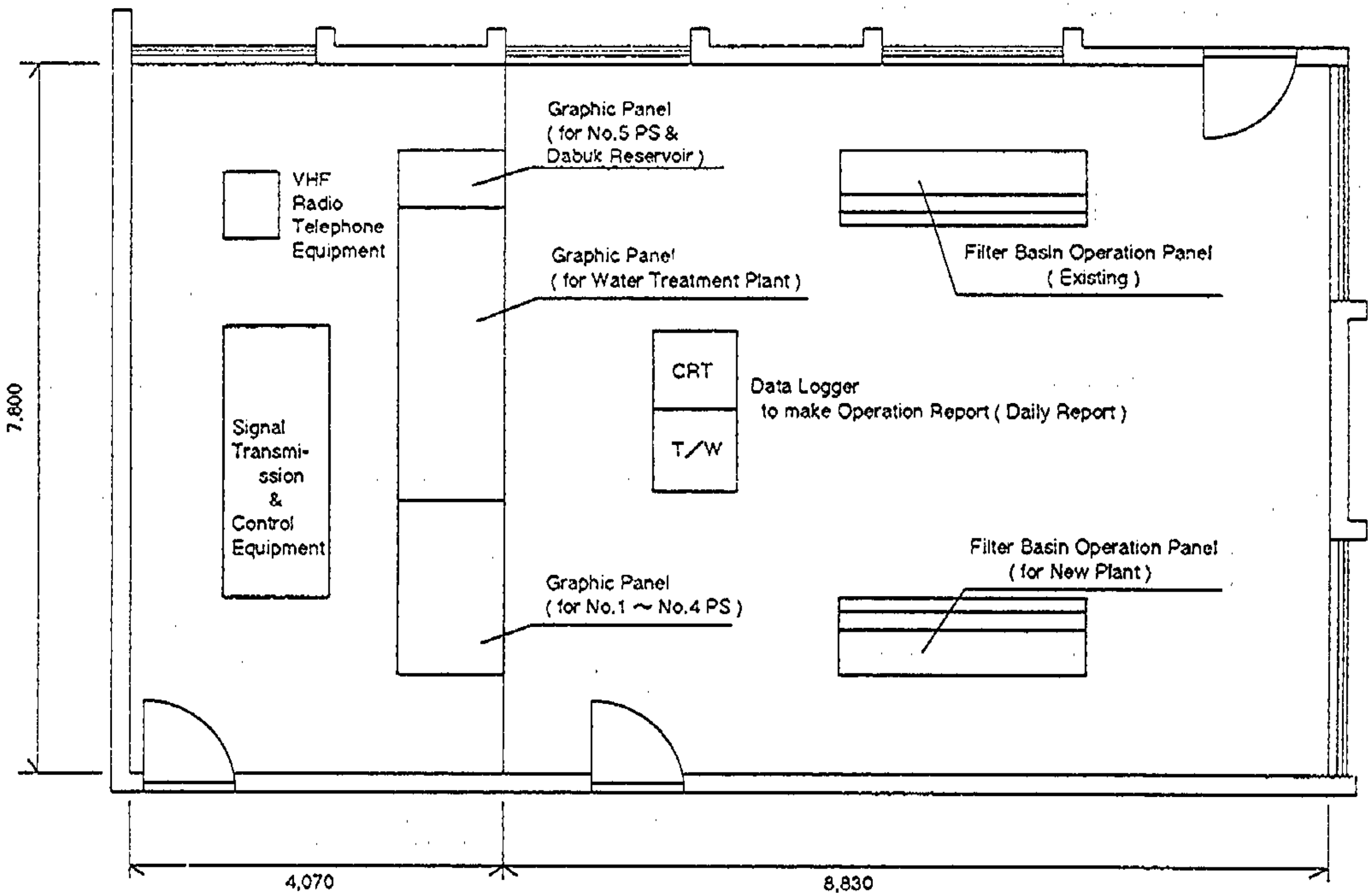
Fig. 16
Treatment plant single line wiring diagram



BASIC DESIGN STUDY ON THE PROJECT FOR INPROVEMENT OF WATER SUPPLY SYSTEM TO GREATER AMMAN

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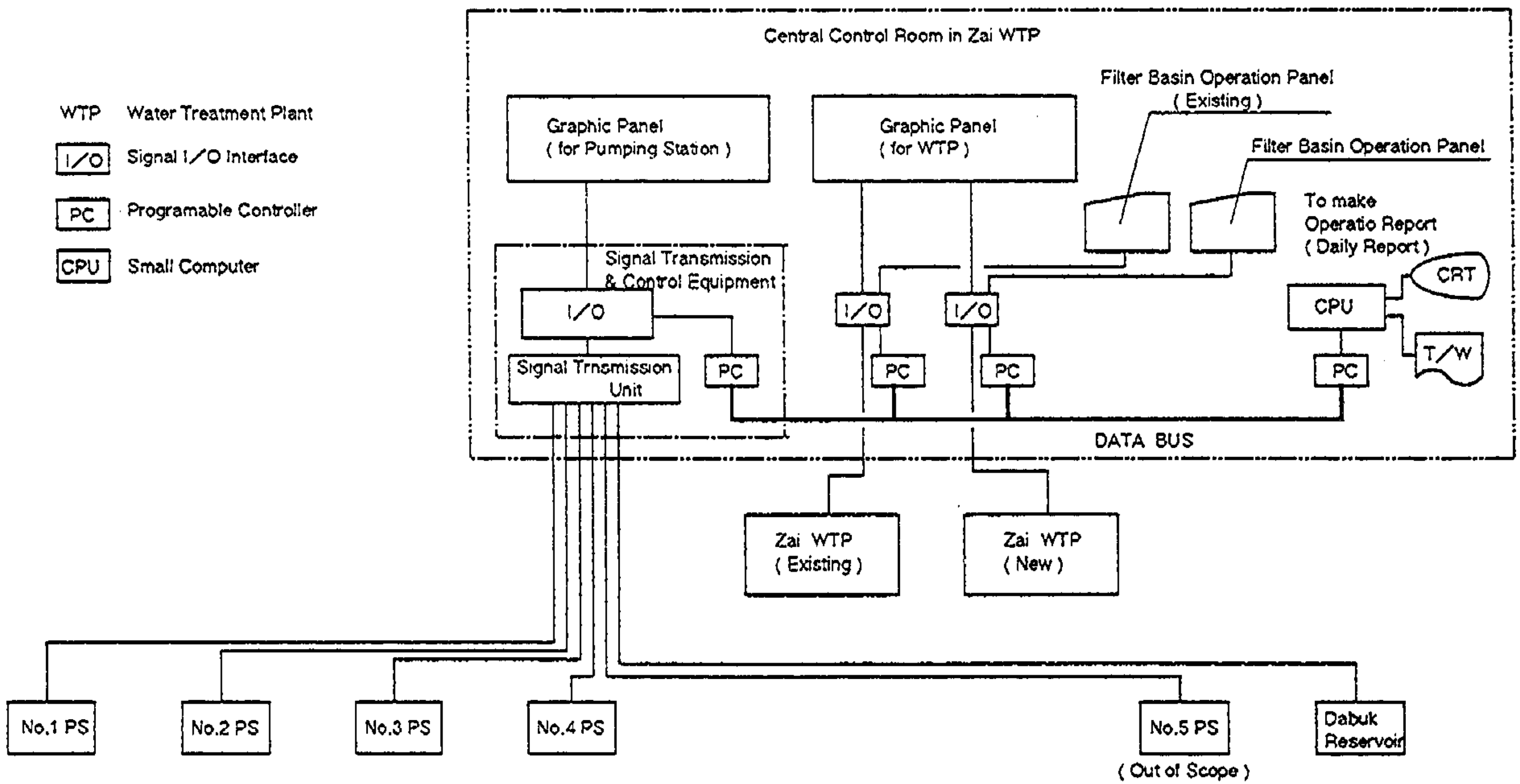
Fig. 17
Treatment plant central control room panel arrangement



BASIC DESIGN STUDY ON THE PROJECT
FOR INPROVEMENT OF WATER SUPPLY SYSTEM
TO GREATER AMMAN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 18 Control and monitoring equipment for conveyance/ delivery system