5-3 Basic Design Plan

(1) Intake facilities

Currently, three intake pumps, each with a capacity of 5.3 m^3 (1,400 gallons)/minute/unit are installed. Raw water is directly conveyed to the water treatment plant by one unit of the intake pump using the existing pipe line (300 mm in diameter). The existing pipeline has a capacity 1.1 times the water consumption for designing the water facilities at the target year, but water is running short due to the shortage of water intake quantity in dry season. It is neccessary, therefore, to convey water to Gihmel Dam when water volume is sufficient in Edeng and Kmekumel rivers so that Gihmel Dam may be filled with water at all times to cope with the daily change in water consumption and to secure sufficient water in dry season. For this purpose, the pipelines in 250 mm diameter will be installed to be used exclusively for conveying water to Gihmel Dam

1) Raw water pipe diameter

The pipe diameter for the pipeline to be laid between the intake pump station and Gihmel Dam are studied to determine the optimum size for sending a specified quantity of raw water. Pipe diameters of 200 mm, 250 mm, and 300 mm are studied to select the optimum pipe diameters.

The friction head loss is calculated by using the Hazen-Williams' Formula, the velocity coefficient of the pipe is assumed to be C = 110 by taking into consideration the increasing coefficient of pipe friction loss caused by the number of years of use and pipeline bends.

The following equations are used to calculate the hydraulic gradient and the friction head loss.

$$I = 10.666 C_H^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85} \quad \text{..........} \quad (1)$$

where:

I	=	hydraulic gradient	
C	=	flow velocity coefficient	110
D	=	inner diameter of the pipe	(m)
Q	=	rate of discharge	(m^3/sec)

$$\Delta H = I \times L \quad \text{..........} \quad (2)$$

where:

ΔH	=	friction head loss	(m)
L	=	piping length	(m)

The pipe diameter of 250 mm is selected for the following reasons:
The results of this study indicate that at pipe diameters of 200 mm, the total pump head for the existing pump is insufficient and the specified rate of discharge would not be achieved, as shown in Table 5-7. Accordingly, the 250-mm diameter pipelines would allow the specified rate of discharge, and thus should be adopted.

Table 5-7 Combinations of Pipe Diameters and Pumping Capability

Pipe diameter	200 mm	250 mm	300 mm
① Discharge $m^3/min.$ (gallons/min.)	2.8 (740)	2.8 (740)	2.8 (740)
② Flow velocity inside the pipe (m/sec.)	1.5	1.0	0.7
③ Friction head loss of piping (m)	79	27	11
④ Elevation difference between Gihmel and intake facilities (m)	10	10	10
⑤ Total head of intake pump (m)	83	83	83
⑥ Pump head difference ⑤ - (③+④) (m)	- 6	+ 46	+ 62
Evaluation	200 mm diameter pipe can not flow the specified discharge rate because of insufficient pump head.	250 mm diameter pipe can flow the specified discharge rate because of sufficient pump head.	300 mm diameter pipe can flow the specified discharge rate because of sufficient pump head.

(Water quantity to be supplied from water intake station to Gihmel Dam is half of the designed water quantity to each house and establishment.)

2) Selection of piping material

The raw water pipelines run across a plateau located between the intake pump station and Gihmel dam. The water hammer, occurring when the intake pump is started or stopped, will not affect the safety of the raw water pipelines for the reasons explained below. Therefore, a study for water hammer has not been undertaken.

- The distance between the intake pump station and the plateau is short (approximately 2.5 km)

- Since the existing raw water pipelines, with the same specifications, pipe diameter and route, have been used for long period, the safety of the pipelines has been confirmed.

The calculated maximum pressure of the pipeline of 8.3 kgf/cm^2 (about 120 psi), is the same as the delivery pressure of the intake pump.

The following pipe materials have been studied.

- Ductile cast iron pipe
- Steel pipe
- Fiber reinforced plastic pipe
- PVC pipe
- Asbestos cement pipe

Since the use of PVC pipes greater than 150 mm in diameter is not permitted in the construction of water works in Japan, PVC pipe will not be used for the water pipeline.

Asbestos cement pipe will not be used because it is not manufactured in Japan at the present time.

The remaining three types of pipes are compared in terms of technical characteristics (strength, durability, impermeability, flexibility and expansion/contraction properties), cost (material, construction and maintenance costs), and workability, as shown in Table 5-8. The ductile cast iron pipe is selected because it has no technical problem, the material cost is the lowest, and it can be easily maintained.

The T-type joint (socket joint) will be used for the straight pipes and the K-type joint (mechanical joint) will be used for fittings.

3) Standard earthcovering thickness

The existing asbestos cement pipe is laid approximately 90 cm below the road, except for places where the pipe runs across the rainwater drain pipe.

The minimum earthcover standard for Japan is 1.2 m.

This value is selected to ensure the safety and protection of various underground structures of various kinds and buried pipes.

In countries with few underground constructions and light traffic, pipelines are often laid under less earthcover to reduce construction cost and to facilitate maintenance work. The thickness of earthcovering will be determined according to a comparative examination of cases of less than one meter for this project, because of light traffic, few underground pipelines, satisfactory soil conditions and the sufficient strength of the ductile cast iron.

After examination, the thickness of earthcover was set at 0.7 m for sloped areas and 0.9 m for flat areas.

The earthcover for the pipelines will be designed to cope with the loads exerted by 20-ton trucks in this project.

The results of the comparative study of earthcover of 70 cm, 80 cm, 90 cm and 100 cm., using 300 mm diameter pipe as a reference are shown in Table 5-9.

4) Standard excavation section

The soil in the project site area, consisting of laterite, is in good condition unless it becomes wet.

Excavation width and depth will be determined, according to pipe diameter, types of pipe joints, the thickness of earthcover, types of foundation work, the working space for laying pipes, the reduction in construction costs and the shortening of construction work period.

The list of excavation width and depth for each pipe size is shown in DWG. No. PAL--08.

Table 5-8 Comparative Table by Type of Pipe

		Ductile cast iron pipe	Steel pipe	Fiber reinforced plastic composite pipe
Durability	1. Service life	• The Local Public Works Law of the Ministry of Interior of Japan assumes 40-years service life. • The durability can be regarded as semi-permanent as long as the fluid does not have acid characteristic. • Rubber rings have service life records surpassing 30 years.	• It is possible to extend the service life of steel pipe over 25 years subjected to good maintenance. • Attention must be paid to the surface coating of site joint welding. There is considerable risk of corrosion in small-diameter pipes in which coating of the inner surface is difficult.	• Long durability is expected, because the material itself has superior corrosion resistance. • Results of the fatigue tests of the FRPM Association indicate service life exceeding 60 years
	2. Corrosion resistance	• Outer surface The material itself has superior corrosion resistance, and furthermore the tar-epoxy type coating of the surface secures excellent corrosion protection effect. • Inner surface The inner surface is provided with a firmly coated mortar lining which is expected to be free from deterioration for an extended period. Mortar lining has the effect of passivating iron due to the alkalinity of cement, and therefore it is quite effective to secure corrosion protection	• Outer surface Prone to be scratched during handling, and the joints require skilled technique to carry out in-situ work. Corrosion may progress from local scratches, ultimately resulting in corrosion hole. • Inner surface The tar-epoxy coating thickness according to the Waterworks Standards is 0.3 mm, which is not necessarily sufficient, and the corrosion resistance is lower compared with ductile cast iron pipe.	• The material itself has superior corrosion resistance, and suffers practically no influence of corrosion.

(cont'd)

		Ductile cast iron pipe	Steel pipe	Fiber reinforced plastic composite pipe
Workability	1. Installation	• The joint work is easy and rapid, and prompt backfilling is possible after jointing the pipes. • The execution of work is possible even in rainy weather, severe groundwater conditions, etc.	• In-situ welding and coating require sophisticated technique, and the work must be done by qualified technician. • Long period of work is required, because of the many steps involved, such as centering, tack welding, regular welding, inspection, coating, etc. • The work must be executed under fully dry conditions, because low temperature and humidity exert adverse influence on the welding and coating.	• The pipes are relatively light, and can be transported even by man power. • The joint work is easy and rapid, and prompt backfilling is possible after jointing the pipes.
	2. Foundation and backfilling work	• Generally no special foundation work is required, and furthermore no special compaction is required when backfilling. • The buried pipe has high safety, due to its superior strength and elasticity. Therefore, there is practically no restriction when laying this pipe in ordinary ground.	• Compaction of the ground beneath the pipe and sand backfilling at the periphery of the pipe are required, to prevent flexion of the pipe and scratching the outer coating. • Large work space must be secured at the joints.	• Sand foundation is required in principle. • Good-quality soil is required for backfilling up to 20-30 cm above the pipe.

(cont'd)

		Ductile cast iron pipe	Steel pipe	Fiber reinforced plastic composite pipe
Construction cost & maintenance	1. Pipe material cost comparison	ϕ300 mm : 1.00 ϕ250 mm : 0.66 ϕ200 mm : 0.52 T-type and K-type pipe joints will be used respectively for straight pipes and fittings. This pipe's material cost is least expensive.	ϕ300 mm : 1.13 ϕ250 mm : 0.96 ϕ200 mm : 0.70 This pipe's material cost is most expensive.	ϕ300 mm : 1.14 ϕ250 mm : 0.70 ϕ200 mm : 0.59 This pipe's material cost is average
	2. Civil construction cost	• It depends on the ground conditions, but in general no special foundation work is required and the excavated soil can be used for backfilling. the cost for removal of surplus soil and backfilling is cheap.	• Many steps of work are required, and the period of work becomes long, because of many rainy days and rainfall in the project site area. The equipment rental and other cost item result in expensive works.	• A supporting angle of 120° for sand foundation is sufficient under normal conditions, and the quantity of sand to be purchased is small. The cost of civil work is cheap because no joint excavation is required as in the case of other types of pipes.
	3. Maintenance	• The pipe can be laid with ease, and prompt countermeasures can be taken even in the case of unexpected accidents. • It is impossible for individuals to attach small-diameter water supply pipes to the water supply pipeline.	• Inner welding and inner coating of joints are practically impossible. • Maintenance costs, such as cathodic protection cost etc., may be required. • It is very difficult for individuals to attach small-diameter water supply pipes to the water supply pipeline.	• It is easy to cut this pipe compared with the ductile cast iron pipe and steel pipe. • Prompt countermeasures can be taken by using FRP lamination even in the case of unexpected accidents. • Individuals can attach small-diameter water supply pipes to the water supply pipeline.

Conclusion:

Results of a comprehensive comparative study from the standpoints of cost of material, construction cost, maintenance cost, etc., indicate that the ductile cast iron pipe has the best economical efficiency. It is decided to use the ductile cast iron pipe (Class-3) in this project, because in addition to the said advantage it allows easy installation and maintenance, it is impossible for individuals to connect water service water supply pipes to housings to the water main pipeline, and this kind of pipe has a extensive record of safety and use under high water pressure conditions.

Table 5-9 Earthcover Comparison Table (pipe diameter ϕ300 mm)

Standard earthcover (cm)	70	80	90	100
Overburden pressure (kgf/cm^2)	0.13	0.14	0.16	0.18
Superim-posed load (kgf/cm^2)	0.94	0.81	0.70	0.62
Hydrostatic pressure (kgf/cm^2)	9.5	9.5	9.5	9.5
Water hammer pressure (kgf/cm^2)	0.3	0.3	0.3	0.3
Design pipe wall thickness (mm)	5.5	5.4	5.4	5.3
Type of pipe	Ductile cast iron pipe Class-3	Ductile cast iron pipe Class-3	Ductile cast iron pipe Class-3	Ductile cast iron pipe Class-3
Items to be taken into considera-tion in the longitudinal section design and applicable counter-measures	• Because the shaft length above the pipe crest surface of the stop valve and air valve is 900 mm with ϕ300 mm pipe, they will project 20 cm above the road surface or ground surface. • The pipe must be laid at least 20 cm deeper at places where these valves are installed, in order to avoid the said problem. • Under these circum-stances, the execution of the work becomes troublesome, and there is risk of accumula-tion of sludge in the recessions, and as a consequence it becomes necessary to install sludge dis-charge pipes between the valve installation positions.	• The problems occurring in this case and the required countermeasures are practically the same as those with 70 cm earthcover.	• It is presumed that there is practically no problem of projection of shafts of stop valves and air valves. • No countermeasure is required in particular.	• There is no projection of shafts of stop valves and air valves. • No countermeasure is required at all.

(cont'd)

	• In the sloped areas, the positions where the stop and air valves will be installed need not be deeper.			
Installation	• The positions where the stop valves and air valves will be installed must be deeper, as mentioned above. • The execution of work becomes troublesome. • In the sloped areas, the pipe must not be laid at deeper places, as stated above.	Same as with 70 cm.	• The valves can be installed at the same depth as the pipe. • The execution of work is easy and reliable. • The excavation depth is 1.4 m, and there is no risk of occurrence of groundwater and reaching the bedrock.	• The valves can be installed at the same depth as the pipe. • The excavation depth becomes 1.5 m, and the risk of occurrence of groundwater and reaching the bedrock is higher compared with the case of 90 cm earthcover.
Safety	No problem	No problem	No problem	No problem
Construc-tion cost	100%	106%	112%	118%
Evaluation	• In the sloped areas, the positions where the stop and air valves will be installed need not be deeper. • In the flat areas, there is a fault that stop and air valves will project on the ground.	• In both sloped and flat areas, 0.8 m earthcover is not at advantage over the case of 0.7 m earthcover.	• The sloped areas do not have superiority compared with the case of 0.7 m and 0.8 m earthcover. • In the flat areas, the pipes can be laid if stop and air valves are not installed at deeper place. • 0.9 m earthcover is at advantage over the case of 0.7 m and 0.8 m earthcover technically and for utilization of ground surface.	• In both sloped and flat areas 1.0 m earthcover is not at advantage over the case of 0.9 m earthcover.

(2) Water supply facilities

Because of the defects in the existing water facilities, the present water supply system needs to be changed to improve the water supply condition in the project site area. The existing pipeline, used for both water distribution and transfer, should be used exclusively for distribution from water tanks to consumers, and a new, separate pipeline should be constructed for water transfer to four existing water tanks, except Malakal tank.

By increasing the water supply quantity and making changes to the existing water supply system, all residents in the planned served area will be able to secure a uniform water supply 24 hours a day. The control system, pumping facilities and pipe diameters are described below.

1) Control system

Since the existing water transfer pump doesn't have an automatic control function, it must be operated manually over three shifts for continuous 24-hour service. The new water transfer pumping facility will operate automatically according to the water level of the existing storage tank and water transfer quantity. A simple control device will be installed so the operators in Palau can easily operate, maintain and repair the automatic control system.

Except for the Ngermid tank, which is equipped with a booster pump on its water transfer pipeline, automatic intake valves will be installed in the three water tanks. These valves will automatically open and close according to the water level of the water tank. Since the elevation of the Ngermid tank is higher than that of the other three tanks, water can not be stored using a water transfer pump, so the pressure will be increased to the existing booster pump to store water. The water level at the tank will be detected by using a water gauge, and the booster pump will be started or stopped according to the water level in the tank.

The number of pumps in operation will be determined automatically by the actual water discharge and pressure. If all pumps are stopped, and no water is flowing, manual operation for re-starting the pumps will be necessary.

2) Water transfer pumping facility

Four water transfer pumps, two rated at 3.97 m^3/min. and two at 1.32 m^3/min., were installed. The operating conditions are as follows:

- Daytime : 3.97 m^3/min.: one pump + 1.32 m^3/min.: two pumps operation
- Night time : 3.97 m^3/min.: two pumps + 1.32 m^3/min.: two pumps operation

The existing one small-capacity pump (1.32 m^3/min.) will be replaced with a large-capacity pump for the reasons explained below and water will be supplied by three large-capacity pumps to transfer the planned water transfer quantity.

- The total head of the small-capacity pump is 80.8 m (265 feet), therefore the total pump head of 85.3 m (280 feet) necessary to pump up the water to the water tank can not be secured so that the water can not be pumped up to the water tank.

- If pumps with the same specifications are not installed, the automatic operation of the pumps will become complicated. If pumps with the same specifications are installed, one of the three pumps will be on a standby, and parallel operation of the other two pumps will be automatically controlled according to the water demand.

- The pumps will be easily operated and maintained.

Since the foundations and suction basin of the existing small-capacity pump were originally constructed for a larger capacity pump, the modi-fication and related expenses of the foundations will be minimal.

3) Water pipe diameter

The diameter of the water transfer pipe to the four water tanks will be studied using three combinations of pipe diameters to make the proper selection.

Water quantity to be transferred is shown in Table 5-4, and the combination of pipe diameters and pipe length are shown in Figure 5-2 and Table 5-10.

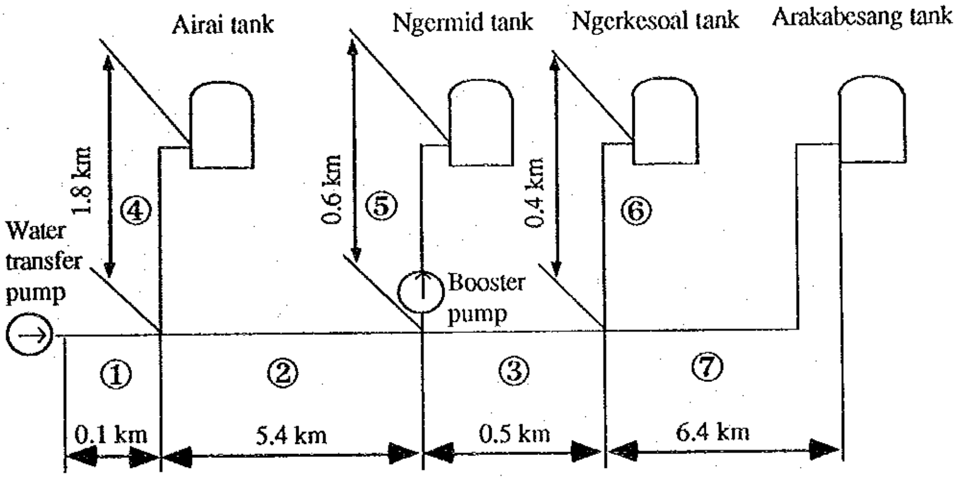

Fig. 5-2 Skeleton of the Water Transfer Pipeline

Table 5-10 Combinations of Pipe Diameters

(Unit: mm)

Piping section	Case-1	Case-2	Case-3
①	300	400	450
②	250	300	350
③	250	300	350
④	200	200	200
⑤	200	200	200
⑥	250	250	250
⑦	250	250	250

The results of hydrological studies for each section indicate that the pipeline diameter for sections ④ ⑤, ⑥ and ⑦ (200 mm or 250 mm) is not changed for each case study.

The friction head loss is calculated by using the generally adopted Hazen-Williams' Formula, the velocity coefficient of the pipe is assumed to be C = 110 by taking into consideration the increase in pipe friction loss caused by the number of years of use and pipeline bends.

The following equations are used to calculate the hydraulic gradient and the friction head loss.

$$I = 10.666 C H^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85} \quad \cdots\cdots \quad (1)$$

where:

I	=	hydraulic gradient	
C	=	flow velocity coefficient	110
D	=	inner diameter of the pipe	(m)
Q	=	rate of discharge	(m^3/sec)

$$\Delta H = I \times L \quad \cdots\cdots \quad (2)$$

where:

ΔH	=	friction head loss	(m)
L	=	piping length	(m)

Case-2 is thus adopted for the following reasons.

In Case-1 the required quantity of water cannot be transferred to the water tanks because of insufficient total pump head, and in Case-3 the pipe diameter is excessively large, as shown in Table 5-11.

Table 5-11 (1/3) Combination of Pipe Diameter and Pumping Evaluation

Case-1

Water tank	Airai	Ngermid	Ngerkesoal	Arakabesang
① Transfer water quantity (m^3/day) Total 7,950 m^3/day [2.1 mil.gallons/day)	1,930 (0.51 mil/gallons)	800 (0.21 mil/gallons)	3,840 (1.01 mil/gallons)	1,380 (0.37 mil/gallons)
② Friction head loss of piping (between water transfer pump and each tank) (m)	9.1 (30 feet)	62.0 (203 feet)	67.7 (222 feet)	70.4 (231 feet)
③ Ground level of each tank (m)	67.4 (221 feet)	77.7 (255 feet)	57.3 (188 feet)	57.4 (190 feet)
④ Suction water level at water transfer pump well (m)	3.0 (10 feet)	3.0 (10 feet)	3.0 (10 feet)	3.0 (10 feet)
⑤ Elevation difference between ground level of each tank and suction water level at supply pump well (m)	64.4 (211 feet)	74.7 (245 feet)	54.3 (178 feet)	54.9 (180 feet)
⑥ Total head of Ngermid tank's booster pump (m)	-	29.0 (95 feet)	-	-
⑦ Total head of water transfer pump (m)	87.2 (286 feet)	87.2 (286 feet)	87.2 (286 feet)	87.2 (286 feet)
⑧ Difference in total head (water level in tank) (m) ⑦[+⑥]-(②+⑤)	+ 13.7 (+ 45 feet)	- 20.5 (- 67 feet)	- 34.8 (- 114 feet)	- 38.1 (- 125 feet)
Evaluation	The required amount of water can be transferred to this tank.	The required amount of water cannot be transferred to this tank.	The required amount of water cannot be transferred to this tank.	The required amount of water cannot be transferred to this tank.

Table 5-11 (2/3) Combination of pipe diameter and pumping evaluation

Case-2

Water tank	Airai	Ngermid	Ngerkesoal	Arakabesang
① Transfer water quantity (m^3/day) Total 7,950 m^3/day [2.1 mil.gallons/day)	1,930 (0.51 mil/gallons)	800 (0.21 mil/gallons)	3,840 (1.01 mil/gallons)	1,380 (0.37 mil/gallons)
② Friction head loss of piping (between water transfer pump and each tank) (m)	8.0 (26 feet)	25.8 (85 feet)	29.0 (95 feet)	30.3 (100 feet)
③ Ground level of each tank (m)	67.4 (221 feet)	77.7 (255 feet)	57.3 (188 feet)	57.9 (190 feet)
④ Suction water level at water transfer pump well (m)	3.0 (10 feet)	3.0 (10 feet)	3.0 (10 feet)	3.0 (10 feet)
⑤ Elevation difference between ground level of each tank and suction water level at supply pump well (m)	64.4 (211 feet)	74.7 (245 feet)	54.3 (178 feet)	54.9 (180 feet)
⑥ Total head of Ngermid tank's booster pump (m)	-	29.0 (95 feet)	-	-
⑦ Total head of water transfer pump (m)	87.2 (286 feet)	87.2 (286 feet)	87.2 (286 feet)	87.2 (286 feet)
⑧ Difference in total head (water level in tank) (m) ⑦[+⑥]-(②+⑤)	+ 14.8 (+ 49 feet)	+ 15.7 (+ 52 feet)	+ 3.9 (+ 13 feet)	+ 2.0 (+ 7 feet)
Evaluation	The required amount of water can be transferred to this tank	The required amount of water can be transferred to this tank	The required amount of water can be transferred to this tank	The required amount of water can be transferred to this tank

Table 5-11 (3/3) Combination of pipe diameter and pumping evaluation

Case -3

Water tank	Airai	Ngermid	Ngerkesoal	Arakabesang
① Transfer water quantity (m^3/day) Total 7,950 m^3/day [2.1 mil.gallons/day)	1,930 (0.51 mil/gallons)	800 (0.21 mil/gallons)	3,840 (1.01 mil/gallons)	1,380 (0.37 mil/gallons)
② Friction head loss of piping (between water transfer pump and each tank) (m)	7.6 (25 feet)	12.4 (41 feet)	14.7 (48 feet)	17.4 (57 feet)
③ Ground level of each tank (m)	67.4 (221 feet)	77.7 (255 feet)	57.3 (188 feet)	57.9 (190 feet)
④ Suction water level at water transfer pump well (m)	3.0 (10 feet)	3.0 (10 feet)	3.0 (10 feet)	3.0 (10 feet)
⑤ Elevation difference between ground level of each tank and suction water level at supply pump well (m)	64.4 (211 feet)	74.7 (245 feet)	54.3 (178 feet)	54.9 (180 feet)
⑥ Total head of Ngermid tank's booster pump (m)	-	29.0 (95 feet)	-	-
⑦ Total head of water transfer pump (m)	87.2 (286 feet)	87.2 (286 feet)	87.2 (286 feet)	87.2 (286 feet)
⑧ Difference in total head (water level in tank) (m) ⑦[+⑥]-(②+⑤)	+ 15.2 (+ 50 feet)	+ 29.1 (+ 95 feet)	+ 18.2 (+ 60 feet)	+ 14.9 (+ 49 feet)
Evaluation	The required amount of water can be transferred to this tank	The required amount of water can be transferred to this tank	The required amount of water can be transferred to this tank	The required amount of water can be transferred to this tank

4) Study of water hammer

Water hammer is caused by water column separation* or pressure rise, when pressure waves occur by the sudden closure of the sluice valve of the water pipeline or sudden start/stop of the pump.

The existing water facilities were constructed under U.S. assistance. Countermeasures to cope with water hammer included using a surge tank constructed before World War II, located next to the water treatment plant. However, this tank is no longer used because of extremely low water pressure in the downstream area.

In the water pipeline to be laid for this project, water is transferred directly from the water transfer pump to the water tank, and water column separation occurs in the section near the water treatment plant and at the higher elevation. As a consequence, water hammer may occur from the water column separation.

Since the total length of water pipeline is about 12.0 km, and the pipeline is laid across an area with a great difference in elevation (maximum difference: 52 m), these conditions may cause a water hammer to occur. Countermeasures to cope with water hammer are required for long water pipelines with a high pressure such as this plan.

The probability of a water column separation occurring was calculated with a computer.

Detailed conditions, including performance characteristics curves and inertia force of the pump impeller, position and size of the air valve, accurate alignment of the pipeline, will be determined for this study. However, the probability of a water hammer occurring is calculated by assuming a worst-case scenario of an electrical power failure at the pump, and by establishing applicable numerical values for the other items.

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* Water column separation is a phenomena in which a pipe collapses or its joints rupture because of a vacuum state caused by a sudden drop of pressure at a given part of the pipeline by a pressure wave. This phenomena occurs often and is particularly prevalent at higher elevations in areas where there is a substantial difference in elevation.

a) Conditions for calculation

Rate of discharge	11,400 m^3 (3.0 million gallons)/day
Pump head	95 m (312 feet)
Pipeline length	5.7 km (from the exit of the water transfer pump to the Ngerkesoal tank)
Air valve	Air valves will be installed at the inlet pipe for Airai and Ngermid tanks.

b) Calculation results

Since water column separation may occur near the Ngermid and Ngerkesoal tanks and between the water treatment plant and K.B. Bridge, counter measures to cope with water column separation are necessary (refer to Fig. 5-3).

Possible alternative measures to cope with water column separation are listed in Table 5-12. Of these various measures, it was decided to adopt the one-way surge tank, because it presents the most reliable method at the lowest cost. The pressure distribution is modified as shown in Fig. 5-4, by installing a one one-way surge tank with 3 m^3 capacity at one place and one one-way surge tank with 7 m^3 capacity. As a result, water column separation can be prevented.

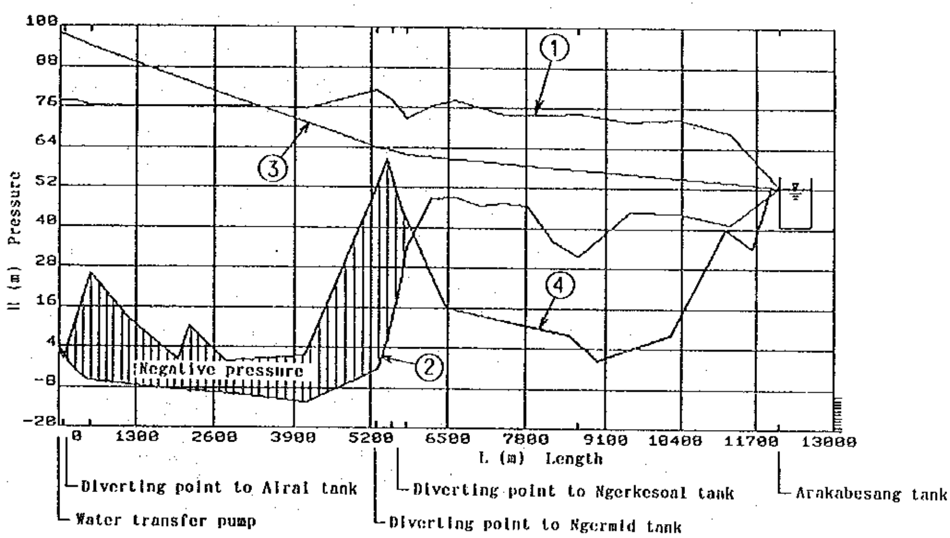


Fig. 5-3 Pressure Diagram Before Taking Measures to Cope With Water Hammer

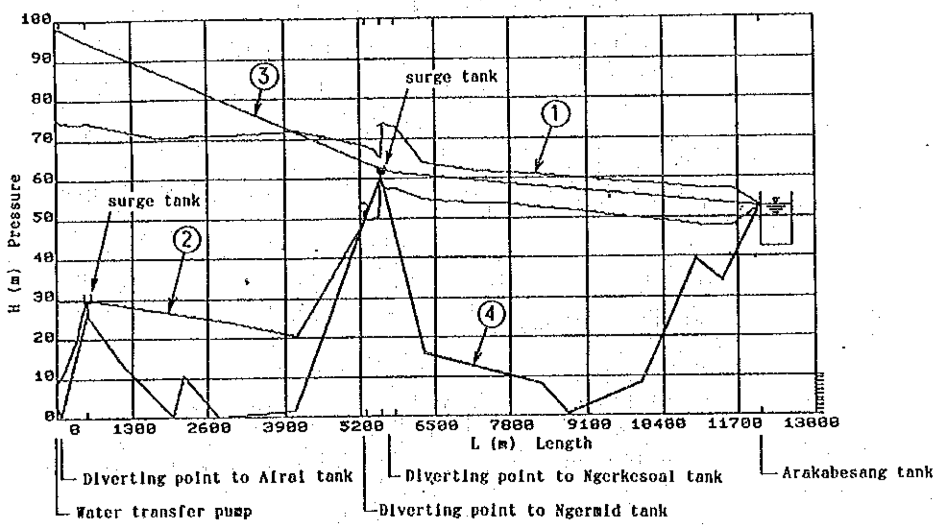


Fig. 5-4 Pressure diagram with installation of surge tanks

① Maximum pressure diagram
② Minimum pressure diagram
③ Hydraulic gradient diagram
④ Water pipeline longitudinal section

Table 5-12 Measures to Prevent Water Column Separation

Object	Method	Mechanism	Remarks
Prevention of the occurrence of negative pressure (water column separation)	Installation of flywheel	Increase of the rotary inertia GD2 to realize slow variation in the revolution speed and flow velocity inside the pipe.	This measure is effective in small-sized pumps, but it is not appropriate for large-sized machines and long pipelines because the flywheel becomes too large.
	Installation of large-capacity air chamber (connected at the pump discharge side)	Prevention of pressure drop by discharging the accumulated pressure energy.	The maintenance is troublesome because the air chamber becomes large.
	Use of large-diameter pipes	Prevention of water pressure drop by lowering the flow speed in the pipe.	Expensive construction cost is required, because it must be implemented in practically the total pipeline length.
	Modification of pipeline route	The pipe is laid as deep as possible along the longitudinal section of the pipeline route.	The implementation of this measure is difficult because there are restrictions regarding the site and cost.
	Installation of air suction valve	Reduction of abnormal pressure drop pressure by automatic suction of air from places with occurrence of negative pressure. The pressure wave propagation speed is also reduced in this case.	The results of this measure are satisfactory when there is natural gravity flow below the air suction point, but otherwise the water hammer is further intensified by the air.
	Installation of an automatic open/close valve between the water suction tank and discharge pipe located before and after the pump	Reduction of abnormal pressure drop by automatically pumping up water of he suction tank.	The desired effect may not be attained, depending on the condition of suction pipe and pit.
	Installation of one-way surge tank	Mitigation of abnormal pressure drop by thrusting water into places with occurrence of negative pressure.	A short tank (one-way) is sufficient even in pumping systems with large head, and furthermore several tanks can be installed along the pipeline.
	Installation of ordinary surge tank	Mitigation of the negative pressure and absorption of pressure rise by thrusting water into places with occurrence of negative pressure.	When the water transfer pressure inside the pipeline is high the surge tanks become tall and this results into expensive construction costs, but in reality this method brings about the ideal effects. There is no water hammer after the surge tank, and only the section between the pump and the tank must be taken into consideration.

(3) Water distribution facilities

Excluding Ngermid and Ngerkesoal tanks, from five existing water tanks the three other water tanks do not function fully because of defects in the water transfer system. In this project, four water tanks, except Malakal tank, will be used as distribution reservoirs. The total storage capacity of the four water tanks is 13,200 m^3 (3.5 million gallons). These tanks have a storage capacity of 2.5 days of the target year's water transfer quantity of 5,300 m^3 (1.4 million gallons)/day. Therefore, a sufficient quantity and pressure of water will be supplied to individual houses during the peak morning and evening water use. In the project, the improvement work of the control facilities necessary for re-use of the water tanks will be made.

(4) Water transfer pipeline

1) Selection of pipe material

200 mm and 400 mm-diameter pipelines were selected for the water transfer pipeline from the water transfer pump to individual water tanks was, as described in Section 5-3 (2). Water supply pressure during the normal operation will be about 9.5 kgf/cm^2 (about 135 psi) near the water transfer pump station, about 3.3 kgf/cm^2 (about 50 psi) near the water tank.

The pipe materials will be selected based on the above conditions. As in the water transfer pipeline, the following pipe materials are generally used.

- Ductile cast iron pipe
- Steel pipe
- Fiber reinforced plastic composite pipe

These pipe materials were compared in terms of technical characteristics (strength, durability, impermeability, flexibility and expansion/contraction properties), cost (material, construction and maintenance costs) and maintenance. The ductile cast iron pipe (Class-3) was selected because it has no technical problem, the material cost is lowest, and can be easily maintained.

T-type joint (socket joint) will be used for the straight ductile cast iron pipes, while K-type joint (mechanical joint) will be used for the fittings for the water transfer pipeline.

2) Standard earthcovering thickness

As in the study for the raw water pipeline, the standard earthcovering thickness for the pipelines is 0.9 m in the flat areas, and 0.7 m in the sloped areas.

In general, all water transfer pipelines will be constructed underneath the 1.5-meter-wide public land running alongside the paved road. However, where 1.5-meter-wide space is not available, the raw water pipeline will be constructed underneath the paved road.

Since the pipelines will be laid alongside the road, vehicle load is not taken into consideration. However, the laying of the water transfer pipeline will be planned to withstand loads of up to 20-tons for places where vehicles will cross the road .

3) Standard excavation section

The soil in the project site area, mainly consisting of laterite, is in good condition except for when it becomes wet. The excavation for each pipe will be determined, according to the pipe diameter, pipe joint types, earthcovering depth, the type of the foundation work, the working space for laying pipes, the construction cost reduction and the shortening of construction work period. The standard excavation sections are shown as follows.

Pipe diameter (mm)	Excavation width (m)	Excavation depth (m)	
		Earthcovering depth: 0.9 m	Earthcovering depth: 0.7 m
300	0.70	1.33	1.13
250	0.70	1.28	1.08
200	0.70	1.22	1.02

A pipe bottom supporting angle will be more than 60 degrees for pipes laid where coral rock is excavated. A layer of good-quality, compacted sand will be provided at a depth of 10 cm below the pipe to protect the pipe. Sleepers will be placed to secure the safety,durability and maintenance of the pipe for the pipes laid where soft ground including mangrove's humus is excavated.

4) The thickness of the pipe

The thickness of the pipe is determined according to the formula for ductile cast iron pipe thickness, JIS G 5526. The pipe thickness corresponding to earthcover are listed in Table 5-9.

$$t = \frac{1.25Ps + Pd + \sqrt{(1.25Ps + Pd)^2 + 8.4\,(Kf \cdot Wf + Kt \cdot Wt)S}}{2S} \times D$$

T = t + 2 + 1 (allowing for 2 mm corrosion margin and 1 mm of minimum casting tolerance margin)

where:

t	=	Net pipe thickness	(mm)
T	=	Design pipe thickness	(mm)
Ps	=	Hydrostatic pressure	(kgf/cm^2)
Pd	=	Pressure due to water hammer	(kgf/cm^2)
2θ	=	Pipe bottom supporting angle	60 Degrees)
Kf	=	Coefficient determined by the soil pressure distribution corresponding to the supporting angle of the pipe.	

Value of Kf

Position 2θ	40°	60°	90°
Top of pipe	0.140	0.132	0.120
Bottom of pipe	0.281	0.223	0.160

Wf = Static soil pressure (the full soil weight formula is used)
$Wf = \gamma H$

γ = Weight per unit volume of soil 1.8×10^{-3} (kgf/cm^3)

H = Earthcover (cm)

Kt = Coefficient determined by the soil pressure distribution caused by the dynamic vehicle load.

Value of Kt

Top of pipe	0.076
Bottom of pipe	0.011

Wt = Dynamic load (the Boussinesq's Formula is applied)

$Wt = 1.5\alpha P$

α = Coefficient of the superimposed load

Overburden (cm)	70	80	90
α	8.35×10^{-5}	7.20×10^{-5}	6.30×10^{-5}

W = Truck weight 20 (ton)

P = Truck rear wheel load 8,000 (kg)

$P = 4/5 \times 1/2\ W$

(5) Water supply condition in Malakal Island

1) Water tank

The water will be supplied from the Ngerkesoal and Arakabesang tanks to Malakal Island.

2) Water supply quantity to each served area

Served population and water supply quantity to each served area is shown below.

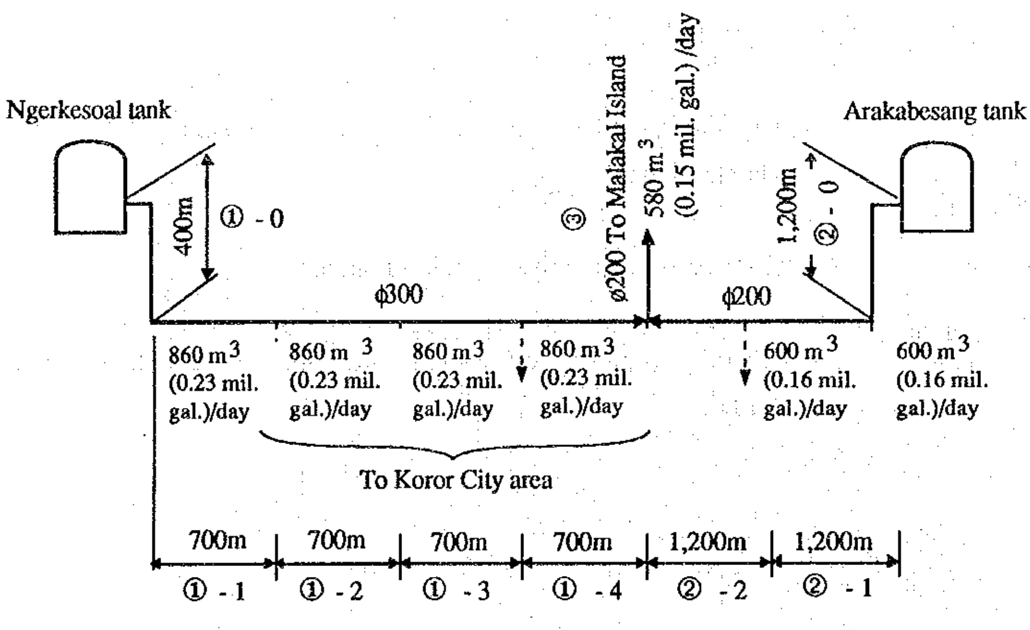
Water Supply Quantity to Each Served Area at the Target Year

Served area by Ngerkesoal tank	West area on Koror Island	Malakal Island	Arakabesang Island	Total
Served population	8,900	1,500	3,100	13,500
Water supply quantity at the target year (m^3/day)	2,300 (0.61 mil gal/day)	400 (0.1 mil gal/day)	800 (0.21 mil gal/day)	3,500 (0.93 mil gal/day)
Water supply quantity for design of water facilities (m^3/day)	3,500 (0.92 mil gal/day)	580 (0.15 mil gal/day)	1,200 (0.32 mil gal/day)	5,280 (1.39 mil gal/day)

3) Calculation of friction head loss of the pipes

The friction head loss of the pipes from the water tank to the served area on each island is calculated by using the generally adopted Hazen-Williams' Formula. The velocity coefficient of the pipe is set at C = 110 by taking by assuming an increase in pipe friction loss caused by the number of years of use and pipeline bends.

Water supply in the Koror area is assumed as the figure below, and the friction head loss of the pipes was calculated, assuming that water is not wastefully used and water does not leaked in the intermediate section of the pipes.



The following equations are used to calculate the hydraulic gradient and the friction head loss.

$$I = 10.666 C H^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where:

I	=	hydraulic gradient	
C	=	flow velocity coefficient	110
D	=	inner diameter of the pipe	(m)
Q	=	rate of discharge	(m^3/sec)

$$\Delta H = I \times L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where:

ΔH	=	friction head loss	(m)
L	=	piping length	(m)

The friction head loss between served areas on Malakal Island and water tanks according to water consumption, , the pipe diameter and length is as follows:

- 4.8 m (16 feet) : [① + ③ in the the table below] — pipeline between Ngerkesoal tank and Malakal Island
- 5.1 m (17 feet) : [② + ③ in the the table below] — pipeline between Arakabesang tank and Malakal Island

Details are given below:

No.	Rate of discharge Q (m^3/s)	Pipe diameter D (m)	Pipe length L (m)	Friction head loss of pipes by segment Δh (m)	Friction head loss of all pipes ΔH (m)	Remarks
① - 0	0.040	0.3	1,100	1.79	33	
① - 1	0.040	0.3				
① - 2	0.034	0.3	700	0.84		
① - 3	0.025	0.3	700	0.48		
① - 4	0.015	0.3	700	0.19		
② - 0	0.016	0.2	1,200	2.58		
② - 1	0.014	0.2	1,200	0.89	3.6	
② - 2	0.002	0.2	1,200	0.06		
③	0.007	0.2	3,100	1.45	1.5	

4) Effective head on Malakal Island

The elevation of the served areas is 51.9 m (170 ft) above sea level, for Malakal Island, as shown in the following table.

a) Effective head on the pipeline from the Ngerkesoal tank

1. Friction head loss of the pipe (m)	4.8 (16 feet)
2. Water level at Ngerkesoal tank (m)	58.9 (19.3 feet)
3. Effective head on Malakal Island [②-①] (m)	54.1 (177 feet)

b) Effective head on the pipeline from the Arakabesang tank

1. Friction head loss of the pipe (m)	5.1 (17 feet)
2. Water level at Arakabesang tank (m)	57.0 (187 feet)
3. Effective head on Malakal Island [②-①] (m)	51.9 (170 feet)

5) Conclusion

On Malakal Island, the districts at an elevation of 30-40 m will be developed as sites for residence, industry and tourism. Thus, water can be supplied to the highland districts.

(6) Plan for provision

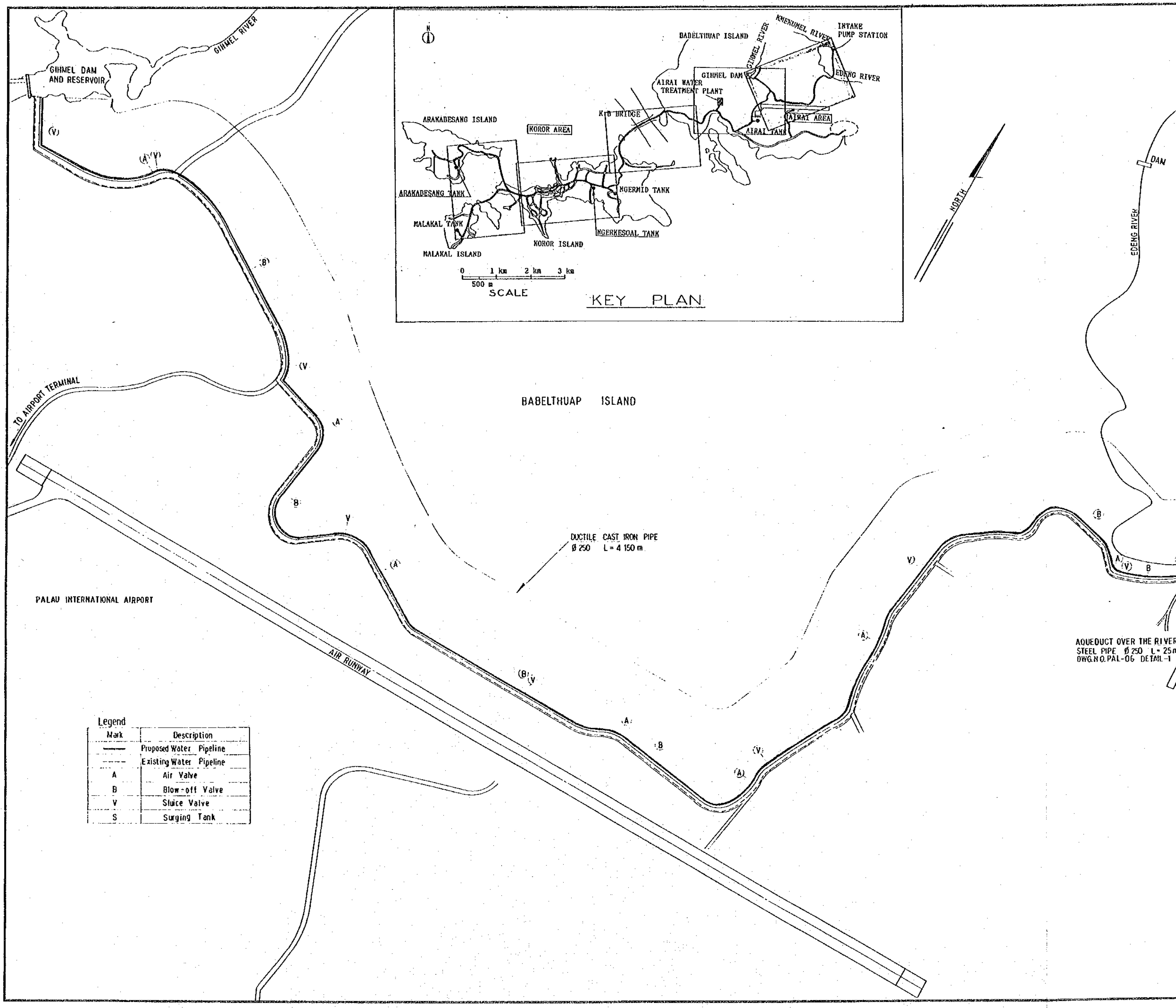
The following facilities which will be provided under Japan's grant aid are as follow:

Pipelines and facilities	Quantity	Description
Raw water pipe (for the intake to Gihmel dam) ø250 ductile cast iron	 5.1 km	
Water transfer pipe (from the water treatment plant to each water tank) ø400 ductile cast iron ø300 ductile cast iron ø250 ductile cast iron ø200 ductile cast iron	 0.1 km 5.5 km 6.8 km 2.4 km	Steel pipes are used in the section installed along the bridge and sidewalk.
Water level control facility for the existing water tank	4 sets	Automatic valve, water gauge, etc.
Water transfer pump	1 set	Multistage turbine pump Capacity: 3.97 m^3 (1,050 gallons)/min. Total head: 87.2 m (286 feet)
Painting work for the Arakabesang tank (outside and inside surfaces) Sand blasting equipment will be supplied to the Government of Palau for repair and maintenance of other water tanks after using for painting work of Arakabesang tank.	1 set	

5-4 Basic Design Drawings

LIST OF BASIC DESIGN DRAWINGS

Drawing No.	Title
PAL - 01	PLAN OF WATER TRANSFER PIPELINE (1/5)
PAL - 02	PLAN OF WATER TRANSFER PIPELINE (2/5)
PAL - 03	PLAN OF WATER TRANSFER PIPELINE (3/5)
PAL - 04	PLAN OF WATER TRANSFER PIPELINE (4/5)
PAL - 05	PLAN OF WATER TRANSFER PIPELINE (5/5)
PAL - 06	DETAIL OF WATER TRANSFER PIPELINE (1/4)
PAL - 07	DETAIL OF WATER TRANSFER PIPELINE (2/4)
PAL - 08	DETAIL OF WATER TRANSFER PIPELINE (3/4)
PAL - 09	DETAIL OF WATER TRANSFER PIPELINE (4/4)
PAL - 10	WATER TRANSFER PUMP IN WATER TREATMENT PLANT



Legend

Mark	Description
———	Proposed Water Pipeline
- - - -	Existing Water Pipeline
A	Air Valve
B	Blow-off Valve
V	Sluice Valve
S	Surging Tank

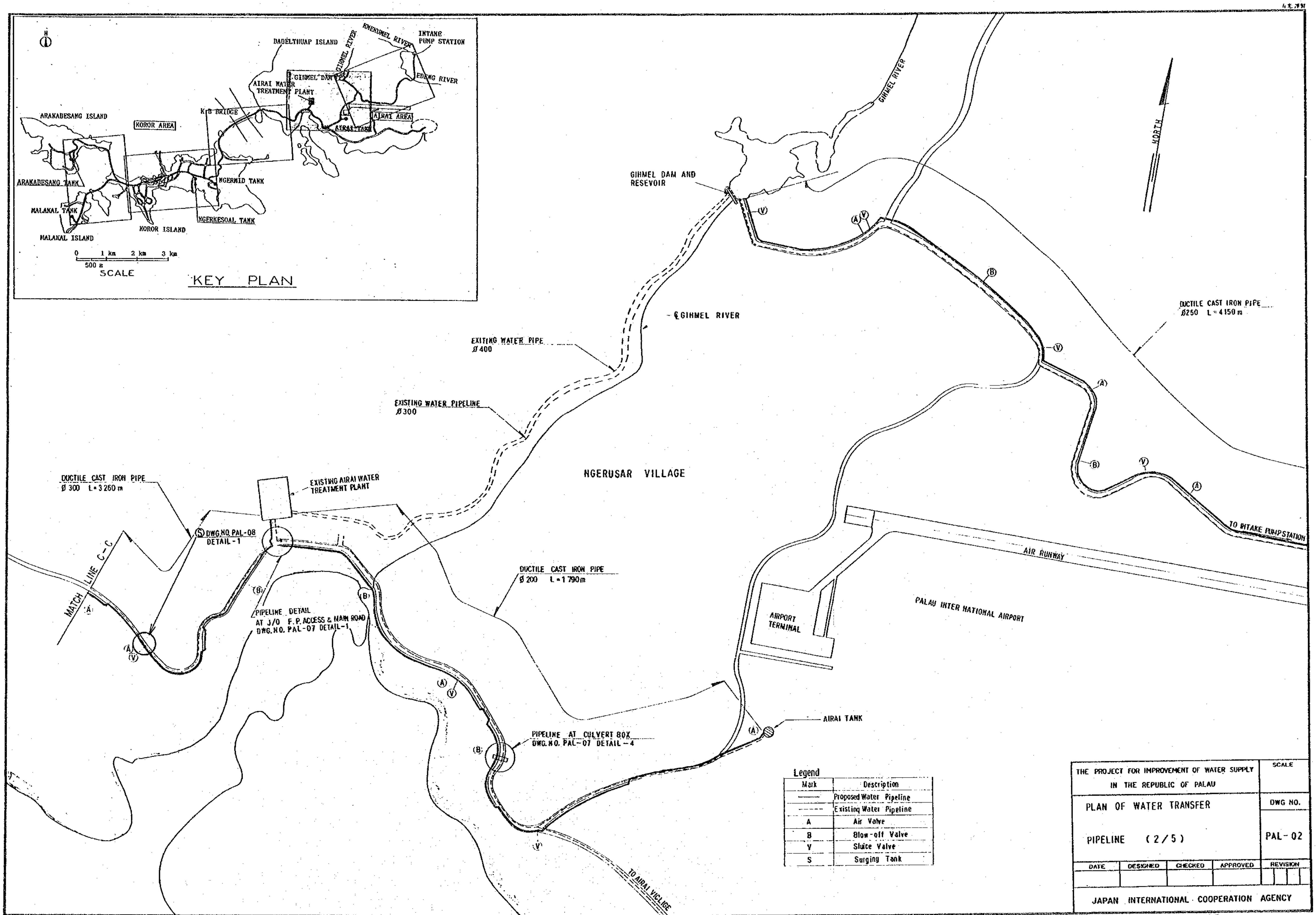
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU

PLAN OF WATER TRANSFER

PIPELINE (1/5)

SCALE	DWG NO.	DATE	DESIGNED	CHECKED	APPROVED	REVISION
	PAL- 01					

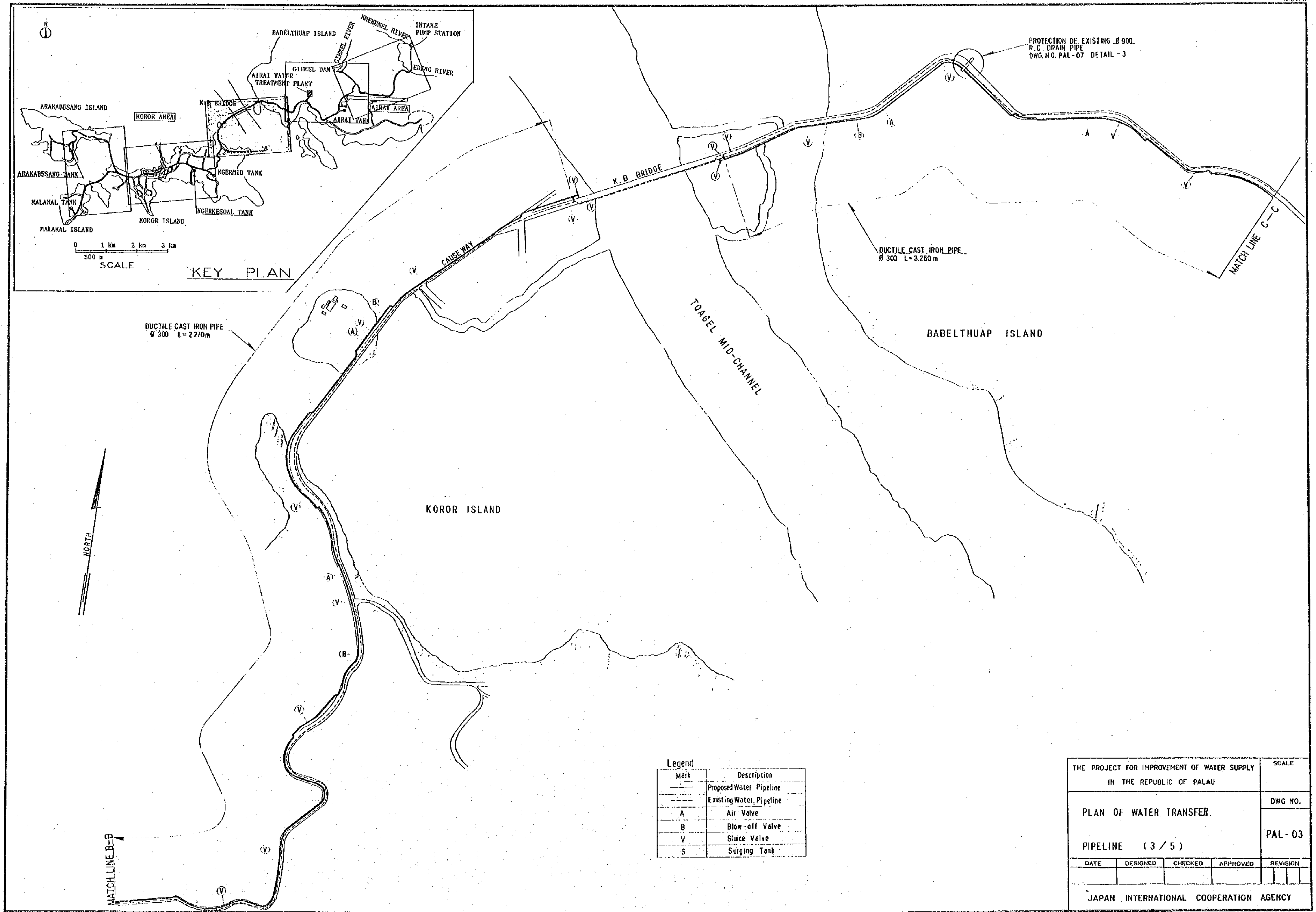
JAPAN INTERNATIONAL COOPERATION AGENCY



Legend

Mark	Description
———	Proposed Water Pipeline
- - - -	Existing Water Pipeline
A	Air Valve
B	Blow-off Valve
V	Sluice Valve
S	Surging Tank

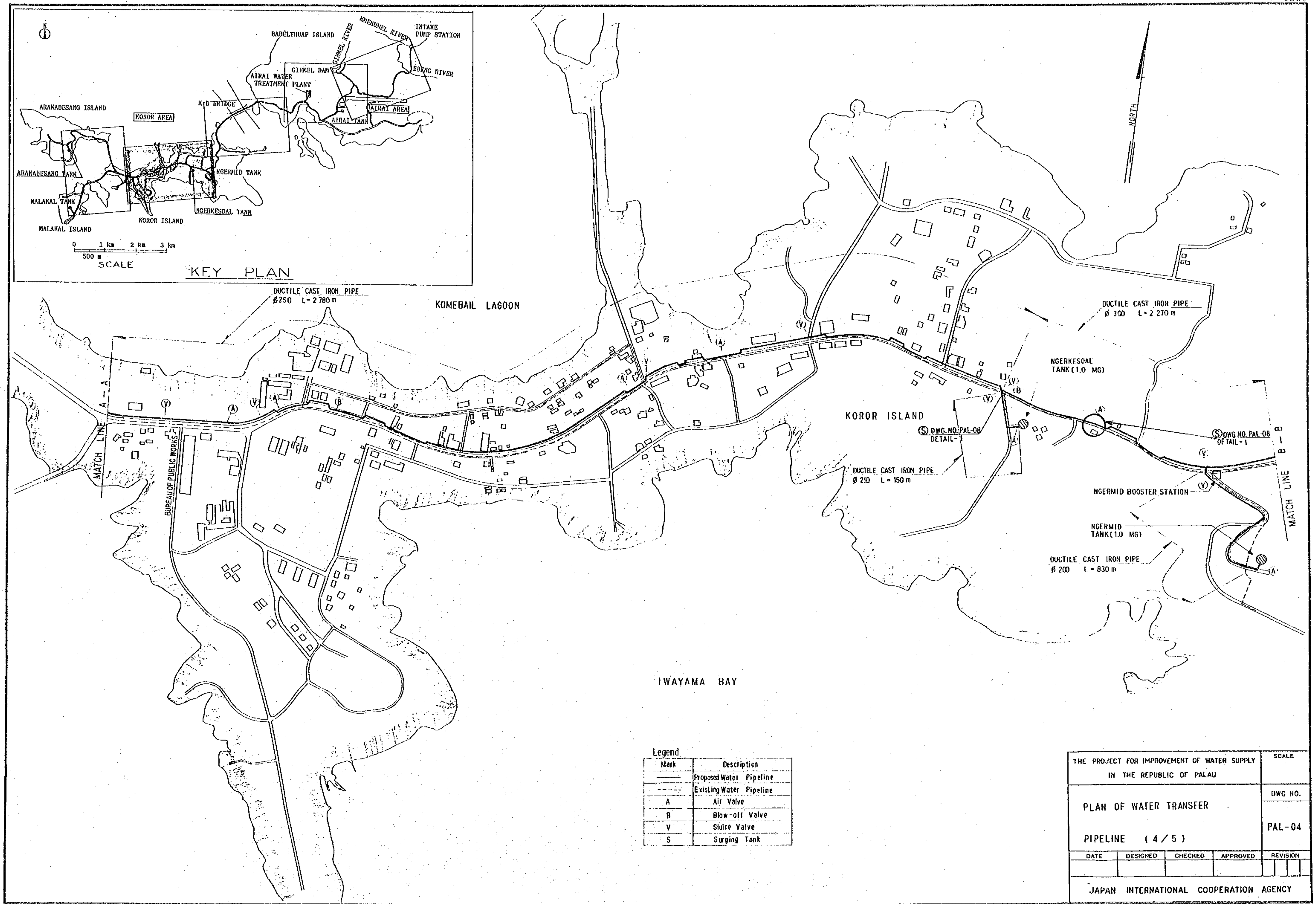
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU				SCALE
PLAN OF WATER TRANSFER				DWG NO.
PIPELINE (2/5)				PAL-02
DATE	DESIGNED	CHECKED	APPROVED	REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY				

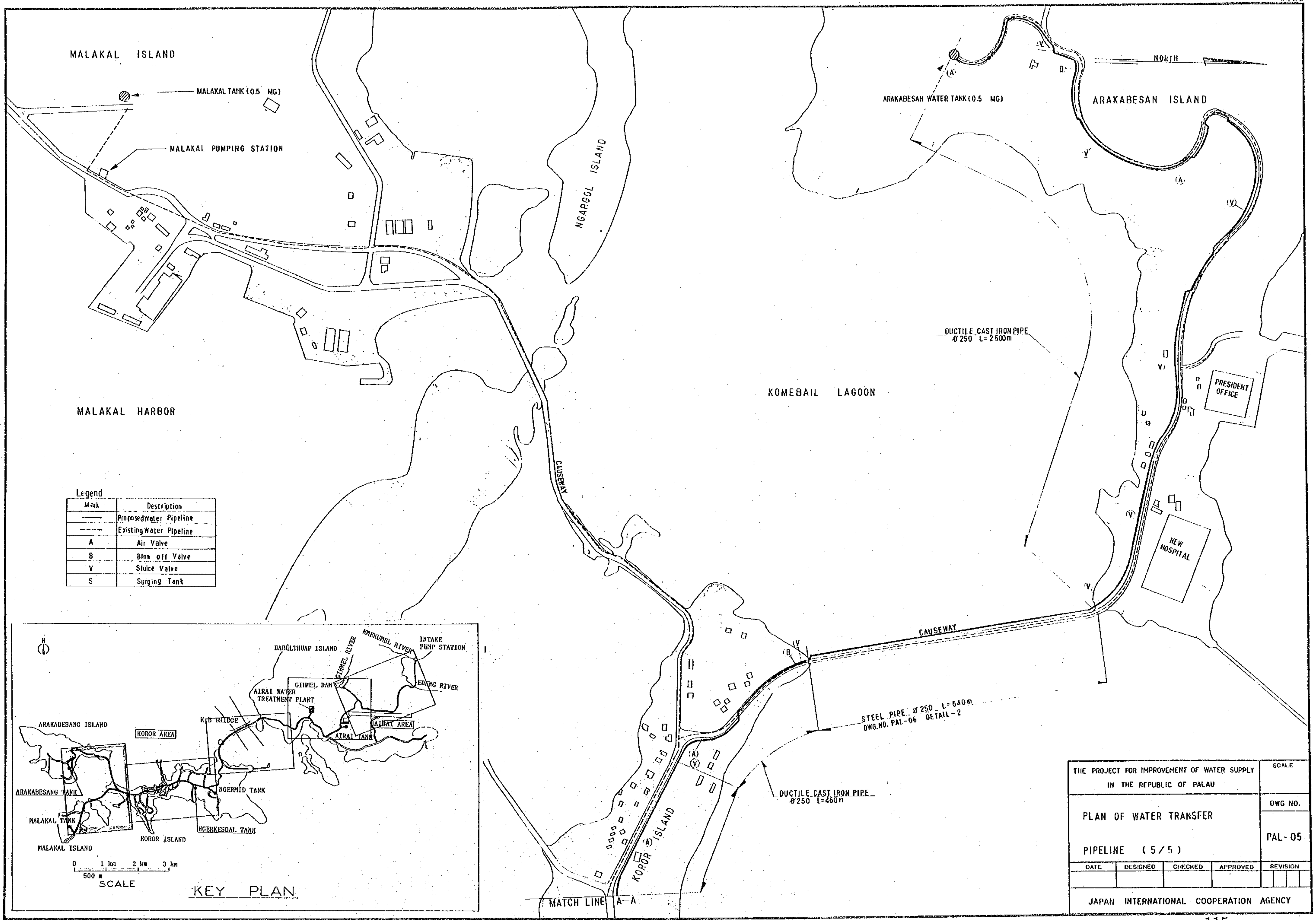


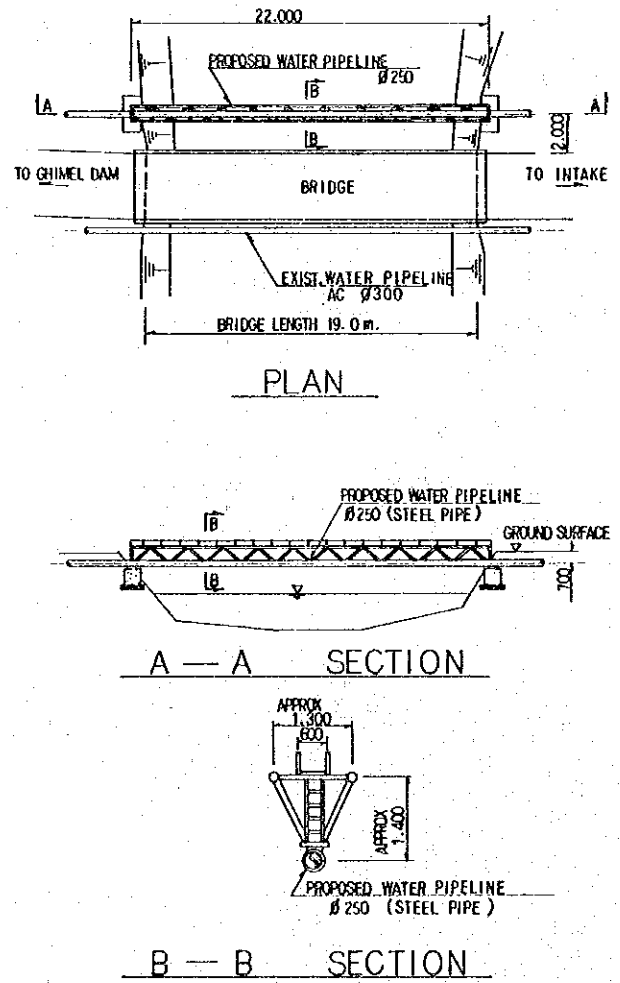
Legend

Mark	Description
———	Proposed Water Pipeline
- - - -	Existing Water Pipeline
A	Air Valve
B	Blow-off Valve
V	Sluice Valve
S	Surging Tank

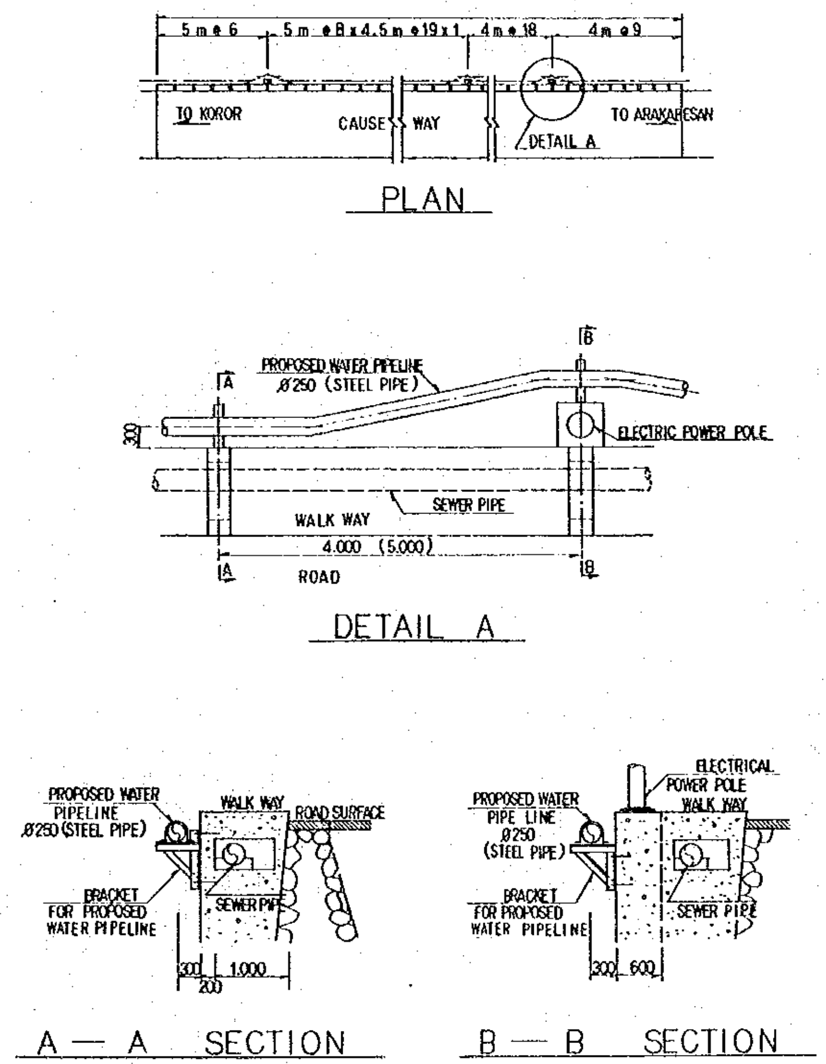
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU				SCALE
PLAN OF WATER TRANSFER PIPELINE (3/5)				DWG NO. PAL-03
DATE	DESIGNED	CHECKED	APPROVED	REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY				


KEY PLAN
BABELTHUAP ISLAND
NGERKUMEL RIVER
GIHMEL RIVER
INTAKE PUMP STATION
EDENG RIVER
GIHMEL DAM
AIRAI WATER TREATMENT PLANT
K-B BRIDGE
AIRAI AREA
AIRAI TANK
ARAKABESANG ISLAND
KOROR AREA
ARAKABESANG TANK
NGERMID TANK
MALAKAL TANK
NGERKESOAL TANK
KOROR ISLAND
MALAKAL ISLAND
0 1 km 2 km 3 km
500 m
SCALE
NORTH
KOMEBAIL LAGOON
DUCTILE CAST IRON PIPE Ø250 L=2 780 m
DUCTILE CAST IRON PIPE Ø300 L=2 270 m
NGERKESOAL TANK (1.0 MG)
KOROR ISLAND
DWG. NO. PAL-08 DETAIL-1
DWG. NO. PAL-08 DETAIL-1
DUCTILE CAST IRON PIPE Ø250 L=150 m
NGERMID BOOSTER STATION
NGERMID TANK (1.0 MG)
DUCTILE CAST IRON PIPE Ø200 L=830 m
MATCH LINE A-A
MATCH LINE B-B
BUREAU OF PUBLIC WORKS
IWAYAMA BAY
Legend
Mark | Description
——— | Proposed Water Pipeline
- - - - | Existing Water Pipeline
A | Air Valve
B | Blow-off Valve
V | Sluice Valve
S | Surging Tank
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU
SCALE
PLAN OF WATER TRANSFER PIPELINE (4/5)
DWG NO.
PAL-04
DATE
DESIGNED
CHECKED
APPROVED
REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY


MALAKAL ISLAND
MALAKAL TANK (0.5 MG)
MALAKAL PUMPING STATION
MALAKAL HARBOR
NGARGOL ISLAND
CAUSEWAY
KOMEBAIL LAGOON
NORTH
ARAKABESAN WATER TANK (0.5 MG)
ARAKABESAN ISLAND
DUCTILE CAST IRON PIPE Ø250 L=2500m
PRESIDENT OFFICE
NEW HOSPITAL
CAUSEWAY
STEEL PIPE Ø250 L=640m
DWG.NO. PAL-06 DETAIL-2
DUCTILE CAST IRON PIPE Ø250 L=460m
KOROR ISLAND
MATCH LINE A—A
Legend
Mark | Description
Proposed Water Pipeline
Existing Water Pipeline
A Air Valve
B Blow off Valve
V Sluice Valve
S Surging Tank
BABELTHUAP ISLAND
NGIMEL RIVER
KMEKUMEL RIVER
INTAKE PUMP STATION
EDENG RIVER
GIIMEL DAM
AIRAI WATER TREATMENT PLANT
K-B BRIDGE
KOROR AREA
AIRAI AREA
AIRAI TANK
ARAKABESANG ISLAND
ARAKABESANG TANK
NGERMID TANK
MALAKAL TANK
KOROR ISLAND
NGERKESOAL TANK
MALAKAL ISLAND
0 1 km 2 km 3 km
500 m
SCALE
KEY PLAN
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU
SCALE
PLAN OF WATER TRANSFER PIPELINE (5/5)
DWG NO.
PAL-05
DATE
DESIGNED
CHECKED
APPROVED
REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY

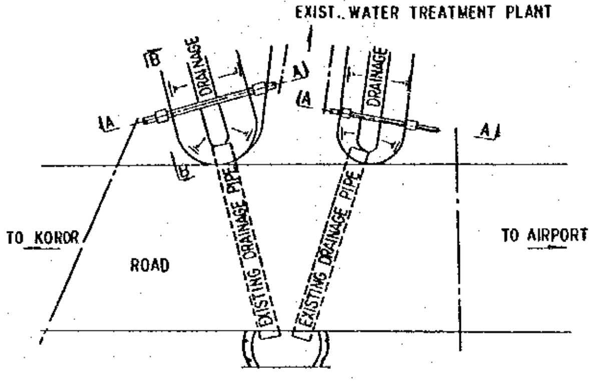


① DETAIL OF WATER PIPE BRIDGE TO INTAKE

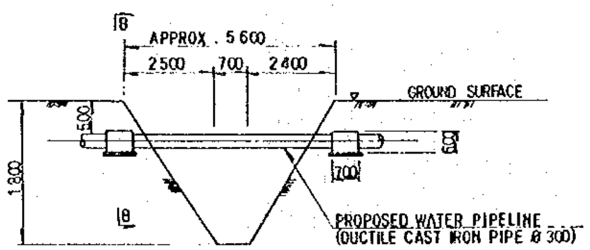


② PROPOSED WATAR PIPELINE ALONG CAUSEWAY

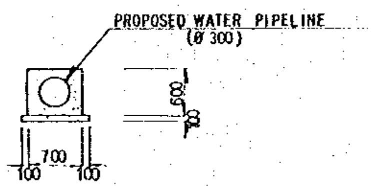
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU		SCALE
DETAIL OF WATER TRNSFER PIPELINE (1/4)		DWG NO. PAL-06
DATE	DESIGNED	CHECKED
APPROVED		REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY		



PLAN

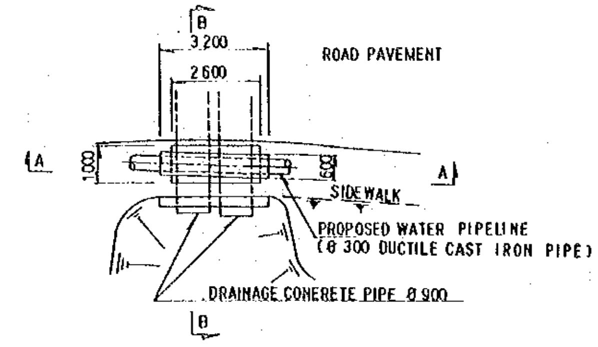


A — A SECTION

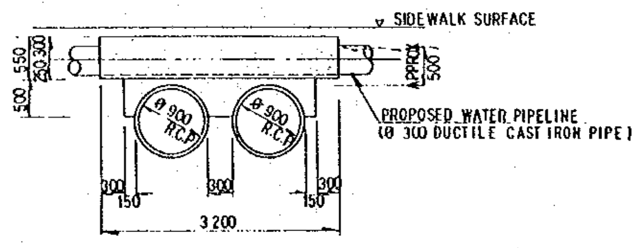


B — B SECTION

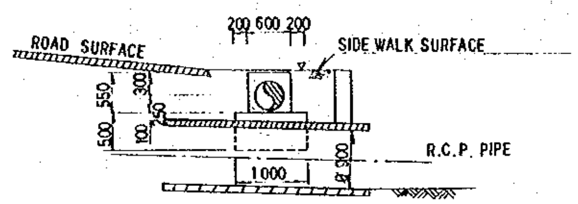
① PLAN FOR PROPOSED WATER PIPELINE NEAR EXIST. WTP



PLAN

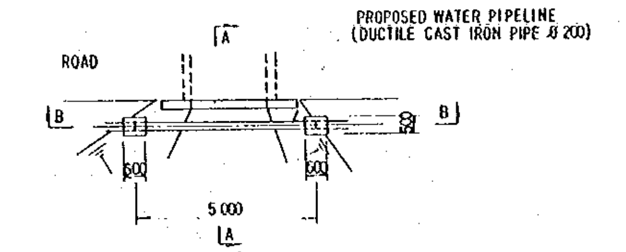


A — A SECTION

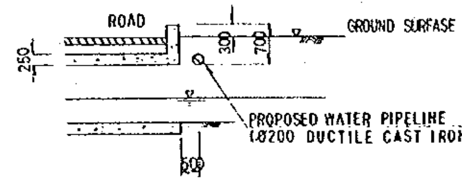


B — B SECTION

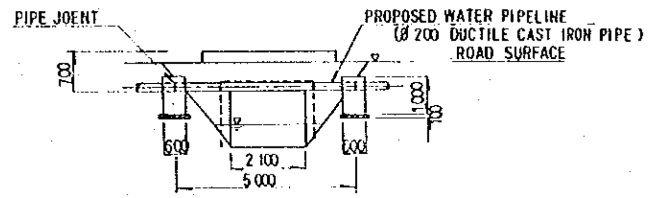
③ DETAIL OF PROPOSED WATER PIPELINE ON R.C.P PIPE



PLAN



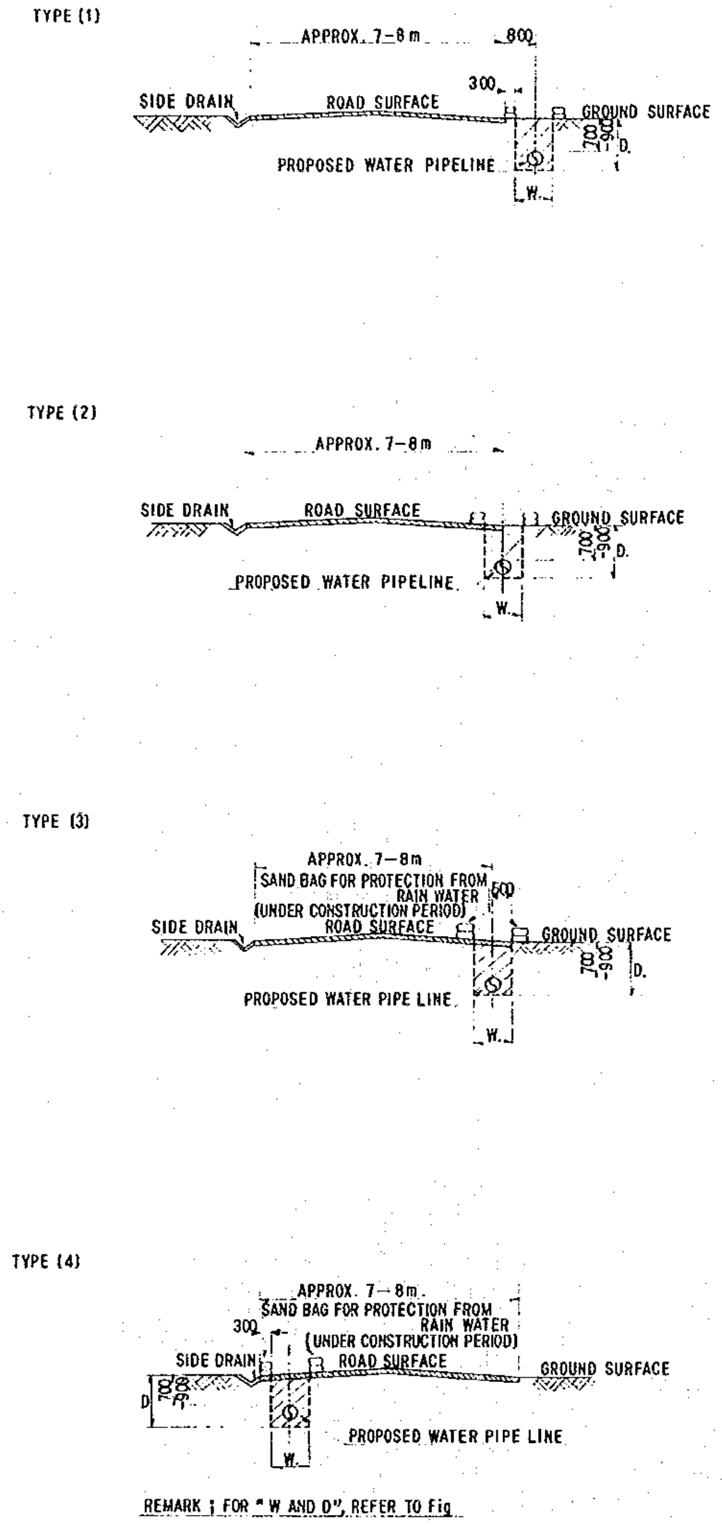
A — A SECTION



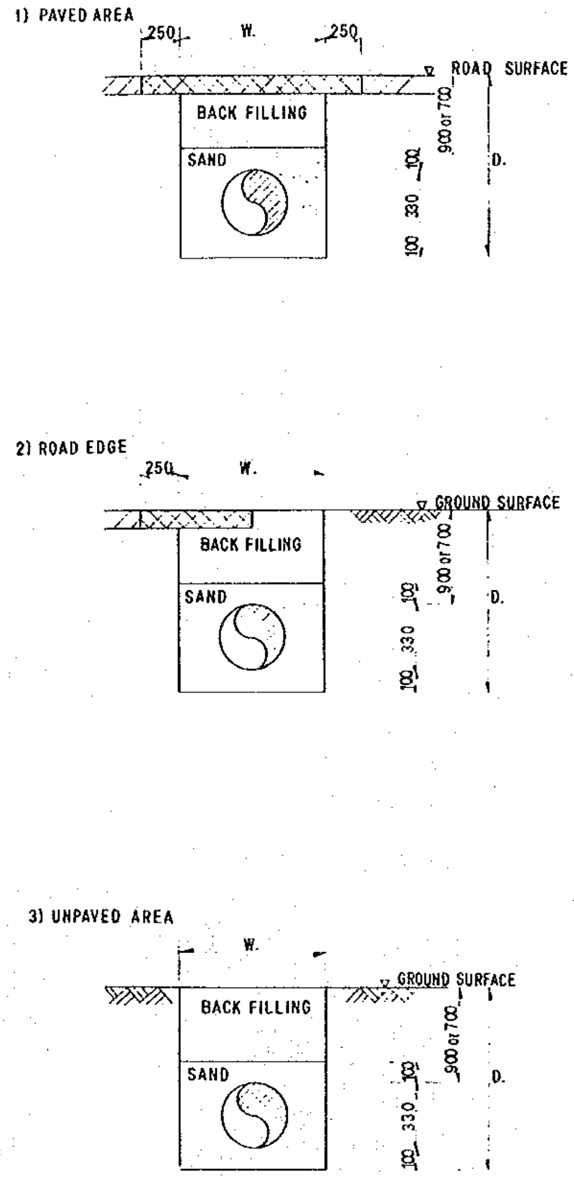
B — B SECTION

④ DETAIL OF PROPOSED WATER PIPELINE BESIDE EXIST. CULVERT AT AIRAI

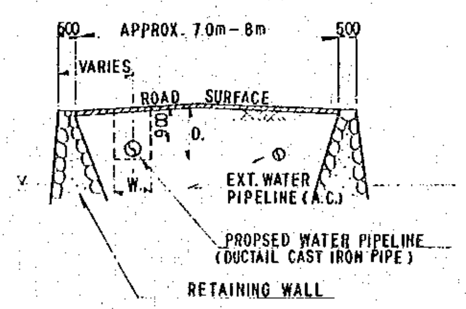
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU				SCALE
DETAIL OF WATER TRANSFER PIPELINE (2 / 4)				DWG NO. PAL - 07
DATE	DESIGNED	CHECKED	APPROVED	REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY				



TYPICAL CROSS SECTION OF WATER PIPELINE



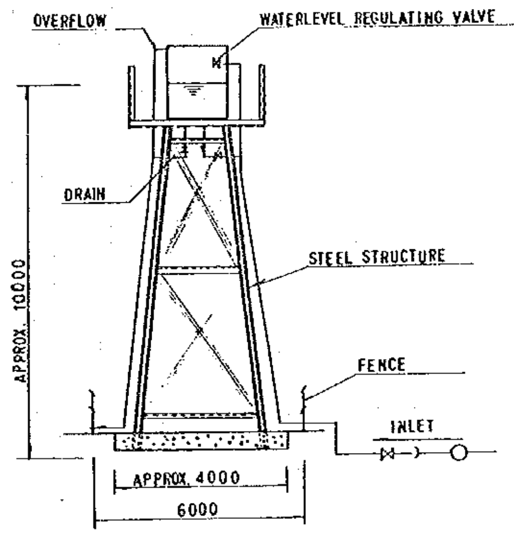
TYPICAL SECTION OF MAIN PIPE
DIAMETER OF PIPE = 300mm



TYPICAL SECTION IN CAUSEWAY

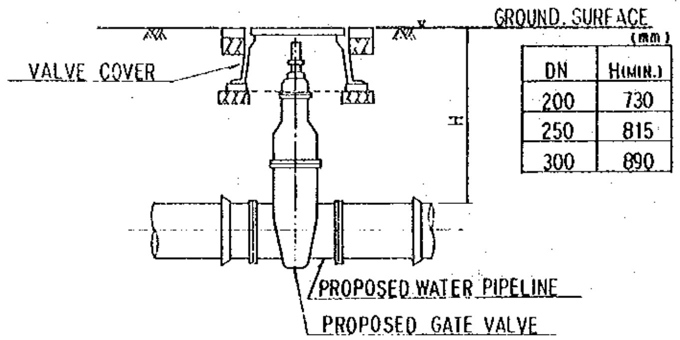
EXCAVATION MEASURE TABLE

LOCATION	PIPE DIAMETER / COVER (mm)	300 (mm)		250 (mm)		200 (mm)	
		900	700	900	700	900	700
PAVED AREA	DEPTH(m)	1.33	1.13	1.28	1.08	1.22	1.02
	WIDTH(m)	0.70	0.70	0.70	0.70	0.70	0.70
ROAD EDGE	DEPTH(m)	1.33	1.13	1.28	1.08	1.22	1.02
	WIDTH(m)	0.70	0.70	0.70	0.70	0.70	0.70
UNPAVED AREA	DEPTH(m)	1.33	1.13	1.28	1.08	1.22	1.02
	WIDTH(m)	0.70	0.70	0.70	0.70	0.70	0.70

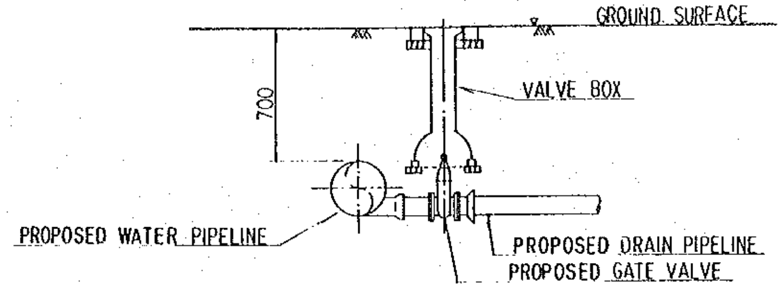


① DETAIL OF SURGING TANK

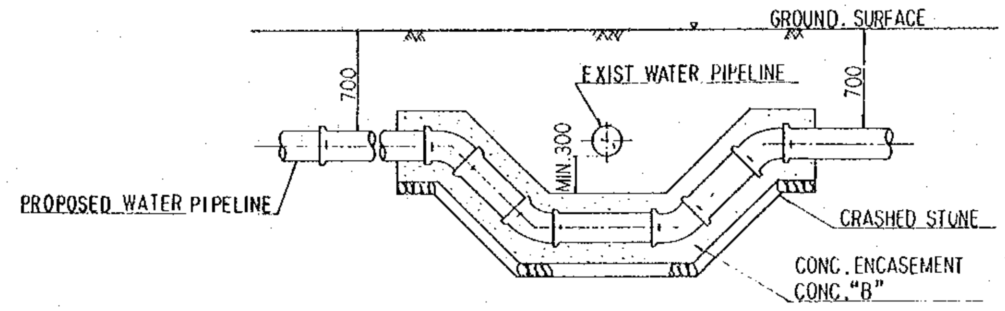
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU	SCALE
DETAIL OF WATER TRANSFER PIPELINE (3 / 4)	DWG NO. PAL - 08
DATE / DESIGNED / CHECKED / APPROVED	REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY	



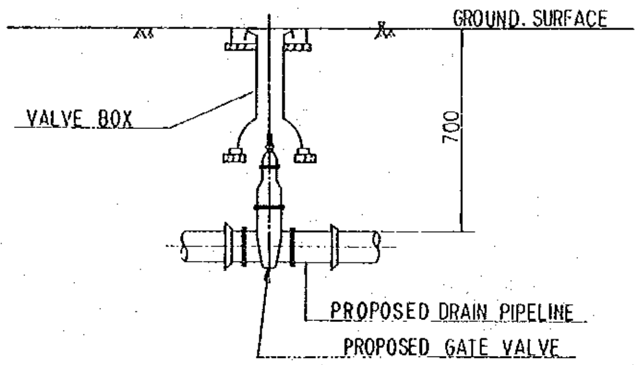
VALVE COVER



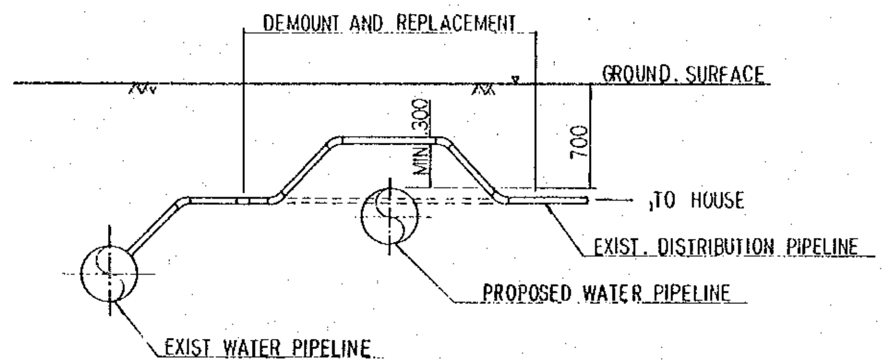
DRAIN BRANCH



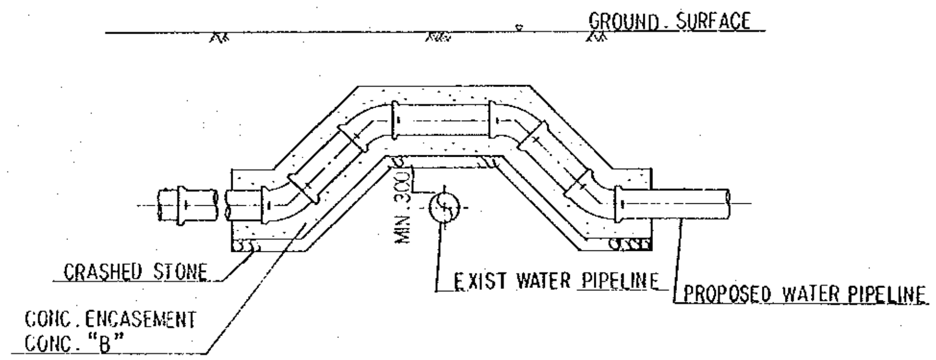
TYPE A



VALVE BOX FOR DRAIN PIPELINE

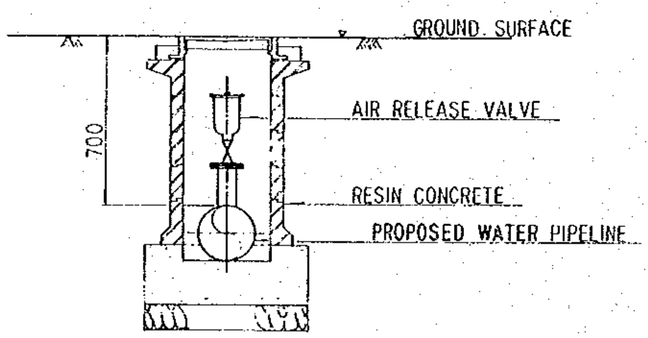


REPLACEMENT OF DISTRIBUTION PIPELINE
AT PARTS CROSSING PROPOSED WATER PIPELINE



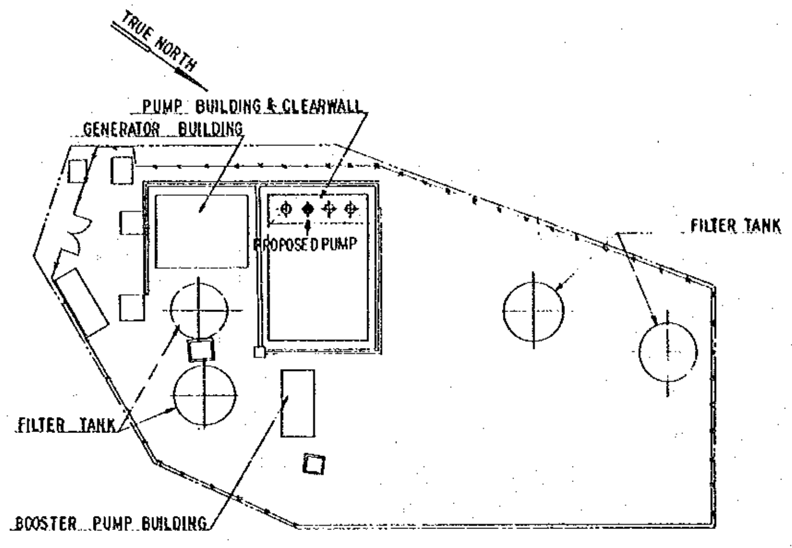
TYPE B

PIPE CROSSING OF EXIST WATER PIPELINE

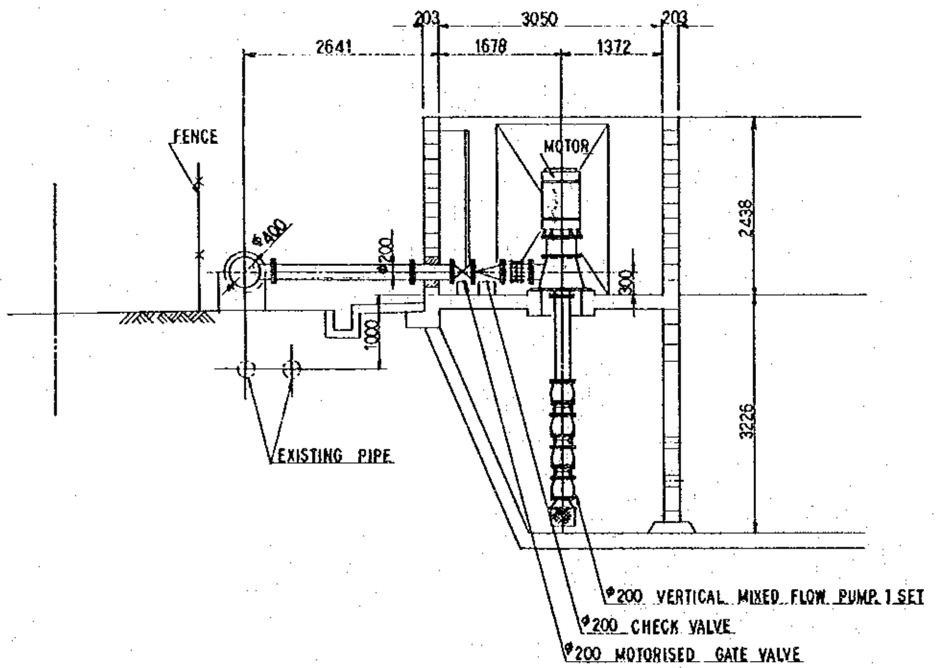


AIR VALVE BOX

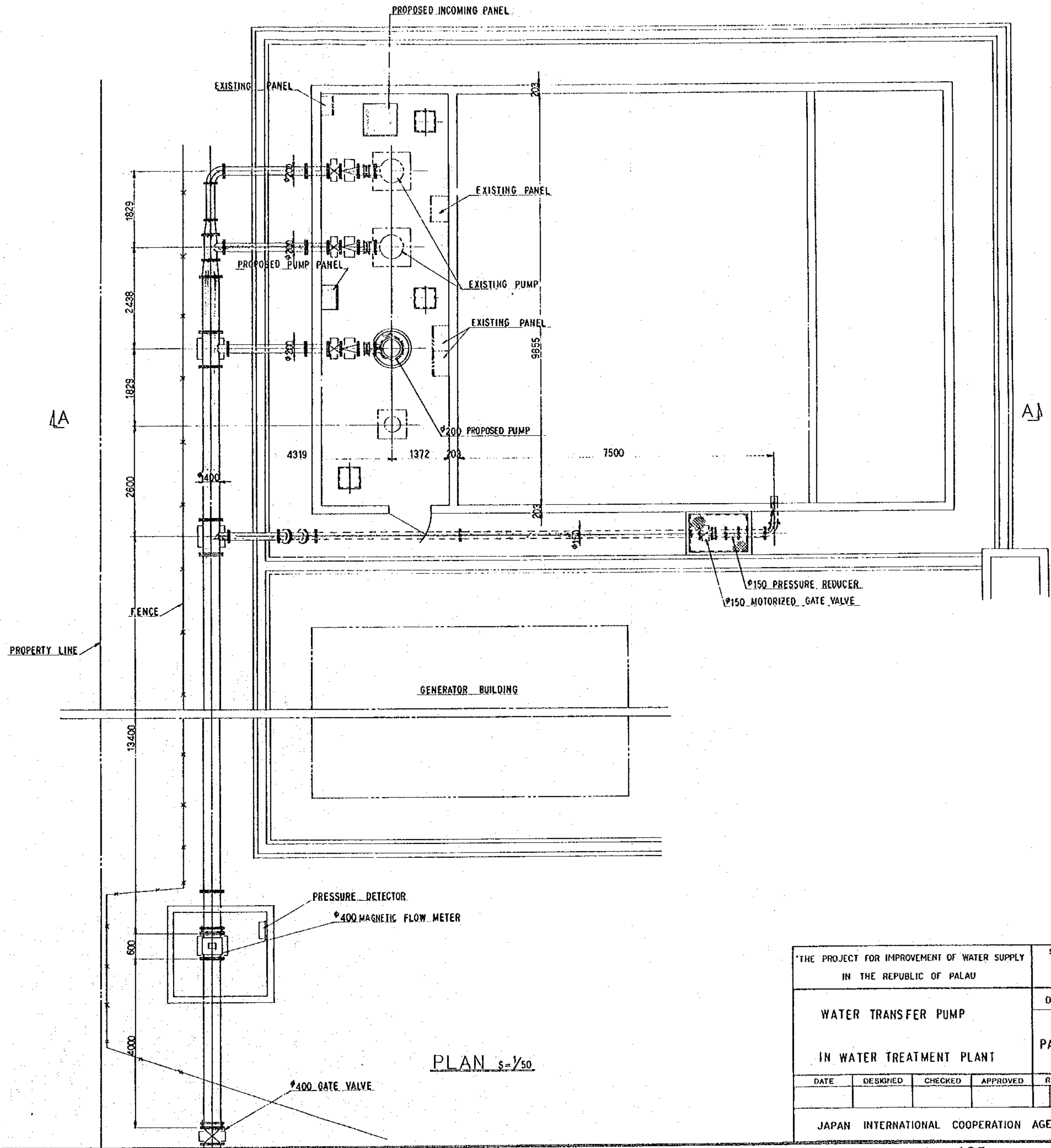
THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU				SCALE
DETAIL OF WATER TRANSFER PIPELINE (4 / 4)				DWG NO. PAL-09
DATE	DESIGNED	CHECKED	APPROVED	REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY				



KEY PLAN NOT SCALE



SECTION A – A S=1/50



PLAN S=1/50

THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY IN THE REPUBLIC OF PALAU				SCALE
WATER TRANSFER PUMP IN WATER TREATMENT PLANT				DWG NO. PAL - 10
DATE	DESIGNED	CHECKED	APPROVED	REVISION
JAPAN INTERNATIONAL COOPERATION AGENCY				

5-5 Execution Plan

5-5-1 Construction conditions and execution method

(1) Construction conditions

Major points in the condition of local construction related to the implementation of this project are follows:

1) Palau depends largely on imports for its construction machines and materials.

2) There are only approximately three local construction firms and their experience is presumed to be limited to earthworks, concrete works, small scale plumbing and piping works and construction works of medium scale buildings and structures.

3) The ability of local engineers and skilled workers is generally considered low. Filipino engineers will be employed to engage in pipe connection and pump installation work. Unskilled workers and laborers will be locally employed.

4) It is necessary to dispatch engineers and technicians from either Japan or a third country to execute works that require highly advanced techniques, as well as to guide, instruct and supervise the local engineers and skilled workers on technical matters. The following works, which require highly advanced techniques, cannot be executed only by the local construction firms.

   - Installation of water transfer pipeline
   - Installation of mechanical and electrical equipment such as motors and pumps.
   - Installation performance tests of machinery and electrical equipment such as pipes, water meters, etc.

5) Since many existing underground pipes (service pipes, sewer pipes) whose actual location and or depth are unknown or different from what is shown in the drawings, special care will be taken to prevent damage to them; and if damaged, to restore them to their original condition.

(2) Precautions in the execution of the work

The execution method will be determined for the improvement work of the water facilities in consideration of the following:

1) Efforts should be made to have local residents fully understand the contents of the project and obtain their cooperation and support in executing the work. Also, every precaution should be taken to prevent residents from being involved in accidents from this work.

2) In executing the work, execution methods, construction machines, work hours, etc. should be carefully selected to minimize nuisance of vibration and noise to residents.

3) Efforts should be made to the safety of pedestrians and traffic flow and commercial activities. For this, execution plans for excavation, pipe laying, backfilling and road reinstatement should be drawn up so that traffic restrictions can be lifted as soon as possible and that all sectional work will be completed within a couple of days.

4) Efforts should be made to ensure the function of and prevent damage to the many existing underground services (sewer and water pipes and electric and telecommunication cables).

5) In executing the pipe laying work, proper countermeasures should be taken to prevent rainwater from entering the excavated trenches, since the drainage and drying conditions of the soil (clay soil) are very poor, and the possibility of heavy rainfall is very high.

6) Efforts will be made to prevent accidents by always checking heavy equipment and machines such as cranes, wires and other critical items.

7) When transport vehicles and construction equipment, travel on public roads, local traffic rules will be strictly observed and every caution will be taken to prevent traffic accidents resulting in injuries or death. Great care will also be exercised not to cause damage to roads, buildings and existing services.

8) Water transfer pump and equipment should be installed while the existing water transfer facilities are in operation, and connected to the existing facilities within a couple of hours.

5-5-2 Execution Policies

(1) Ordinary sections of water pipeline

1) The detailed route of water transfer pipeline will be decided after the location of existing underground services has been confirmed by conducting test pits in the initial stage of this project, because there are many services including water and sewer pipelines. Trenches will be vertically excavated mainly using machines for excavation to lay pipes (except for areas around existing pipes and other underground structures where excavation will be done manually). The last 30 cm of the bottom level will be excavated by hand to facilitate the bedding.

2) Pipes will be backfilled using good-quality excavated soil and the backfilled soil will be compacted using a rammer.

(2) Special sections of water transfer pipeline

1) Rock excavation will be executed at places where the pipes are laid on the exposed coral rock. At places where the coral rock is exposed, a supporting angle to the bottom of the pipe will be greater than 60°. A good-quality sand will be placed at a depth of 10 cm below the bottom of the pipe and compacted for the protection of the pipe.

2) A road was constructed at the place where a mangrove swamp district was landfilled. When topsoil was dug to a depth of 1.2 - 1.5 m, soft ground, including mangrove humus, was visible. Replacement with sandy soil, placement of sleepers and shoring work are required for the pipe laying work in this area.

3) Since underground water level and tide level at the causeway, linking K.B. Bridge, Koror, Arakabesang Islands, fluctuate almost equally, and the

coefficient of permeability is high, proper measures for draining water will be taken when the laying and backfilling works of pipes are executed.

5-5-3 Construction Supervision Plan

Adequate construction supervision over the entire project needs to be carried out to ensure that the construction work for water transfer facilities be conducted safely within the prescribed construction period. For this purpose, one construction supervisor from consultant firm will be stationed in the construction site during the construction work.

(1) Schedule control

Control will be monitored on the amount of completed work by comparing actual production or performance with the schedule at all times for procurement, fabrication and installation of pipes. Since there is a limit in the production of the materials which can be obtained locally, and because production for some other projects may coincide with this project, guidance will be given to the contractor so that they will promptly place orders with the manufacturers to execute each stage of works on schedule and meet the delivery date under this project.

(2) Quality control

Quality control will be conducted primarily over the pipe laying work and machine installation work. Hydrostatic tests and performance tests will be conducted according to the instructions of the construction contract.

(3) Safety control

1) Guidance will be given to the contractor so that even workers at the lowest level will be conscious about accident prevention and the foreman class will be given training to have the ability to prevent dangerous situations.

2) Efforts will be made to prevent accidents by always checking heavy equipment and machines such as cranes, wires and other critical items.

3) When transport vehicles or construction equipment travel on public roads, local traffic rules will be strictly observed and every caution will be taken to

prevent traffic accidents resulting in injuries or death. Great care will also be exercised not to cause damage to roads, buildings and existing services.

5-5-4 Procurement of Materials and Equipment

(1) Construction materials

1) Locally procured materials

- Coarse aggregates
- Fine aggregates
- Reinforcing bars
- Coral sand
- Cement
- Plywood forms
- Wood
- Concrete block
- Fuel
- Grease

2) Major construction materials to be brought in from Japan

- Ductile cast iron pipes
- Steel pipes
- Steel plates
- Pumps
- Electrically operated valves and manually operated valves
- Electrical instrumentation equipment and apparatus

3) Procurement from third country

Materials or products will be procured from third country when:

a) Materials are cheaper than the Japanese materials and are satisfactory in terms of functional performance.

b) The products are definitely easier to maintain than the Japanese products and the supplier offers satisfactory follow-up (maintenance) service.

c) Manufacturers can assume full responsibility in providing maintenance service in the event of breakdown or failure of the equipment.

(2) Construction machine

1) Locally procurable construction machine

The locally procurable construction machines are shown below.

- Truck with crane	20 ton
- Trailer	20 ton
- Backhoe	0.7 m^3
- Wheel loader	2.0 m^3
- Dump truck	10 ton
- Bulldozer	11 ton
- Welding machine	120 Amp - 6.8 ps
- Air compressor	7 m^3/min.
- Water tanker	6 m^3

2) Major construction machinery to be brought in from Japan

The following construction machine, in principle, will be brought in from Japan, because they are not available in Palau.

- Truck with crane	15 ton
- Backhoe (wheel type)	0.35 m^3
- Dump truck	8 ton
- Truck	4 ton
- Truck with crane	4 ton
- Generator	10 kVA
- Engine pump	4-inch
- Engine pump	2-inch
- Damper	60 - 100 kg
- Rammer	60 - 100 kg
- Pavement cutter	

- Concrete breaker

(3) Transportation

Both marine and air transportation are available for shipment of cargo to Palau. Malakal Port can accommodate large transport ships alongside its quay so that cargo can be shipped by container.

Ships from Japan call at Malakal Port once a month for transporting construction machine and materials from Japan by sea. Cargo can be unloaded only at Malakal Port on Malakal Island.

Continental Air Micronesia has one to two flights a day from Japan via, Guam and Yap, but it is not likely that any machine or materials will be air shipped from Japan for this project.

5-6 Implementation Schedule

(1) Detailed design and construction supervision

1) Detailed design and tendering

a) Execution of detailed design and preparation for tendering

Upon Exchange of Notes for each phase, the Japanese consulting firm will conclude a Consultant Contract with the Government of Palau and thereupon commence the detailed design work.

The detailed design and preparation for tendering will be executed on the basis of the basic design study, detailed design study and confirmation and discussion thereof with the Government of Palau.

b) Tendering and conclusion of contract

After announcement of tender, acceptance of the request for participation in tender, holding of explanatory meeting on tender and issuance of tender documents, a certain fixed interval will be provided for preparation of tender. The tenders submitted will be promptly evaluated upon their receipt, and conclusion of the Construction Contract between the Government of Palau and the successful Japanese construction firm will be expedited.

2) Construction supervision

With the conclusion of the contract between the Government of Palau and the Japanese contractor, a Japanese juridical person, this project will enter the stage of construction supervision.

Immediately after the signing of the contract the Consultant will carry out the procedure for approval of the design drawings on behalf of the Government of Palau in order to make prompt implementation of the project. Furthermore, the procurement of material and equipment in Japan will be supervised as well, with the participation of the Consultant.

The Consultant will guide and supervise the Contractor regarding preliminary meetings and arrangements prior to commencement of work, transport of material and equipment to the site, execution of construction work, installation and adjustment of equipment, operation tests and completion tests etc. and also carry out the management of the progress, quality management and cost management in order to complete the work within the time stipulated in Exchange of Notes.

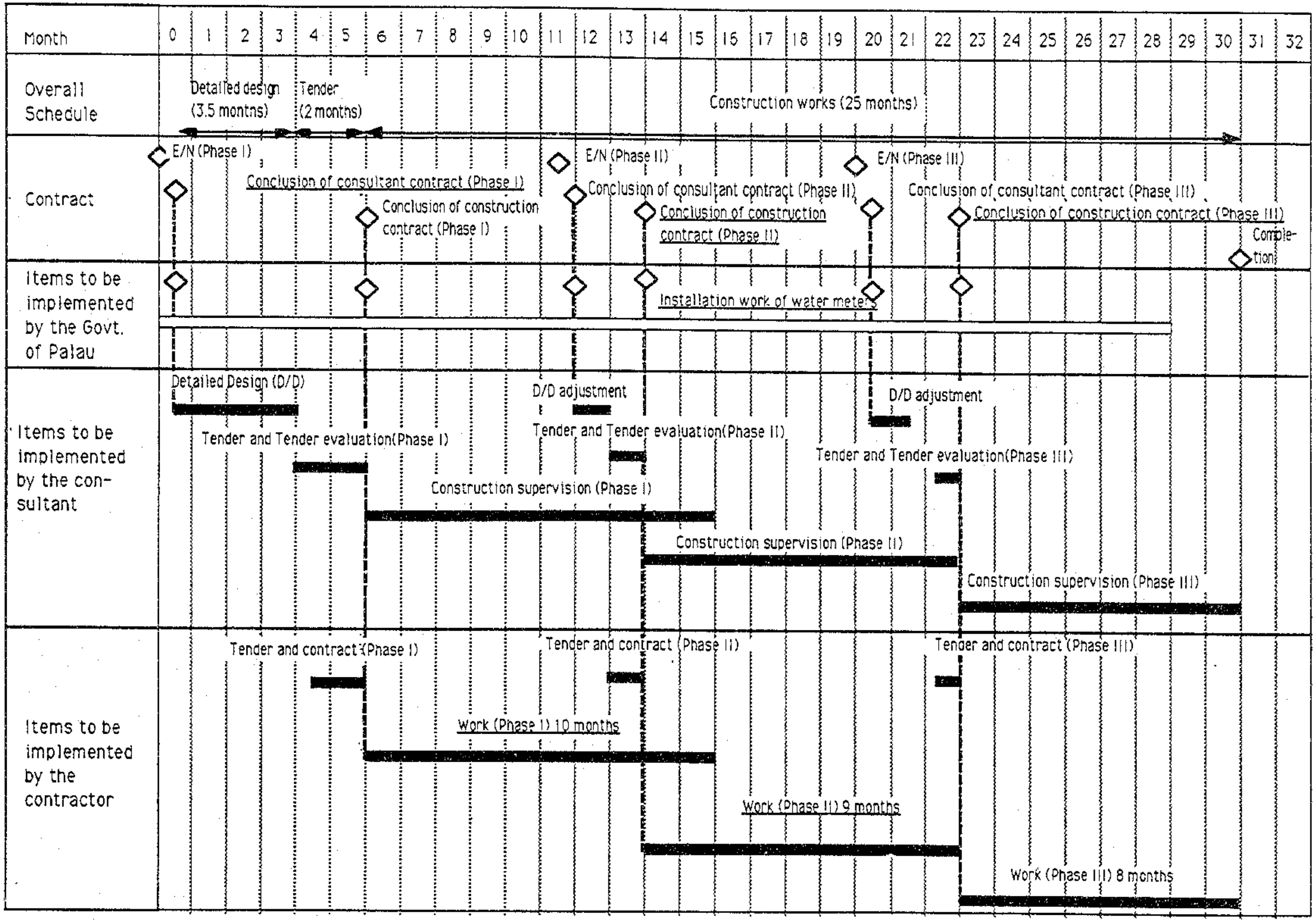
(2) Construction period

Since the construction work of this project based on Japan's grant aid will be completed within each fiscal year, the entire work will be divided into Phase I, Phase II and Phase III.

The construction period, after the conclusion of the contractor contract for each phase, will be as follows:

Phase I	:	10.0 months
Phase II	:	9.0 months
Phase III	:	8.0 months
Total		25.0 months (partially overlapping)

Figure 5-5 Tentative Implementation Schedule



CHAPTER 6 PROJECT IMPREMENTATION SYSTEM

CHAPTER 6 PROJECT IMPLEMENTATION SYSTEM

6-1 Organization for Implementation

(1) Overall Relationship

The overall relationship among the Implementing Organizations for the Project on the basis of Japan's grant aid is illustrated below:

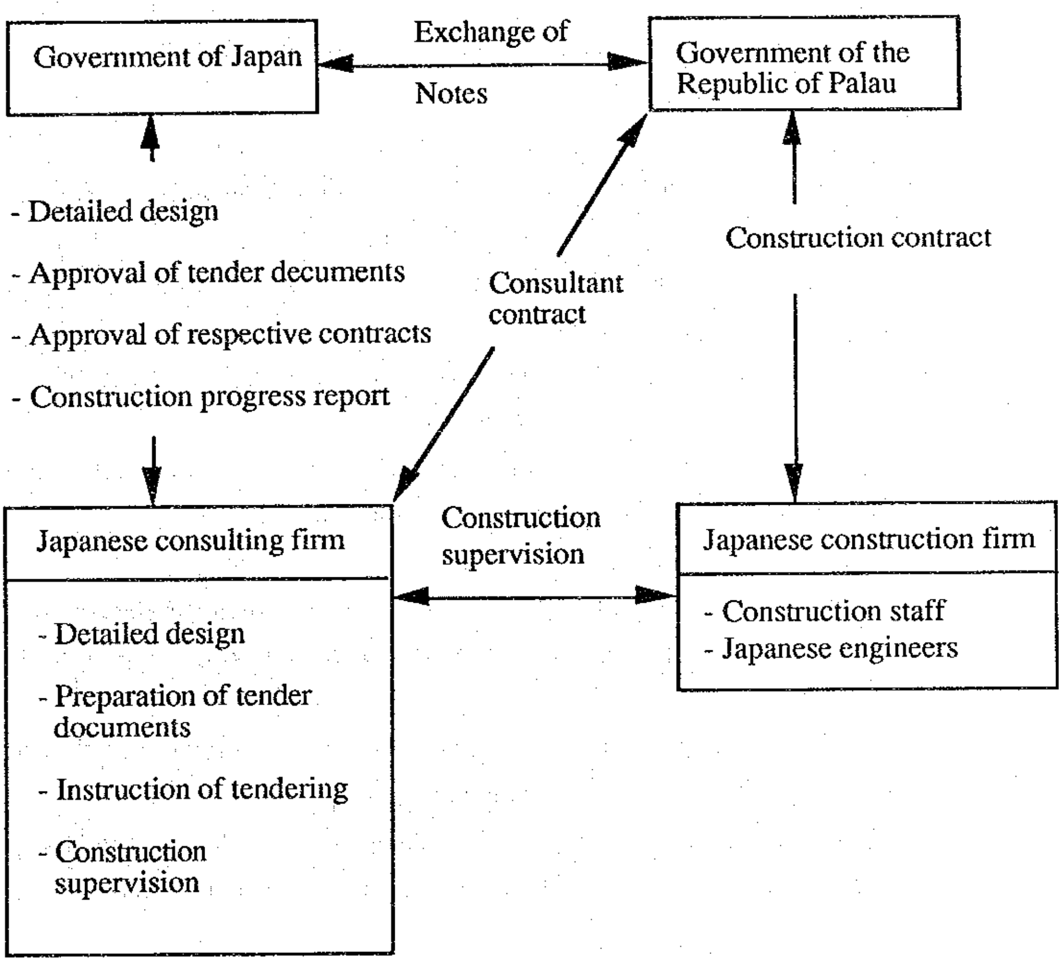


Fig. 6-1 Overall relationship among the Implementing Organization for the Project

(2) Executing agency

The competent authority responsible for implementing this project on the part of Palau will be the National Planning Council. Palau will appoint an officer-in-charge of this project who will maintain close contact and discuss with the Japanese Consultant and the Japanese construction firm to ensure that all works for this project may be carried out smoothly.

The Japanese consulting firm will be responsible for the detailed design and the construction supervision. The Japanese construction firm will be the Contractor of the construction work and will execute same.

6-2 Scope of work

6-2-1 Scope of work to be undertaken by the Government of Palau

(1) To secure land for water pipelines and related facilities
(2) To provide the temporary land for a construction liaison office, warehouse, stockyard, etc., during the construction period
(3) To provide the disposal places of the surplus soil including silt, clay, gravel, etc., during the construction period
(4) To provide the access road to the construction site for construction purposes
(5) To supply electricity to the construction site
(6) To clean and paint the existing water tanks, and clear and maintain the water tank area by fencing, leveling and cleaning the grounds
(7) To install the water meters
(8) To ensure speedy unloading, tax exemption, customs clearance at ports of disembarkation in the Republic of Palau, of the products purchased under the grant aid
(9) To give the permission required for all the works related to this project, e.g., opening of manholes, surveying on the road, etc.
(10) To witness and confirm by the authorities concerned when test pitting and, protection and relocation of existing services such as buried pipelines are carried out
(11) To take necessary measures for inhabitant's cooperation and traffic control
(12) To secure the suspension of water supply during the connection of the proposed transfer pipeline to the existing pipeline
(13) To bear the expenses for opening an account with a foreign exchange bank officially approved by the Government of Japan
(14) To grant special conveniences and tax exemptions to the Japanese nationals dispatched

6-2-2 Scope of work to be undertaken by the Government of Japan

(1) Installation of raw water pipeline, water transfer pipeline (total length: 19.9 km) and appurtenant facilities
(2) Installation of one water transfer pump [3.97 m^3 (1,050 gallons)/minute]
(3) Installation of four water level control units for water tanks
(4) Painting work of the Arakabesang water tank (inside and outside surfaces)

6-3 Operation and Maintenance Plan

(1) New organization

Since the present organization for operation and maintenance, as described in Chapter 2, Section 2-3-2, is insufficient for managing a financially self-sufficiency, a new organization for the exclusive management, operation and maintenance systems for water works will be established, separate from the organization of electricity, telephone and sewer within the Bureau of Public Works. This new organization will adopt a self-paying basis, clarify the responsibilities and make effective use of the water facilities and water resources. The new operation and maintenance organization for water works will consist of construction, design, operation, maintenance, sales, general affairs sections. These will be closely linked, and the overall administration will be executed to secure a stable quantity of clean water economically. For this purpose, the following items will be considered. The new organization is shown in Figure 6-2.

1) Collected water charges will meet the expenses incurred for the water works.
2) The organization will establish a clear system of role delegating assignments among the staff, and each will be accountable for duties discharged.
3) The organization will be capable of promptly coping not only with normal operation management routine but also with emergency situations.
4) The organization will be capable of preparing programs for periodical daily inspection.
5) The organization will establish a complete system for improving technical level of personnel for construction, planning, operation and maintenance to prepare education and training programs.
6) The organization will promote the effective and economic use of water to help improve the living environment and foster the industry.

7) The organization will be in charge of recording and putting in order the daily data of operation and maintenance for future water system improvement projects.
8) The organization will have personnel for supervising and instructing for the prevention of water waste by individual houses and establishments.

Fig. 6-2 New Organization of Water Works

Waterworks Bureau

Division	Design & construction		Operation & Maintenance				Sales		General affairs			
Contents of work	Planning and design	Execution of construction	Operation and maintenance of the intake and Gihmel Dam	Operation and maintenance of the water treatment plant	Maintenance of pipelines, supervision and guidance for prevention of water waste	Operation and maintenance of water tank	Meter reading	Rates collection	General affairs	Purchasing, accounting	Planning and public relations	General affairs (education and training)

(2) Required staff for operation and maintenance

The development of an organizational system as previously proposed is indispensable for the efficient and stable administration, operation and maintenance of the water facilities. In addition, the technical competence of the operation and maintenance staff who make up the organization and the appropriateness of manpower assignment require careful consideration.

Although some of the existing staff engaged in operation and maintenance have received education and training from an American adviser, the number of staff with a sufficient level of specialized knowledge and skill is few. Hence, the development of a foremen and operators with specialized knowledge is especially important.

At present the water treatment plant adopts the operator rotation of three-shifts-a-day, around-the-clock system, but the manpower allocation on the whole is not established. It is necessary that it adopts a more appropriate staff assignment plan, while also making organizational improvements stated reviously.

(3) Contents of operation and maintenance

1) Operation management

Since water is indispensable for daily life, a stable supply of clean, suitable water for consumption needs to be secured. The implementation of this project needs to ensure that a water quantity to be transfered meets the demand in the served area at the required hydraulic pressure, and that the water facilities are functioning and operating normally.

a) The amount of water transfered and water distributed must be measured and recorded to control the water facilities. It is particularly important to regulate the quantity of water by comprehensively evaluating the river water discharge, the quantity of water stored in Gihmel Dam, the rainfall and the estimated required water demand, and the water facilities can be operated efficiently according to changes in water demand. It is also recommended that the transferred water quantity data will be analyzed in formulating prevention programs for water waste and leakage.

b) Water quality should be inspected periodically to ensure that the water supplied is always clean and in a normal, acceptable condition. The periodical water quality inspections include the daily inspection of residual chlorine and the daily inspection of coliform bacilli as currently being practiced in Palau. Efforts shall be made to conduct an all-item water quality inspection by Palau side in the future.

c) In operation of mechanical and electrical systems for the water facilities, a suitable management system must be adopted as it constitutes the very core that governs the total function of a water supply system. Pumps and filters must not be overworked nor used beyond their rated capacity; and standby machinery or electrical equipment should be installed to maintain continuous operation. Also, the complex systems, including the automatic control device, should be operated only after acquiring the knowledge for proper operation. All necessary data needs to be entered into the operating logbook.

2) Maintenance management

Each water facility should be inspected, and adjusted or repaired accordingly to ensure the efficient and safe operation and management of the water facilities.

The water facilities need to be maintained in good condition by systematical and periodical inspecting and adjusting or repairing the water facilities. For this purpose, a manual that shows how to perform maintenance work needs to be prepared, and a checklist should be maintained, which will be used to compare the inspection results with the predetermined standards and goals. Additional materials or parts needed for adjusting or repairing the equipment or system, should be kept readily available if they can not be easily procured.

3) Sales

The water works should try to become a financially sound enterprise. The installation of water meters to all houses and establishments will permit the establishment of a water bill collection system. This would not only promote the economical use of water and prevent the wasteful use of water, but imporve the financial condition of the water works and contribute to the development of the industries.

4) Planning and public relations

The general state of water conservation apathy is not due solely to problems in the administration, operation or maintenance of the water system, but may also be attributed to the lack of public relations campaigns to educate the general public on the importance of effective use of water. In order for the water works to be effective, not only are the water facilities and organization improvements necessary, but the cooperation of the inhabitants is needed. Therefore, education campaigns must be staged to publicize the need for effective use of water at schools and through the media.

(4) Operation and maintenance costs

1) Operation and maintenance costs for the existing water facilities in 1989 were as follows:

Chlorine injection	US$ 20,000 (¥3.0 million)
Spare parts and repair of machinery	US$ 5,000 (¥0.7 million)
Electric charges	US$ 140,000 (¥20.7 million)
Total cost	US$ 165,000.(¥24.4 million)/year

2) Operation and maintenance costs for the water facilities in 1993 (the year that the project is completed) are estimated below in US$. This estimate includes anticipated cost increases for electricity for the reinforcement of the water transfer pump, and chlorine injections, for the increased quantity of water transferred.

Operation and maintenance costs	
Chlorine injection	US$ 24,000 (¥ 3.6 million)/year
Spare parts and repair of machinery	US$ 6,000 (¥ 0.9 million)/year
Electric charges	US$ 155,000 (¥ 22.9 million)/year
Total cost	US$ 185,000 (¥ 27.4 million)/year

Although pipes and pumps will be reinforced, the improvement will be made to a degree that the existing water facilities and new water facilities can be operated and maintained at the same time. And the automation of the water transfer pump and the installation of the automatic water level control device for the water tank will lead to the decrease in operation personnel. Therefore no change in the number of staff of water supply branch (20 persons) shall be made. Operation and maintenance costs in 1993 will be increased by approximately US$ 20,000 (¥ 3.0 million), as compared with those in 1989.

3) Income by water rates consumed

- Record in the latest three years

1987	US$ 110,816 (¥ 16.4 million)/year
1988	US$ 120,381 (¥ 17.8 million)/year
1989	US$ 108,924 (¥ 16.1 million)/year

- Estimated value in 1993 (on assumption the percentage of water meter's dissemination is 100%)

Basic charge	2005 x US$ 5 x 12 months = US$ 120,300
Service charge	US$ 0.5/1,000 gallons x 15,800 persons x 68 gallons x 365 days = US$ 196,100
Total	US$ 316,400 (¥ 46.8 million)/year

Statistical data in 1989 and 1993 were used respectively for the number of houses distributed and population.
Revenue from water charges for 1993 will increase by US$ 207,500 (¥ 30.7 million), as compared with the figures for 1989.

CHAPTER 7 PROJECT EVALUATION

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The Koror and Airai areas are the political and economic center of Palau. If these areas are to adequately function as the pivotal center of the country, it is necessary to improve the public infrastructure and living environment.

The water facilities are indispensable for basic human needs and the city's development. The existing water facilities, except for some part of the pipeline laid in 1940, were constructed with U.S. assistance. However, the water is wasted due to defects of the water facilities, insufficient number of installed water meters, inadequate maintenance and operation of such facilities, and an incomplete system of charge collection. As a result, the water supply is shut off eight hours a day (from 9 p.m to 5 a.m.) throughout the year. In the high elevation residential and commercial areas, only a small amount of water can be secured even when water is supplied during the daytime. Water supply is also restricted depending on the rainfall condition during the dry season.

This situation is being further aggravated by the rapid increase in population from the socio-economic development of the Koror and Airai areas.

Therefore the existing water supply situation in the Koror and Airai areas is critical. Palau is pressed to take immediate countermeasures to remedy the situation not only to stabilize the livelihood of its people, but to maintain the urban functions of these two areas. The implementation of this project at an early date would be effective.

7-1 Effects

7-1-1 Direct Effects

The completion of this project for the improvement of the water supply system would have the following direct effects:

(1) The separation of the water transfer and water distribution pipelines, and installation of an additional water transfer pump would secure a stable water supply for 24 hours a day to meet the served population and in the design target year 2000.

(2) Presently, a large amount of water is wasted by the hoarding of water by individual houses and establishments for the daily suspension of the water supply, insufficient number of installed water meters, and imperfect education of water conservation. However, water wasted can be avoided by securing a stable water supply 24 hours a day and installing water meters at all houses and establishments.

(3) The Koror and Airai areas development project can be realized by the design target year 2000.

(4) The system for the billing and collecting of water charges according to actual water consumption would be established. A new organization for the administration and operation of a financially solvent water facilities would be established. After the completion of this project, future expansion, improvement, operation and maintenance of the water facilities, as well as purchasing of spare parts, would be made within the national budget of Palau.

(5) The water facilities would be automated so that the operation and maintenance of these facilities would be simplified.

7-1-2 Indirect Effects

(1) Socio-economic benefits

The improvement of the existing water facilities under this project would secure a stable supply of clean water throughout the year, promote the development of the urban area, and develop the economy. It would also lay the foundation for the industrial development and improvement of the standard of living, the main themes of the nation's Five-year Development Plan.

(2) Residents life

The implementation of this project is expected to remove the inhabitants anxieties, improve the deplorable and unsanitary living environment originating from the shortage of water supply and defects in the existing water facilities, and thereby contribute greatly to the improvement of the inhabitants life and stability of civic life.

(3) Technology of water facilities

The improvement plan, as well as the operation and maintenance of the water facilities have progressed under technical cooperation of the U.S. However, rehabilitating the existing water facilities is behind schedule because of financial problems. The implementation of this project will lead to the improvement of the water facilities in Palau, and the transfer of maintenance technology will contribute greatly to the advancement of technology in Palau.

(4) Health and sanitation

The specialists from the U.S. and Palau on site, have also conducted periodic testing of clean water for residual chlorine and coliform bacteria group.

No incidences of infectious disease of the digestive system, such as dysentery, which can occurs through drinking or eating contaminated water and food have been reported. An outbreak of such diseases is reported to have occurred in the past.

During water supply failure, negative pressure occurs in the pipelines, mixing polluted groundwater with the clean water, thus the existing water facilities are not safe. The implementation of this project would secure a safe, stable supply of cleaner water, which should drastically reduce incidences of disease and contribute to the overall improvement of the health of the population.

(5) Securing a reliable water facilities for the inhabitants

The existing water facilities are unreliable because of frequent failure of water supply and insufficient quantity of water supply. The implementation of this project would secure a constant water supply to the planned served areas for 24 hours a day. And the reliance of inhabitants for water facilities will be recovered.

7-2 Propriety

(1) Technical aspect

In this project, the existing system for water transfer and distribution from the water treatment plant is changed by establishing separate pipelines for water transfer and water distribution, which would secure a sufficient water quantity and pressure.

These water facilities constructed under this project, would not send water directly to houses and establishments near the water treatment plant and avoid wasteful use of water. After water was transferred and stored at the existing four water tanks installed in the individual served areas, a uniform quantity of water would be supplied from these water tanks to all the planned served areas 24 hours a day.

Since the existing water tanks have a larger storage capacity (approximately 2.5 times), than water consumption per day for the design target year, the required quantity of water and water pressure would be satisfied during the morning and evening peak periods and the existing tanks could be used for water shortages or as emergency reservoirs. Higher reliability, safety and stability of the water facilities would be secured. Therefore, this project is considered appropriate..

Further benefits from the construction of the water facilities include the promotion of the planned housing developments in the highland districts of the Koror and Airai areas, as well as the growth of tourism.

(2) Financial aspect

The major annual expenses for the operation and maintenance of the water facilities to be constructed under this project are described below.

1) Cost for regular inspection of water pipeline after the completion of the improvement work

2) Cost for the operation and maintenance of water transfer pump for the water treatment plant

3) Cost for the operation and maintenance of the aqueduct that would be installed over the Edeng River and causeway

4) Installation cost of water meters

The implementation of this project would not burden the Palau side financially.

(3) Operation and maintenance

The present technical level of the operation and maintenance staff is inadequate. Since no special technical competence is required in operating and maintaining the water facilities which would be completed under this project, technologies for the operation and maintenance would be transferred to personnel of Palau during the implementation of this project, so they should be able to continue the operation and maintenance of the water facilities.

The improvement of the water facilities would increase their functional performance, upgrade efficiency and reduce the manpower and expenses for maintenance.

It is concluded that the implementation of this project would be highly appropriate from the technical, economical and operational aspects.

CHAPTER 8 CONCLUSION AND RECOMMENDATIONS

CHAPTER 8 CONCLUSION AND RECOMMENDATIONS

Except for one section of pipelines in the Koror urban area, the existing water facilities in the Koror and Airai areas were constructed with U.S. assistance. The water facilities are beset with problems, including defects in the water facilities, inadequate operation and maintenance, insufficient budget and system for charge collections and wasted water. To solve these problems, measures including changes in the existing water system, installation of water meters, prevention of water waste and improvements in the operation and maintenance system should be implemented.

The improvement of the existing water system facilities will include separating the water transfer and water distribution pipelines and installing a raw water pipeline to Gihmel Dam. The improvement plan was conceived to integrate the existing water system with the new system to fully utilize their functioning.

This project will achieve the benefits described in Chapter 7 and contribute greatly to the development of Palau in accordance with Palau's Five-year Development Plan, as described below.

- Lay the foundation for achieving long-term self-reliance within a free market economy.
- Develop the full potential of the natural resources of Palau to expand exports to acquire foreign currency and thus meet increased domestic demands for an improved standard of living.
- Develop human resources through increase employment opportunities and training programs.
- Achieve a balanced growth and development amongst the states, as well as income opportunities for the population.
- Protect of the environment and preserve the cultural heritage of the country.

Therefore, improvements will be made by implementing this project under Japanese Grant Aid. And, if appropriate measures are taken to resolve the following points, this project will be implemented more efficiently.

(1) The Bureau of Public Works is comprised of the Power Generation Branch, Water Works Branch, Power Distribution Branch and Sewer Works Branch. However, since Palau

needs to secure a reliable and stable water supply and establish a profitable water supply system, a new and separate Bureau of Water Works for the management and operation of the water works system should be established. Financial solvency and profitability will be a priority for this new organization.

(2) This new organization should employ several technical personnel to oversee the operation and maintenance of the water facilities. These personnel will participate in this project on a full-time basis from the first stages of construction to acquire sufficient knowledge of the technical aspects of the water facilities.

(3) The water supply is insufficient primarily because of defects in the existing water facilities, the inadequate operation and maintenance of these facilities, the wasteful use of water and uncooperative residents. Palau officials should try to educate local residents on the importance of the water facilities, the correct way to use the facilities, as well as encourage water conservation by mass media promotions. Some examples are described below.

- Prevent leaks from household and establishments water faucets
- Stop illegal connections of residential supply pipes to the main water pipelines
- Prevent damage to tanks, pipelines, faucets and water meters
- Educate the residents on the proper use of water to prevent water in washing machines or storage tanks from back-flowing into and contaminating water in the pipelines during the suspension of the water supply.

(4) A complete billing and collection system should be established to bill water consumers according to actual water use. To learn about the Japanese collection, operation and maintenance system, Palau should dispatch personnel to Japan for one month of training, or a Japanese experts will be dispatched to Palau for 2 -3 weeks to provide training and guidance.

(5) Monthly metered water consumption of households and establishments should be compared with water quantity from the water treatment plant for operation and maintenance of the water facilities. Examples of how the data may be used are described below.

- Check on waste at residences and establishments.

- Monitor those who habitually waste water and strengthen supervision, guidance and educational activities.
- Check for leakage in the water transfer and distribution pipelines.
- Check for leakage in the supply service pipes.
- Check for illegal tap-ins through water pipes.
- Operate water facilities within the balance of water supply and demand.

(6) To conserve and use water appropriately, all the faucets at establishments should be replaced with spring-type faucets.

(7) Periodical checkup and maintenance of facilities, equipment and rotating operation of equipment together with periodical testing of standby equipment and valves which are not in ordinary use.

(8) Restoration measures in times of emergency and periodical drills in preparation for breakdowns in the system or deterioration of water quality should be established.

(9) The accumulated sand from Gihmel Dam should be removed to increase storage capacity.

(10) A settling basin as a pre-filtering device at the water treatment plant to improve the sand filtering function, water quality and long term service of the facility should be installed.

(11) To secure a stable, clean water supply, chlorine needs to be automatically infused into the water supply, in proportion to the water delivered.

(12) A storage reservoir at the water treatment plant should be installed to provide a stable water supply during peak times.

APPENDIX

APPENDIX I

MINUTES OF DISCUSSIONS

MINUTES OF DISCUSSIONS

ON

THE PROJECT FOR

IMPROVEMENT OF WATER SUPPLY

IN

THE REPUBLIC OF PALAU

In response to the request of the Government of the Republic of Palau, the Government of Japan decided to conduct a basic design study on the Project for Improvement of Water Supply (hereinafter referred to as "the Project") and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to the Republic of Palau the study team headed by Dr. Minori Sano (Team Leader) from December 1 to December 25, 1989.

The Japanese team had a series of discussions and exchanged views on the Project with the authorities concerned of the Government of the Republic of Palau headed by Mr. Koichi L. Wong and conducted a field survey on the sites.

As a result of the study and discussions, both parties mutually agreed to recommend to their respective Governments that the major points of understanding reached between them, attached herewith, should be examined towards the realization of the Project.

Palau, December 8, 1989

Minori Sano
Leader
Basic Design Study Team
JICA

Koichi L. Wong
National Planner
Republic of Palau

1. The Objective of the Project

The objective of the Project is to improve the water supply system in the Koror-Airai area in order that the living standards and conditions of the people in these states may be upgraded.

2. Description of the Project

2.1 Project originally requested by the Government of the Republic of Palau

(a) Procurement and installation of two 300KVA, emergency diesel generator sets in the intake pump station.

(b) Procurement and installation of about 6.2 km of 400 mm dia. ductile cast iron pipe for raw water transmission main line.

(c-1) Alternative (1)

Procurement and installation of about 5.0 km of 400 mm dia. ductile cast iron pipe and 0.5 km of 400 mm dia. steel pipe for underwaterchannel crossing.

(c-2) Alternative (2)

Procurement and installation of about 5.0 km of 400 mm dia. ductile cast iron pipe for crossing over the Toagel-mid-channel along by the K.B Bridge.

(d) Procurement and installation of about 3.4 km of 400 mm dia.and about 7.4 km of 300mm dia. ductile cast iron clear water transmission main line for Koror city water system.

2.2 Project resulting from Basic Design Study

a) Procurement and installation of one 300KVA, emergency diesel generator set in the intake pump station.

b) Procurement and installation of about 5.2 km of 300 mm dia. ductile cast iron pipe for raw water transmission main line.

c) Procurement and installation of about 5.6 km of 400 mm dia. ductile cast iron pipe for clear water transmission main line from the existing Airai water treatment plant (WTP) to the existing Ngermid and Ngerkesoal steel tanks.

d) Procurement and installation of about 3.5 km of 300 mm dia. and about 6.6 km of 250 mm dia. ductile cast iron clear water transmission main line for Koror city water system.

e) Procurement and installation of about 1.8 km of 200 mm dia. ductile cast iron clear water transmission line for Airai city water system.

f) Procurement and installation of Rubber dam (H=60cm) to be installed at the existing Gihmel dam to increase the capacity of raw water.

g) Procurement and installation of one unit of automatic valveless gravity filter with a capacity of 700 GPM at WTP.

h) Procurement and installation of two sets of multistage turbine pump with pumping capacity 1050 GPM at WTP.

i) Provide one unit of appropriate capacity sand blast or high pressure water blaster machine to be used for cleaning off old paint and rust from existing steel water tanks so that tanks could be painted on a regularly scheduled basis.

j) Provide one set 4-wheel drive vehicle (pick-up) equipped with mobile communication equipment.

k) Provide one unit of flat-bed truck with a hydraulic lifting device of one-ton capacity to be used as a maintenance vehicle.

3. Responsible and Coordinating Agency for the Project

National Planning Council

Implementation Agency for the Project

Ministry of National Resources

4. Project Sites

The Project sites are located in the Koror-Airai area as shown in Annex-I with intended improvement of water supply system.

5. The basic concept of the improvement of water supply system shall be described in the Field Report which will be submitted to the Govenment of the Republic of Palau at the end of the field survey by the Basic Design Study Team.

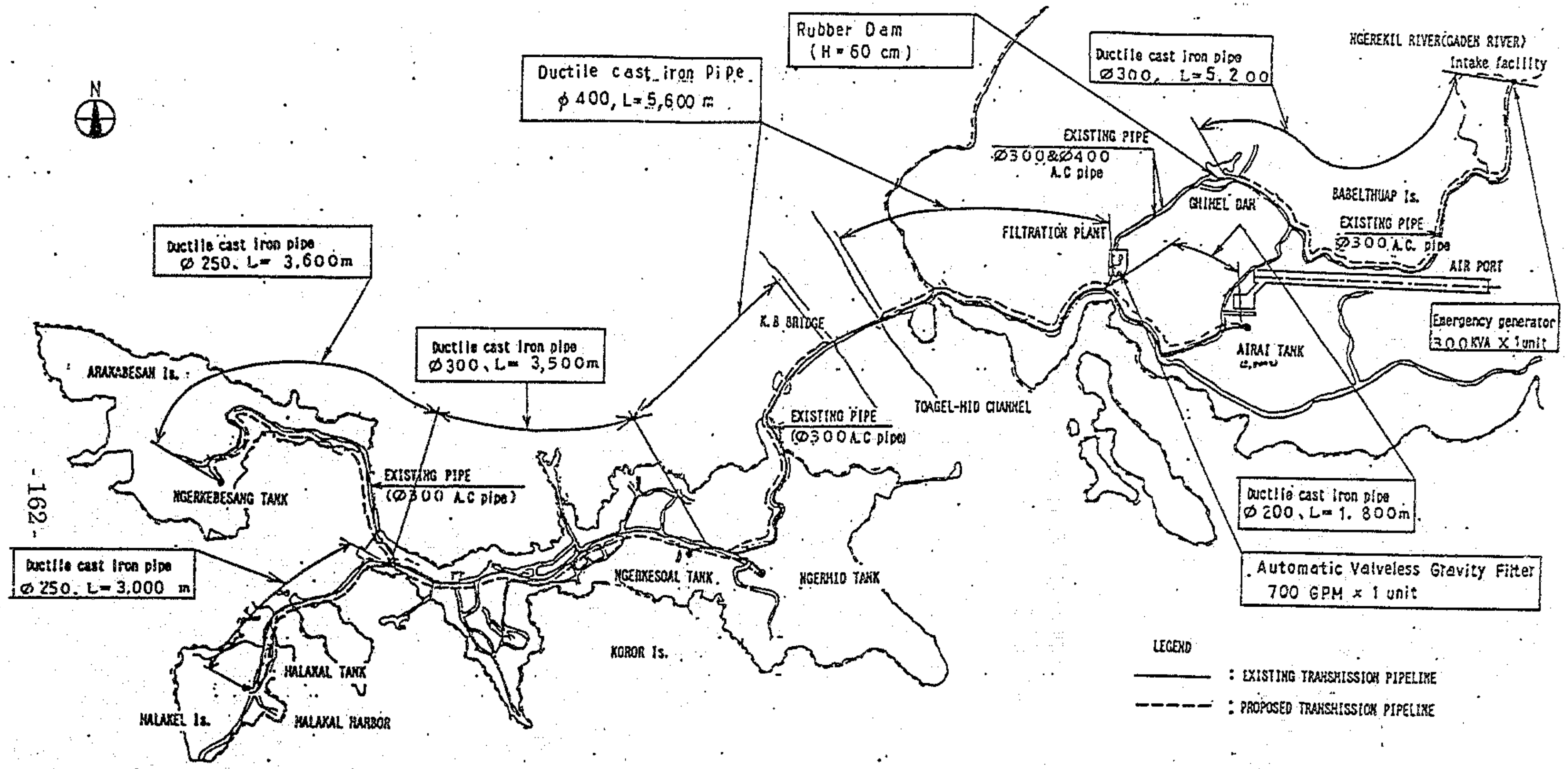
6. The Basic Design Study Team has agreed that the Japanese side is responsible for relocation and protection of the existing underground services which may be encountered during the construction on condition that sufficient information is provided by the Palau side during this field survey period.

7. The Palau side has understood the Japanese grant aid system as explained by the Study Team including a principle that contracts are to be concluded with a Japanese consulting firm and Japanese general contractor for the implementation of the Project.

8. The Government of the Republic of Palau has agreed to provide the necessary measures as listed in Annex II on condition that grant aid by the Government of Japan is extended to the Project.

9. The Government of the Republic of Palau has agreed to provide the necessary budget and personnel for the proper and effective maintenance of the facility provided under the grant aid.

ANNEX I Project Sites



ANNEX-I SITE LOCATION MAP
(KOROR AIRAI WATER DISTRIBUTION SYSTEM)

ANNEX II Undertakings by the Government of the Republic of Palau, which are in accordance with Local Regulations and Relevant Laws:

(1) To secure land for water supply main lines and related facilities.

(2) To provide the temporary land for a construction liaison office, warehouse, stock yard, etc., during the construction period.

(3) To ensure speedy unloading, tax exemption, customs clearance at ports of disembarkation in the Republic of Palau, of the products purchased under the grant aid.

(4) To give the permission required for all the works related to this project, e.g., opening of manholes, surveying on the road, etc.

(5) To witness and confirm by the authorities concerned when test pitting and, protection and relocation of services are carried out.

(6) To take necessary measures for inhabitant's cooperation and traffic control.

(7) Palau side will be responsible for relocation of underground services which may be encountered during construction period, if information and data regarding the location of such services were not made known to the Basic Design Study Team during field survey period.

(8) To take necessary measures for historical remains which may be encountered during the construction period, if any.

(9) To accord Japanese nationals whose services may be required in connection with the supply of the products and the services under the verified contract such facilities as may be necessary for their entry into the Republic of Palau and stay therein for the performance of their work.

(10) The Japanese nationals involved in the project will not be subject to any customs duties, internal taxes, and other fiscal levies which may be imposed in Palau with respect to the supply of the products and services under the verified contract.

(11) To bear all expenses, other than those to be borne by the grant, necessary for the execution of the grant.

(12) To maintain the water supply main lines and related facilities properly constructed under the grant aid.

(13) To clean and paint the existing steel water tanks which new clear water transmission main line will be connected to.

Ken

(14) To install the fences and gate to avoid the outsider enter into the area of the existing steel water tanks.

(15) To provide necessary data and information for detailed design.

(16) To provide the disposal places of the surplus soil including silt, clay, gravel, etc., during the construction period.

(17) To secure the suspension of water supply during the connection works of the proposed water supply main line and the existing line.

(18) To take necessary actions to expedite the approval for executions of this project by the Government of the Republic of Palau.

(19) To give the permission required for test pitting to check underground services at the time of detail design, if necessary.

(20) To remove the existing bombs which may be encountered during the construction period, if any.

MINUTES OF DISCUSSIONS

ON

THE DRAFT FINAL REPORT OF THE BASIC DESIGN STUDY

ON

THE PROJECT FOR

IMPROVEMENT OF WATER SUPPLY

IN

THE REPUBLIC OF PALAU

In response to the request of the Government of the Republic of Palau, the Government of Japan decided to conduct a basic design study on the Project for improvement of Water Supply (hereinafter referred to as "the Project") and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to the Republic of Palau the study team headed by Dr. Minori Sano, Senior Assistant to the Managing Director of Grant Aid Planning & Survey Department, JICA, from December 1 to December 25, 1989.

The Team had a series of discussions on the Project with the officials concerned of the Government of the Republic of Palau and conducted a field survey.

As a result of the study, JICA prepared a draft final report and dispatched a team headed by Mr. Yoshiaki Hata, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs, to explain and discuss it from April 16 to April 24, 1990.

Both parties had a series of discussions on the draft report and agreed to recommend to their respective Governments that the major points of understanding reached between them, attached herewith, should be examined towards the realization of the Project.

Palau, April 19, 1990

Yoshiaki Hata
Leader
Basic Design Study Team
Japan International Cooperation Agency

Koichi L. Wong
National Planner
Republic of Palau

ATTACHMENT I

1. The Palau side has agreed in principle on the basic design proposed in the Draft Final Report and appropriate alterations agreed by both sides, in the course of discussions, will be incorporated in the Final Report.

2. The Palau side ensures the provision of the necessary budget for the works such as maintenance and operation expenses for the project.

3. As a means of conservation of water, Palau side will expeditiously identify leaks in the existing water system and fix them, install 1000 water meters procured by Palau Government for metering all the existing unmetered houses, commercial establishments and other facilities and implement a program to admonish the general public to refrain from wasteful use of water.

4. The Palau side has understood Japan's grant aid system and the necessary arrangement listed in the Annex to be taken by the Palau side for realization of the Project.

5. The Final Report (10 copies in English) will be submitted to the Palau side by the end of June, 1990.

y. h.

KEW

ANNEX

UNDERTAKINGS BY THE GOVERNMENT
OF THE REPUBLIC OF PALAU

1. To secure land for water supply main lines and related facilities such as surge tanks.

2. To provide the temporary land for a construction liaison office, warehouse, stockyard, etc., during the construction period.

3. To ensure speedy unloading, tax exemption, customs clearance at ports of disembarkation in the Republic of Palau, of the products purchased under the grant aid.

4. To give the permission required for all the works related to this project., e.g., opening of manholes, surveying on the road, etc.

5. To witness and confirm by the authorities concerned when test pitting and protection and relocation of services are carried out.

6. To take necessary measures for inhabitant's cooperation and traffic control.

7. To take necessary measures for historical remains which may be encountered during the construction period, if any.

8. To accord Japanese nationals whose services may be required in connection with the supply of the products and the services under the verified contract such facilities as may be necessary for their entry into the Republic of Palau and stay therein for the performance of their work.

9. The Japanese nationals involved in the project will not be subject to any customs duties, internal taxes, and other fiscal levies which may be imposed in Palau with respect to the supply of the products and services under the verified contract.

10. To bear all expenses, other than those to be borne by the grant, necessary for the execution of the grant.

11. To maintain the water supply main lines and related facilities properly constructed under the grant aid.

12. To clean and paint the existing steel water tanks which new clear water transmission main lines will be connected to.

13. To install the fences and gate to avoid the outsider enter into the area of the existing steel water tanks.

14. To provide necessary data and information for detailed design.

15. To provide the disposal places of the surplus soil including silt, clay, gravel, etc., during the construction period.

Y. G.   KEW

16. To secure the suspension of water supply during the connection works of the proposed water supply main line and the existing line.

17. To take necessary measures to expedite the approval for executions of this project by the Government of the Republic of Palau.

18. To give the permission required for test pitting to check underground services at the time of detail design, if necessary.

19. To remove the existing bombs which may be encountered during the construction period, if any.

Y. Le. Kew

ATTACHMENT II

Palau side requests the Government of Japan to consider the inclusion of the following items in the Project for Improvement of Water Supply in the Republic of Palau:

A. Design and construct the manifold piping at the Airai water treatment plant such that four water transfer pumps of no less than 1050 gpm capacity could be accommodated.

B. Design and install the appropriate electrical control panel unit for water transfer pumps referenced in A above.

C. Design and make necessary arrangement in the installation relative to the proposed transmission pipeline and the existing transmission/distribution pipeline such that the existing transmission/ distribution pipeline will remain to function as a transmission/distribution pipeline.

D. Include in the project scope a 700 gpm automatic valveless gravity filter similar in function and capacity to the filters presently installed at the Airai water treatment plant.

E. The system must be designed and installed/constructed in such a manner that daily supply of water will get to the general public as normal as possible without interruption. Down time is expected, but must only be allowed for the least amount of time.

Y. A.   Ken

APPENDIX II

MEMBERS LIST OF THE BASIC DESIGN STUDY TEAM

MEMBERS OF THE TEAM (BASIC DESIGN)

Name	Assignment	Position
Dr. Minori Sano	Team Leader	Senior Assistant to The Managing Director of Grant Aid Planning & Survey Department
Mr. Kenji Miyane	Chief Water Supply Planner	Section Manager of Planning Devision, Technical Department, Kobe City Waterworks Bureau
Mr. Masatoshi Seno	Water Supply Planner	Yachiyo Engineering Co., Ltd.
Mr. Ryosuke Teranishi	Water supply Designer	Yachiyo Engineering Co., Ltd.
Mr. Seiichi Oyamada	Facility Planner	Yachiyo Engineering Co., Ltd.

MEMBERS OF THE TEAM (FOR EXPLANATION OF DRAFT FINAL REPORT)

Name	Assignment	Position
Mr. Yoshiaki Hata	Team Leader	Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs
Mr. Masatoshi Seno	Water Supply Planner	Yachiyo Engineering Co., Ltd.

APPENDIX III
SURVEY SCHEDULE

1. Field survey for basic design study

The study team carried out a field survey from December 1, to December 25, 1989 with the field survey schedule as listed below.

Date	Schedule	Details of Study Items
Dec.1 Fri.	Left Narita 10:00 NH-911 Left Guam 18:25 CO-964 Arrived at Palau	Visit to Consulate General of Japan in Agana : Explanation of the field survey implementation schedule.
2 Sat.		Survey of the existing water pipeline and the existing water treatment plant.
3 Sun.		Survey of the existing water pipeline and the existing water treatment plant.
4 Mon.		Courtesy visit to the President and the Vice President. Explanation of the inception report, the grant aid system, the questionnaire. Survey of the existing intake pump station and the Gihmel dam.
5 Tue.		Discussion with the members of Palau National Congress and the Governor of Koror State.
6 Wed.		Collection of data.
7 Thu.		Discussion with OICC(Office In Charge of Construction), U.S. Navy. Collection of data.
8 Fri		Discussion with the officers of Airai State. Preparing the Munites of Discussions.
9 Sat.		Discussion and Signature of the Minutes of Discussions.
10 Sun.		Return Dr. Sano and Mr. Miyane to Japan. Survey of the overall pipeline route.
11 Mon.		Survey of the pipeline in Koror area.
12 Tue.		Survey of the pipeline in Airai area including the intake pump station and the Gihmel dam.
13 Wed.		Survey of local contractor.

Date	Schedule	Details of Study Items
14 Thu.		Test pitting along the pipeline route, Survey of local contractor.
15 Fri.		Measurement of tide velocity, depth of sea water at Toagel-mid channel and water pressure
16 Sat.		Collection and sorting data.
17 Sun.		Collection and sorting data.
18 Mon.		Discussion with the Bureau of Public Works.
19 Tue.		Preparation of the field report.
20 Wed.		Survey of the water tanks. Discussion with the Governor of Airai State.
21 Thu.		Discussion with the Bureau of Public Works. Preparation of the field report.
22 Fri.		Collection of water samples for testing. Discussion with Koror State. Explanation of the field report.
23 Sat.		Signature of the field report.
24 Sun.	Left Palau 10:15 CO-953	The survey members left Palau to Guam.
25 Mon.	Left Guam 16:20 CO-967	Visit to Consulate General of Japan in Agana. The survey members arrived Japan.

2. Explanation of Draft Final Report

The study team carried out a explanation of the draft final raport (D/F) to the authorities concerned of the Government of Palau from April 16, to April 24, 1990 with the schedule as listed below.

Date	Schedule	Details of Study Items
Dec.16 Mon.	Left Narita 9:30 CO-962 Left Guam 18:25 CO-958 Arrived at Palau	Visit to Consulate General of Japan in Agana :
17 Tue.		Courtesy visit to the President. Survey of the existing water facilities. Explanation and discussion of the D/F with the National Planning Council and the Bureau of Public works.
18 Wed.		Discussion with the National Planning Council and the Bureau of Public Works.
19 Thu.		Discussion with the National Planning Council and the Bureau of Public Works. Signature of the Minutes of Discussions.
20 Fri.		Return Mr. Hata to Japan. Discussion with the National Planning Council and the Bureau of Public Works.
21 Sat.		Collection and sorting data. Survey of the existing water facilities.
22 Sun.		Discussion with the National Planning Council.
23 Mon.	Left Palau 20:00 CO-959	Discussion with the National Planning Council and the Bureau of Public Works.
24 Mon.	Left Guam 16:20 CO-967	Visit to Consulate General of Japan in Agana. Mr. Seno arrived Japan.

APPENDIX IV

LIST OF INTERVIEWEES

LIST OF INTERVIEWEES

The interviewees concerned with this study team are listed as follows:

Occupation and Name	Position
CONSULATE GENERAL OF JAPAN IN AGANA.	
Mr. Masao WADA	Consul General
Mr. Yoshio KOSHIO	Consul
Mr. Hideo AIHARA	Vice Consul
PRESIDENT'S OFFICE	
Ngiratkel ETPISON	President
Bonifacio BASILIUS	Chief of staff
Johanes ADELBAI	Special Assistant to the President (ECONOMIC MATTERS)
Selestiono E. OTONG	Special Assistant to the President (INTERNAL AND INSULAR AFFAIRS)
VICE PRESIDENT'S OFFICE	
Kuniwo NAKAMURA	Vice President
NATIONAL PLANNING COUNCIL	
Koichi L. WONG	National Planner
BUREAU OF PUBLIC WORKS	
Marcelino MELAIREI	Director of Public Works
August REMOKET	Water Branch Supervisor
Regis AKITAYA	Energy Program Planner

PALAU NATIONAL CONGRESS

Evans BECHES	Delegate
Surawgel WHIPPS	Delegate
Masayuki ADELBAI	Senator
Minoru UEKI	Senator/Senate Chairman Foreign Affairs
Thomas PATRIS	Delegate
Peter SUGIYAMA	Senator
Minami UEKI	Delegate
Peter SADANG	Senator
Hideo TELL	Delegate/House of Delegates Chairman Foreign Affairs

KOROR STATE GOVERNMENT

Ibedul Y.M. GIBBONS	Governor
Francisco C. NGIRAILEMESANG	Special Assistant to Paramaunt Chief Ibedul

AIRAI STATE GOVERNMENT

Roman TMETUCHL	Governor
Aantos NGIRASECHEDUI	Chairman Airai State Land Authority
Tatsuo KAMINGAKI	Member Airai State Land Authority
Juan POLLOI	Staff Office of Airai State Governor
Sechei REBLUND	Member Airai State Land Authority

O.I.C.C.(Officer In Charge of Construction, Department of NAVY)

Gergory F.MILLS	RESIDENT OFFICER, IN CHARGE OF CONSTRUCTION

CHOI ENGINEERING CORPORATION

LARRY B. PETERSON	PRESIDENT

SOCIO MICRONESIA INC.

Chan WOO LEE	General Manager

G & N CONSTRUCTION CO.

Jane ALBERT	Office Manager

PACIFICA DEVELOPMENT CORPORATION

Hideshi MATSUMOTO	Manager

BELAU TRANSFER & TERMINAL COMPANY

Bill KELDERMANS	Manager

PALAU TRANSPORATION COMPANY

Mlib TMETUCHL	Manager

NISHIMATSU CONSTRUCTION COMPANY

Tomojiro OKAMOTO	Manager