period has no meaning. Therefore, the objective is to allocate a large number of personnel for the work and complete it within a single year.

7) Transmission pipelines

The existing system makes use of the natural downflow of water, using the steep and irregular natural terrain. The design of the transmission pipeline shall be such that it can withstand with the water pressures (static pressure, dynamic pressure, water-hammer action) satisfactorily.

4.2 Design conditions

1) Design criteria of facilities

The design of the facilities shall conform to the standards given below.

* Design Criteria for Waterworks Facilities: Japan Waterworks Association, Supervision by the Ministry of Health and Welfare
* NCDC Subdivision Code
* Standard Specifications: Department of Works

2) Applicable Standards

The standards given below shall apply.

* Japan Waterworks Association Standards
* Japanese Industrial Standards
* International Organization for Standardization (ISO) standards and manufacturer's standards.

3) System of units

The metric system shall be used.

4) Type of pipe

Pipes that can withstand a maximum static pressure of 130 m shall be used.

5) Hydraulic calculations

William and Hazen's formula shall be used for hydraulic calculations of the pipeline.

$$H = 10.66 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85} \times L$$

where, H: loss of head (m)
C: coefficient of flow velocity
D: diameter of pipe (m)
Q: flow rate (m^3/sec)
L: length of pipeline (m)

4.3 Basic plan

The outline of the work for installation of transmission pipelines of diameter 1,000 mm and 600 mm is described below.

1) Dia. 1,100 mm transmission pipeline installation work

Type of pipe	Ductile cast iron, T and K-shaped joints, mortar lining		
Length	2,596 m (From Airport to Erima point)		
Accessory equipment	Butterfly valves and equipment	Dia. 1,100 mm	4 sets
	Double orifice air valve equipment	Dia. 200 mm	1 location
		Dia. 80 mm	1 location
	Blow-off equipment		4 sets
	Creek crossing by siphon culvert		1 location
Sheeting	1) Steel sheet pile	Used over a space of 300 m approximately at creek crossings by siphon culverts	
	2) Lightweight steel sheet pile	Used in the city area in the downstream parts (not rocky). Used as contact sheet only, without setting.	
	3) Excavation without timbering	Comparatively hard ground in the upstream parts.	

2) Dia. 600 mm transmission pipeline construction work

Type of pipe	Ductile cast iron, T and K-shaped joints, mortar lining.		
Length	7,195 m (From Erima point to 3 Mile point)		
Accessory equipment	Sluice valves and equipment	Dia. 250 mm	1 set
	Butterfly valves and equipment	Dia. 600 mm	6 sets
	Double orifice air valve	Dia. 80 mm	At 5 locations
	Blow-off equipment		8 sets
	Creek crossing by aqueduct		At 1 location
Sheeting	1) Lightweight steel sheet piles	Used in the upstream parts (not rocky). Used as contact sheets only, without setting.	
	2) Excavation without timbering	This method is used for downstream parts that are comparatively rocky.	

3) Asphalt paving

Asphalt paving work is contemplated for the areas mentioned below in the planned routes.

a) Road crossing locations (5 locations)

b) All routes through the shopping district along the Spring Garden Road.

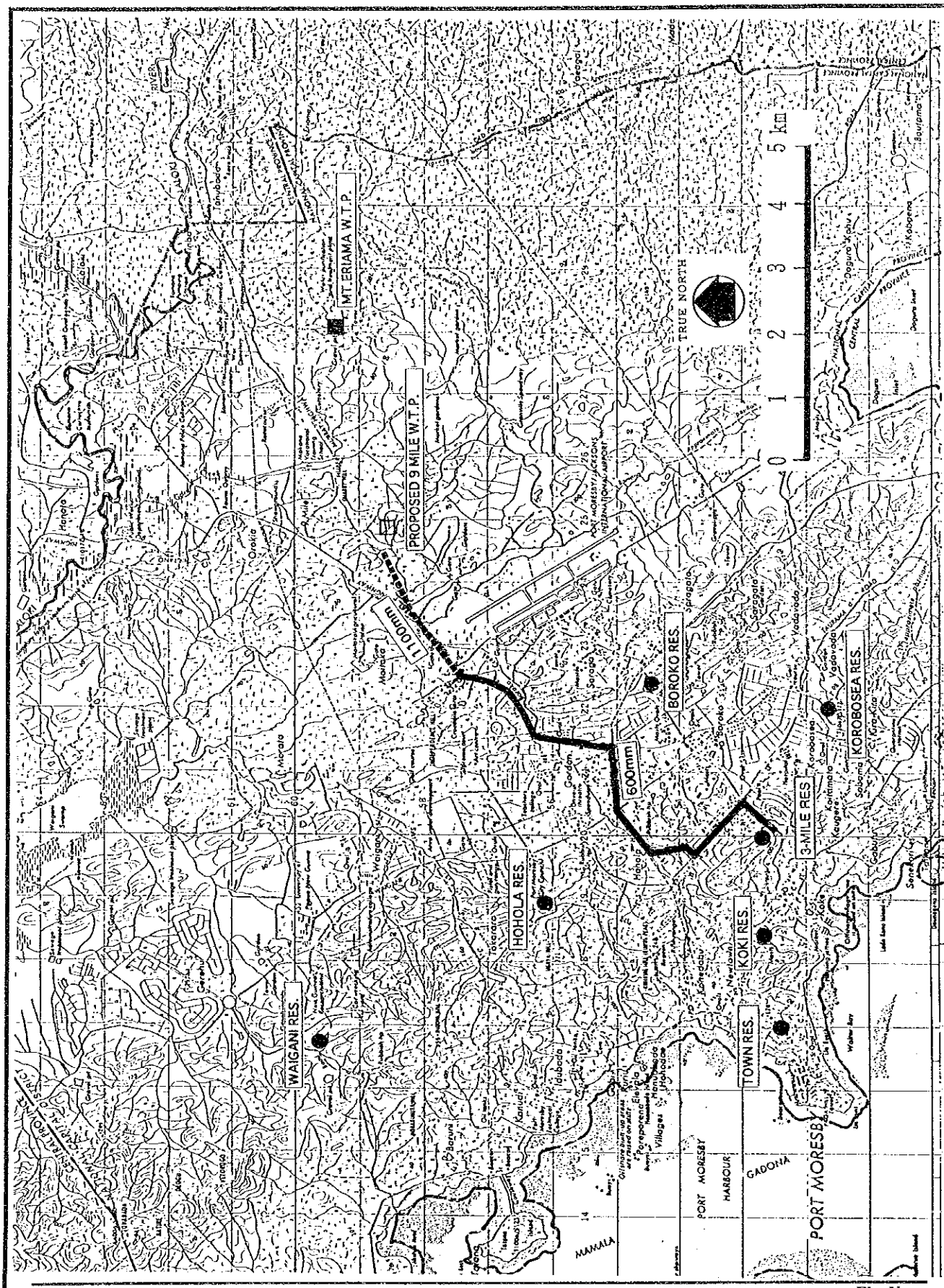
c) A part of the route through the residential areas.

The specifications for asphalt paving shall conform to local specifications (all materials procured locally).

4) Basic design drawings

The basic design drawings are as listed below.

Drawing No.	Title of Drawing
4-1	Complete Route Drawing
4-2	Route Details 1/5
4-3	Route Details 2/5
4-4	Route Details 3/5
4-5	Route Details 4/5
4-6	Route Details 5/5
4-7	Creek crossing by dia. 1,100 mm siphon culvert
4-8	Creek crossing by dia. 600 mm aqueduct
4-9	Valve chamber and blow-off equipment
4-10	Cross section of excavation



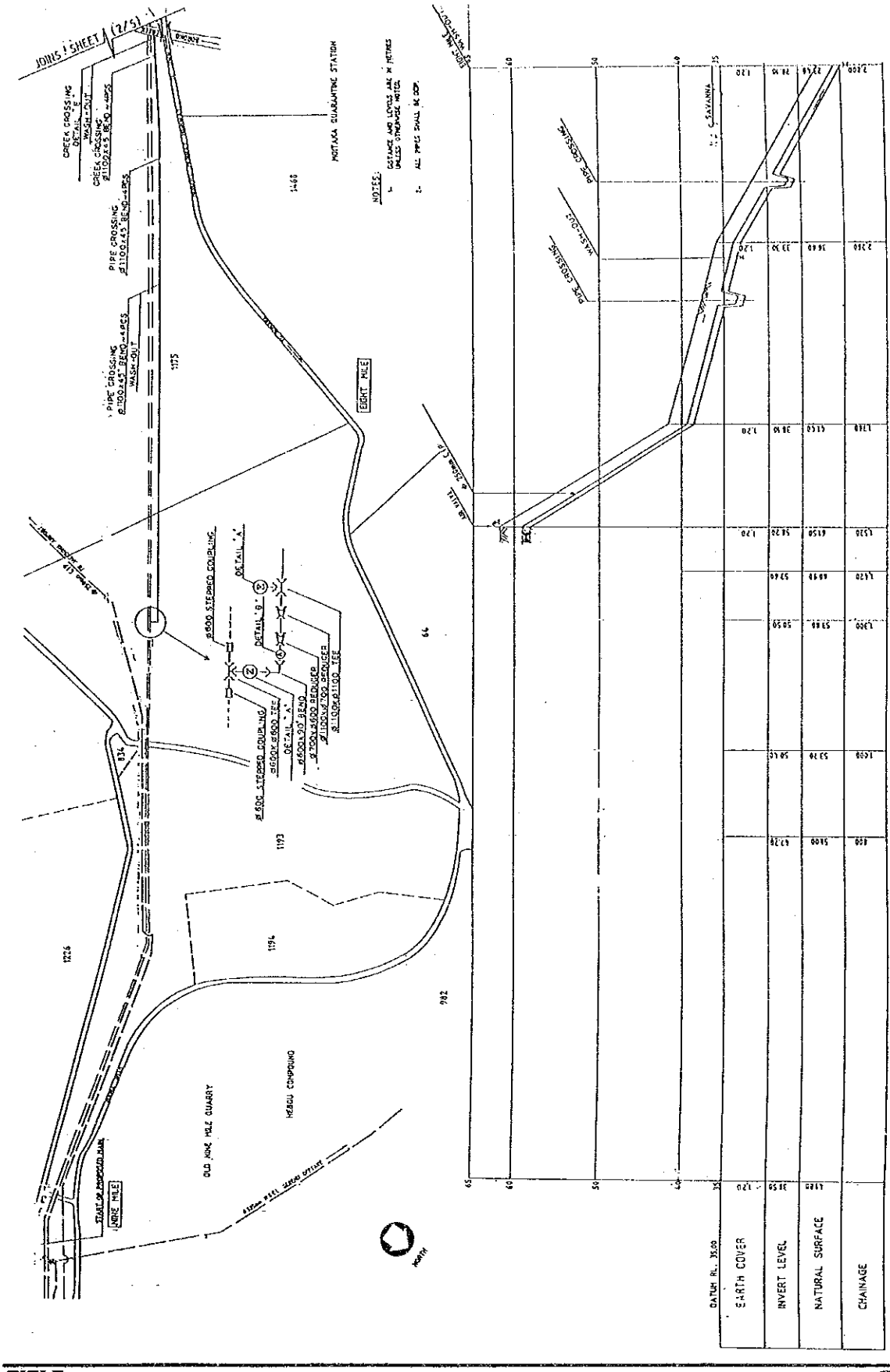
TITLE

COMPLETE ROUTE DRAWING

Fig. No. 4.1

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

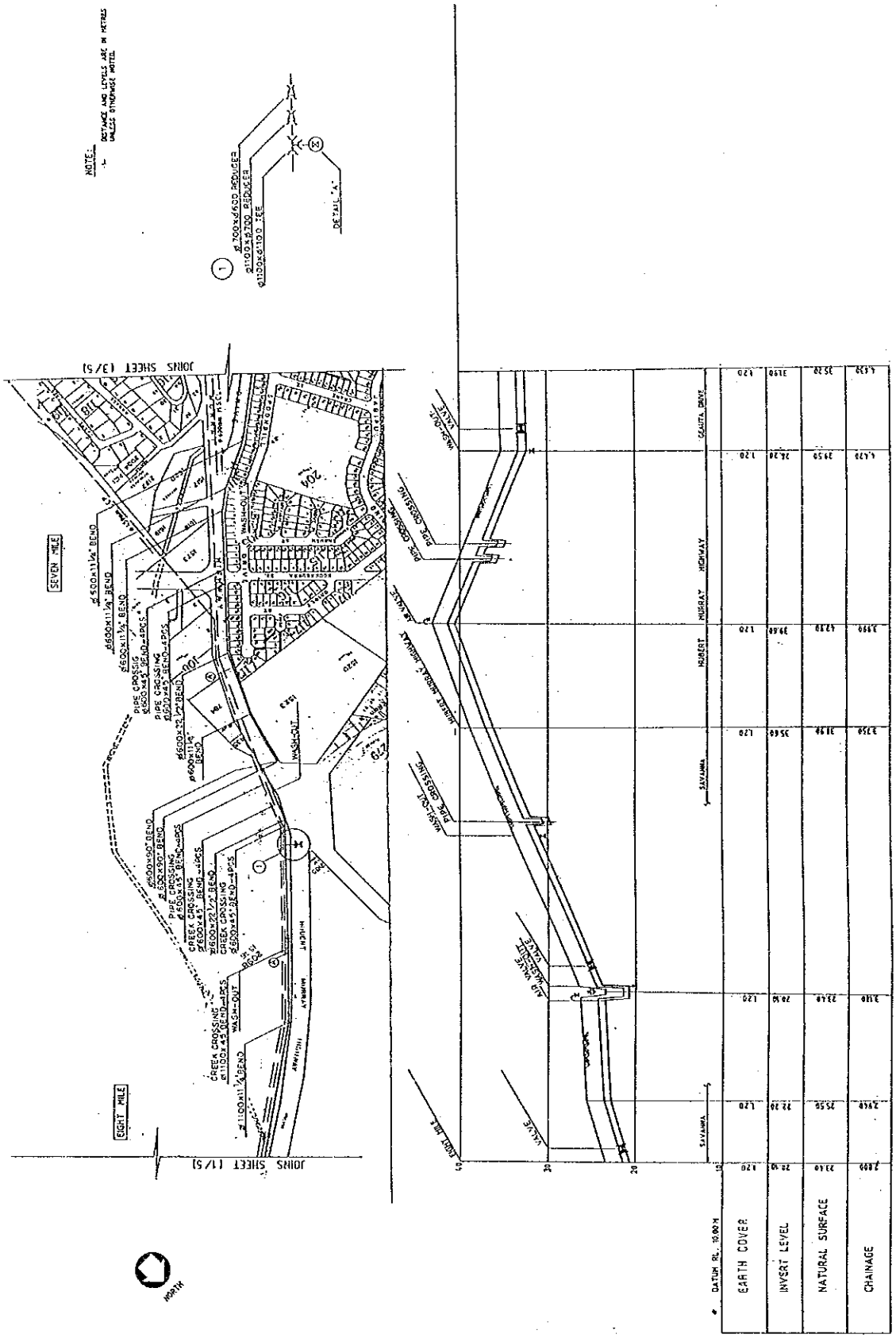
ROUTE DETAILS (1/5)

Fig. No.

4.2

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

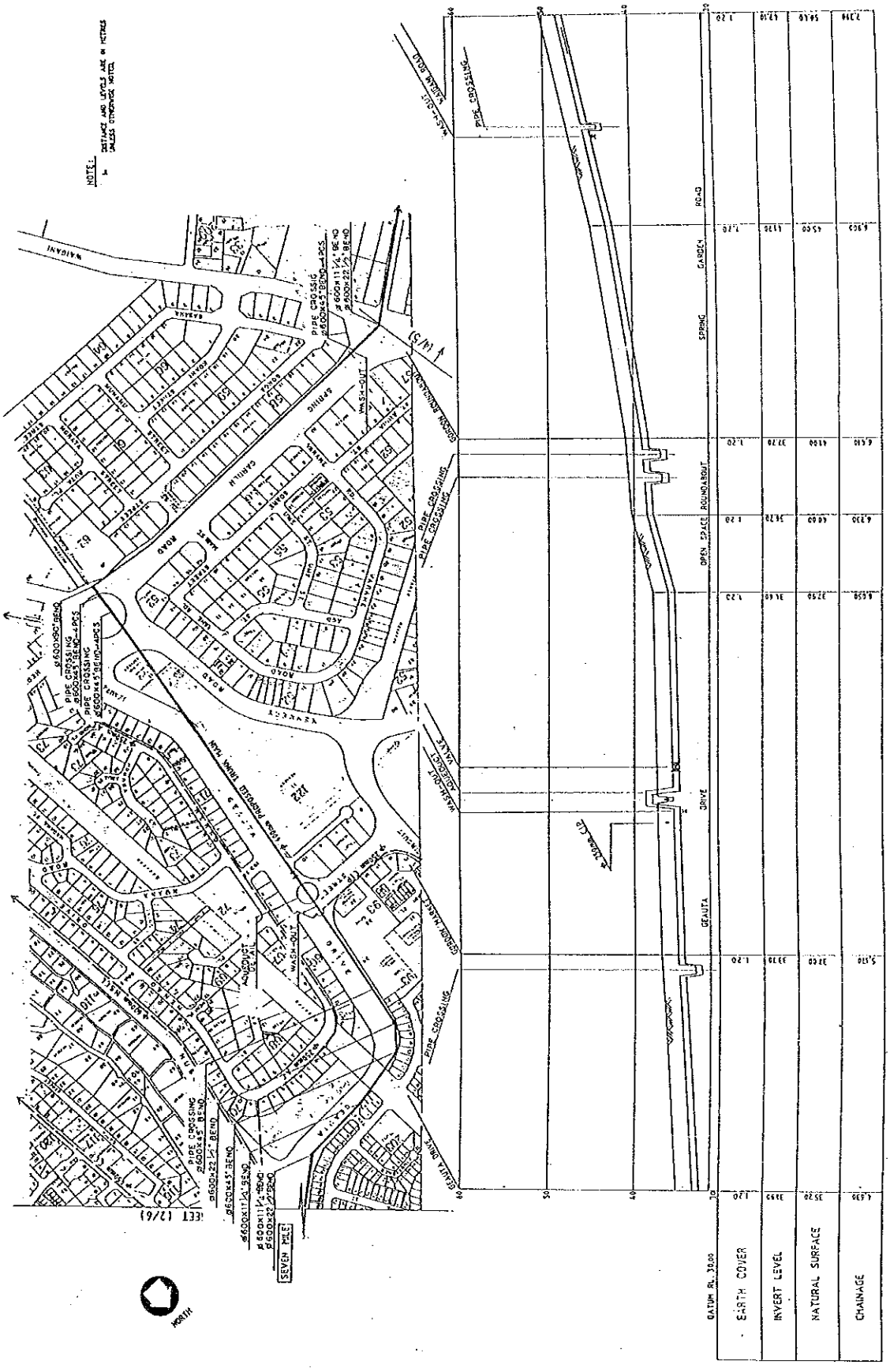
ROUTE DETAILS (2/5)

Fig. No.

4.3

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

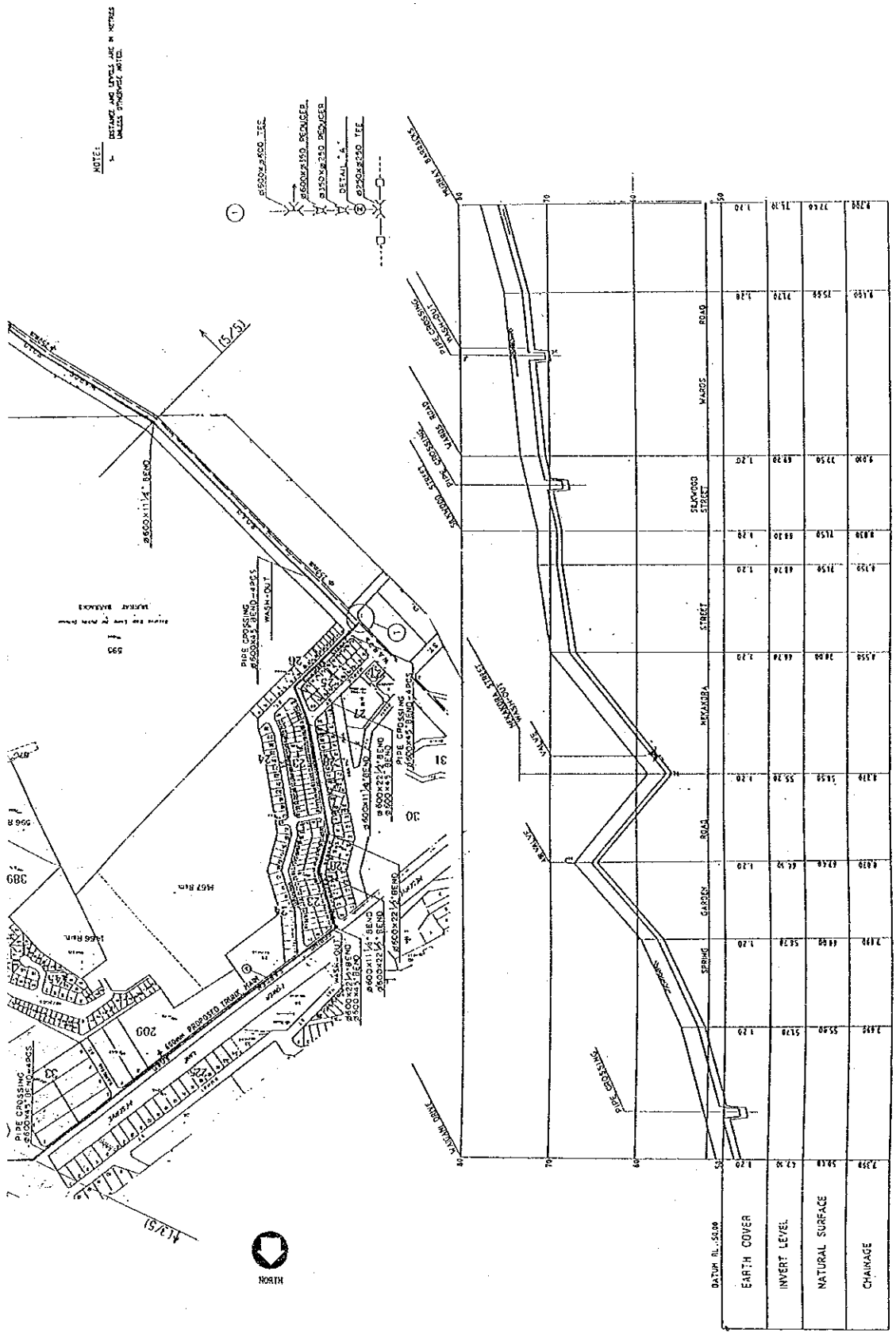
ROUTE DETAIL (3/5)

Fig. No.

4.4

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

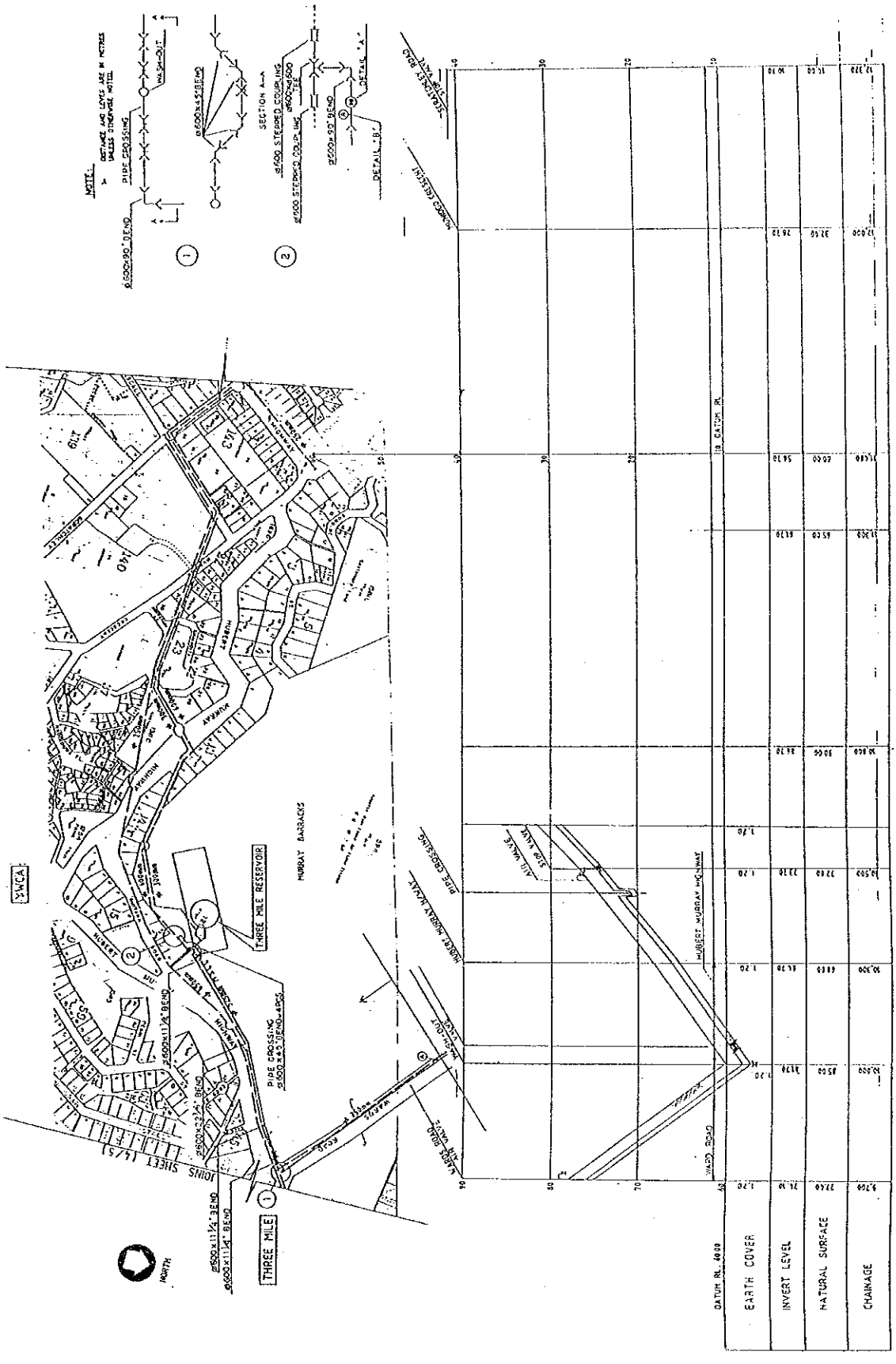
ROUTE DETAILS (4/5)

Fig. No.

4.5

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



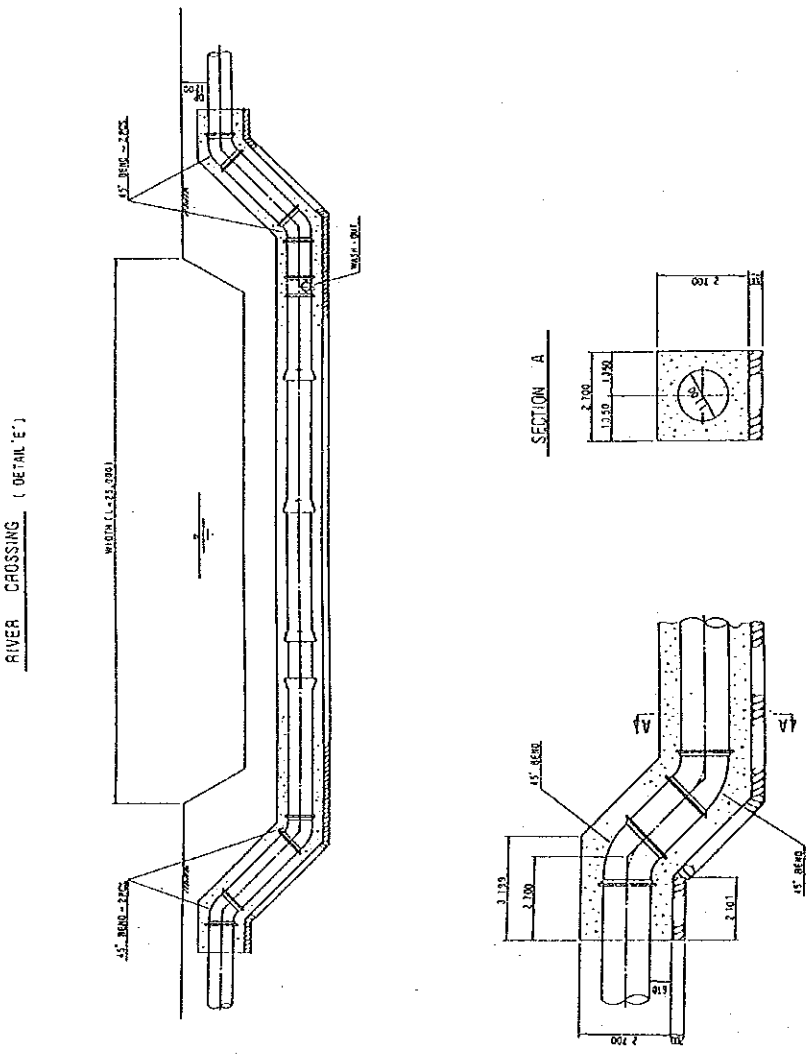
TITLE

ROUTE DETAILS (5/5)

Fig. No. **4.6**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



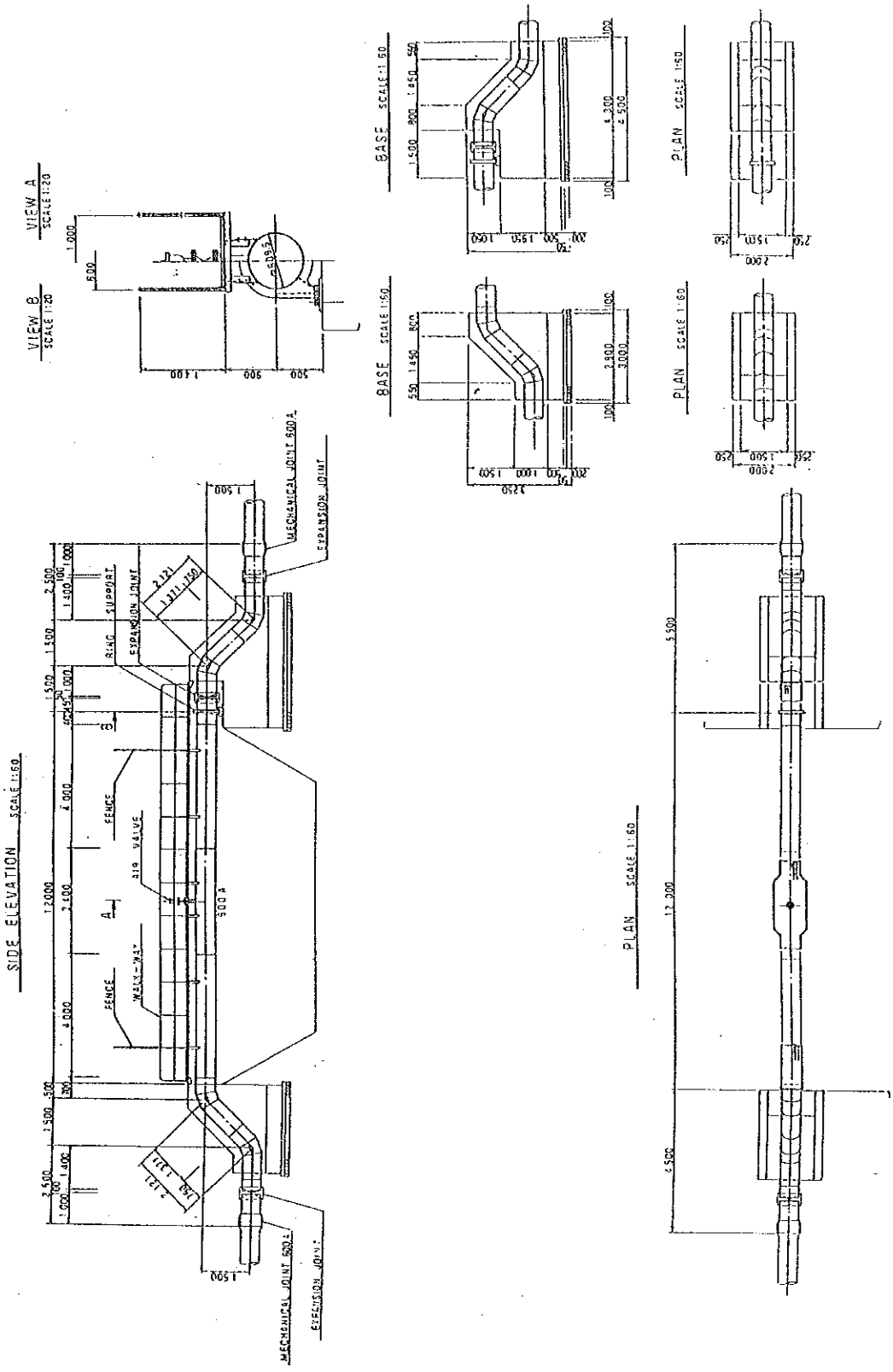
TITLE

CREEK CROSSING BY DIA. 1,100 mm SIPHON CULVERT

Fig. No. **4.7**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



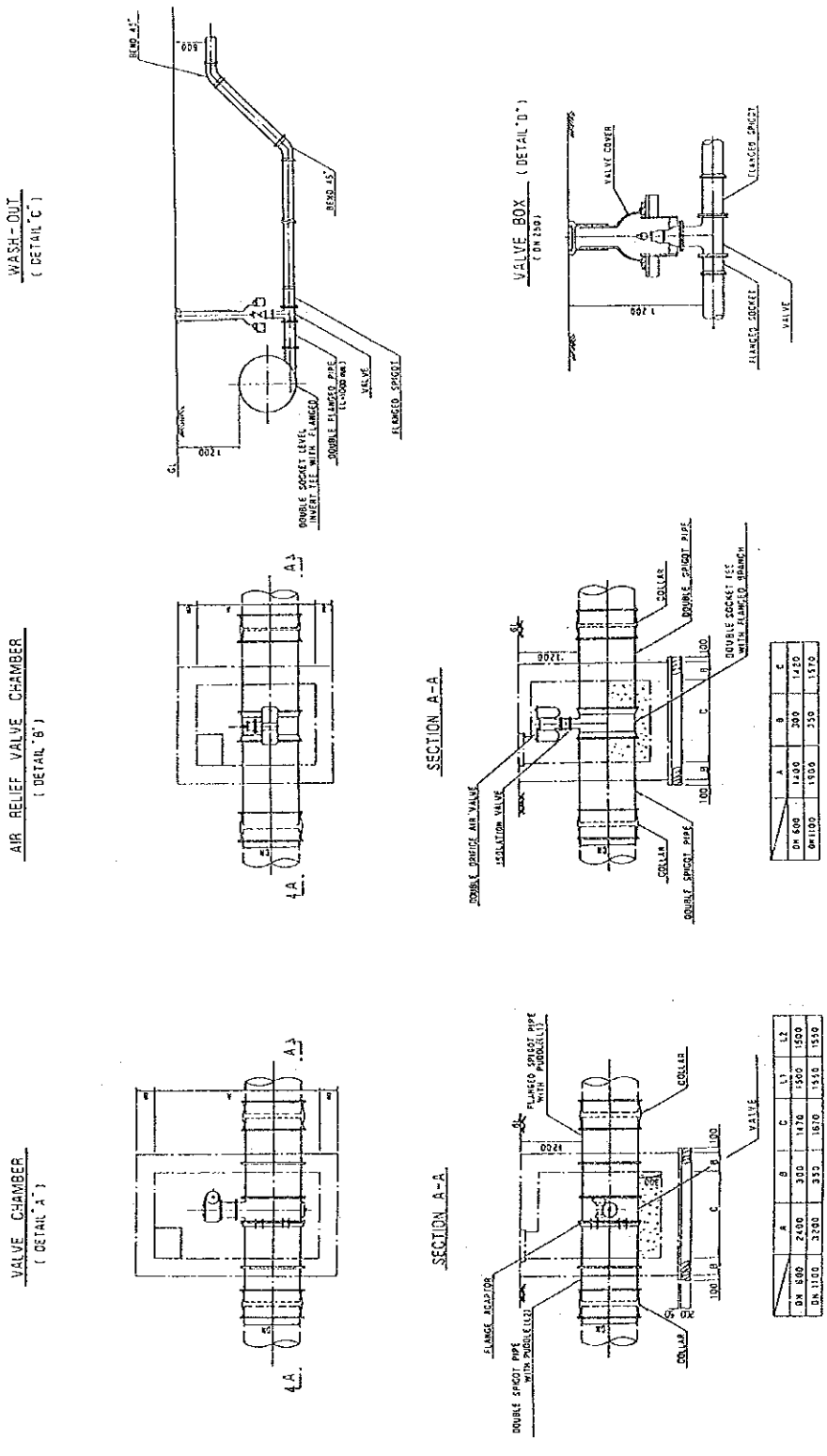
TITLE

CREEK CROSSING BY DIA. 600 mm AQUEDUCT

Fig. No. 4.8

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



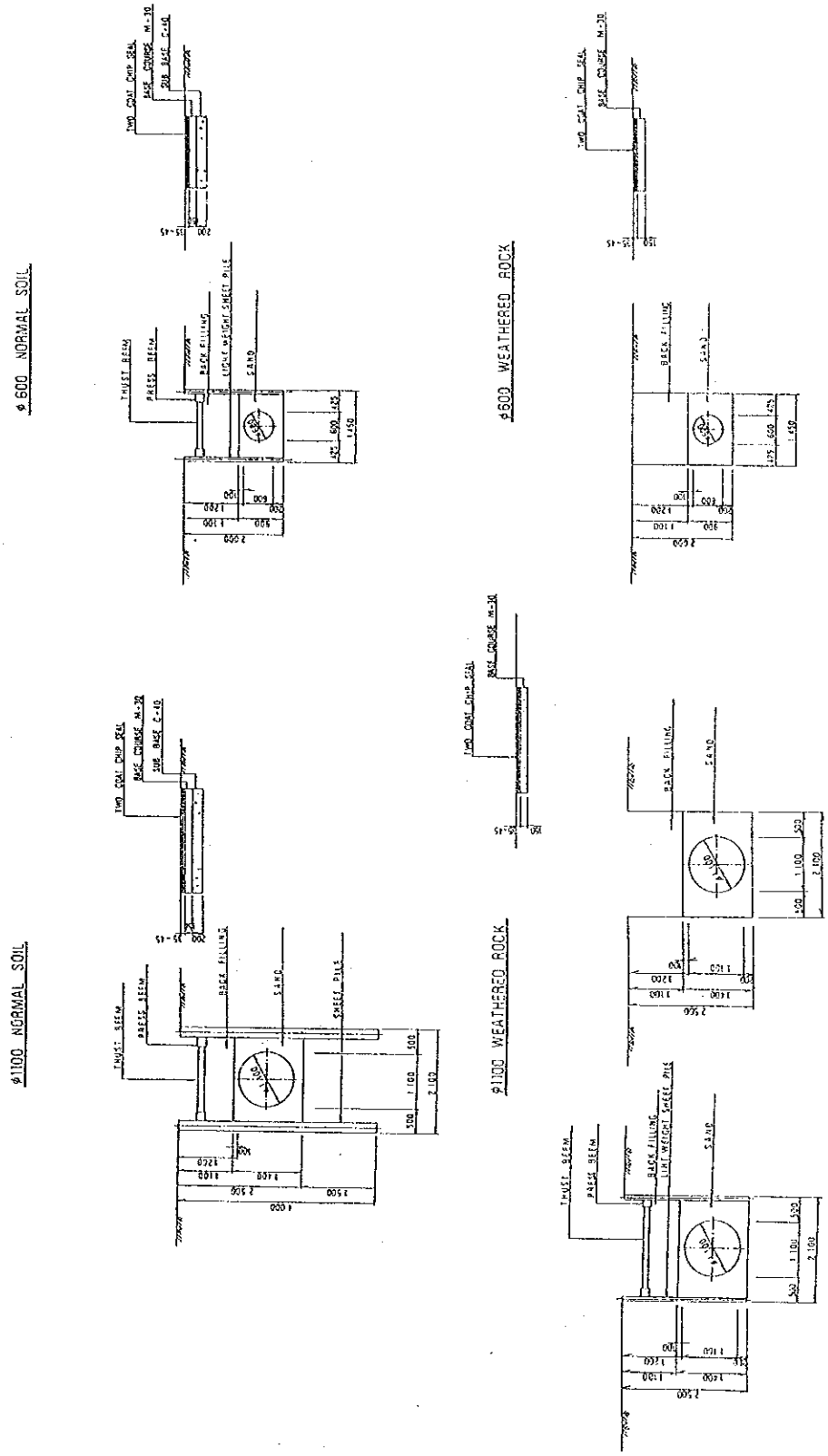
TITLE

VALVE CHAMBER AND BLOW-OFF EQUIPMENT

Fig. No. 4.9

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

MANNING, EQUIPMENT AND TOOLS FOR LEAKAGE

Fig. No. 4.10

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL

4.4 Implementation plan

4.4.1 Construction Condition

During the implementation of the water supply work, the construction method shall be decided with particular consideration given to the points mentioned below.

(1) The inhabitants shall be made fully aware of the details of the work and their cooperation and assistance obtained.

(2) Care shall be taken to select construction methods, construction machines, and working times so that disturbances such as noise and vibrations are restricted to a minimum for the residents.

(3) Since there is a large number of commuters, vehicles, shops and residences, efforts are necessary to ensure the safety of the commuters and normal operation of the shops. For this purpose, a draft of the construction plan shall be offered to suspend traffic regulations at an early stage during the excavation, pipe installation, land refilling and pavement restoration work.

(4) Efforts are necessary to prevent damage to buried equipment (sewage, water supply pipelines, power and telephone cables) and ensure their proper, continuing operation.

(5) Efforts shall be made to prevent hindrance and obstruction to the operation of military planes and airport facilities at the work locations in the vicinity of the airport.

(6) As described in the construction conditions also, the technical skills mentioned below for the installation of large diameter pipelines required for this project are not available in PNG. Therefore, the deputation of engineers from Japan for the work mentioned below is proposed.
Piping work
Sheet pile driving work

The work implementation system is shown in Fig. 4.11.

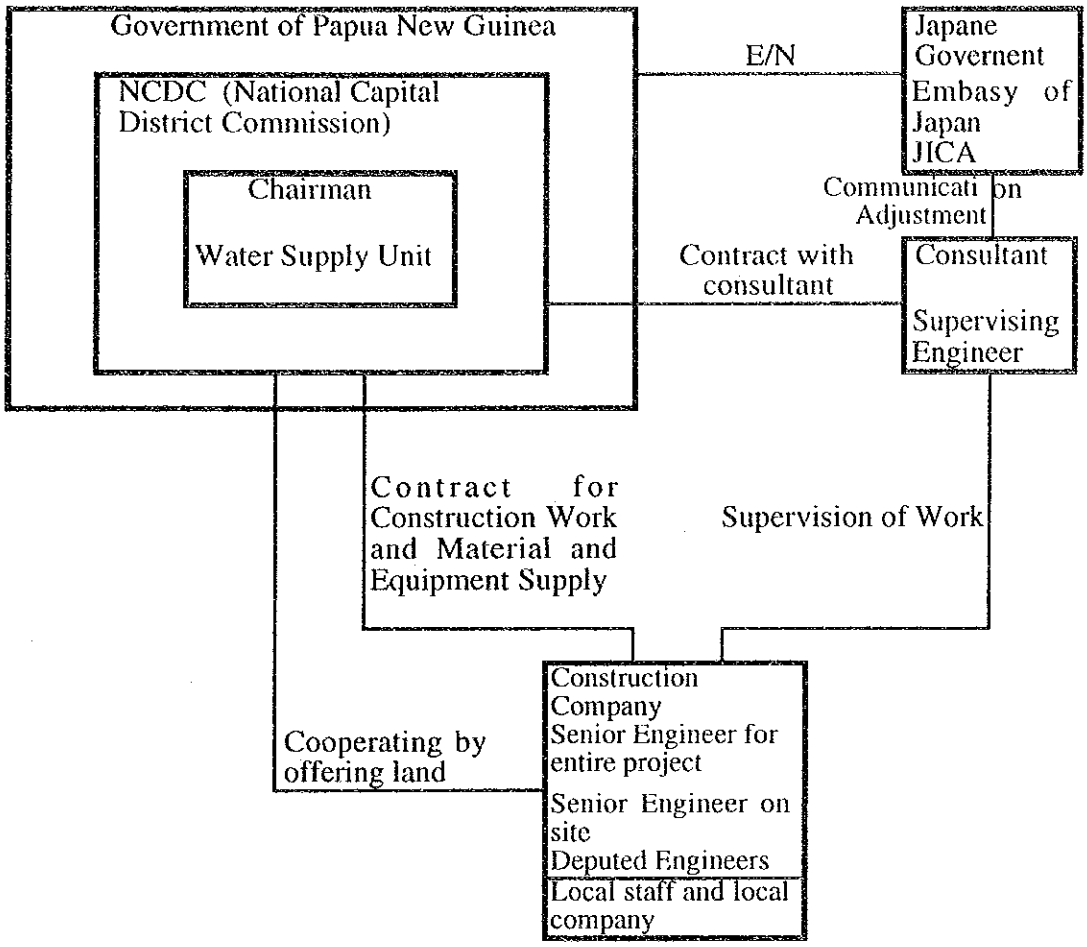


Fig. 4-11 Work implementation system

4.4.2 Implementation Method

The main construction conditions related to the implementation of this project are given below.

(1) Construction conditions

(a) Australian and New Zealand managers and foremen mainly work for general constructors and construction subcontractors in PNG. Skilled personnel are few, but there is an abundant number of semi-skilled personnel and assistants.

(b) The construction materials that can be procured in PNG include aggregate, concrete blocks, wood, plywood, paints, PVC pipes, etc. Recently, a cement factory has been completed in PNG and there are restrictions in importing cement. Other important construction materials are imported from foreign countries, such as the neighboring countries and Japan.

(2) Considerations in implementation

(a) General

For detailed installation locations of the water supply pipelines, test excavations shall be carried out in the initial stage after the work contract is signed because already installed water supply pipes, sewage pipes, electric cables and telephone cables are buried. After confirming the position, the installation locations shall be decided.

For the excavation work for installing pipelines, machines will mainly be used (area around existing pipelines, buried items shall be excavated manually). The last 20 cm bedding shall be manually excavated, and sheet piles shall be driven.

Land filling shall be carried out by using a part of the excavated soil. Rammers shall be used for tamping and the soil shall be packed tightly.

At locations where the pipelines cross existing pipelines, siphon culverts shall be used.

(b) Road intersections

There are 5 locations where the proposed route crosses trunk roads. Particularly, the rotary part that intersects the Spring Garden Drive and Waigani Drive has a large traffic volume, and one-way road restrictions, and temporary roads such as detours must be set, and measures adopted to ensure that there are no adverse effects on commercial activities.

(c) Creek crossings

There are two locations where the proposed route crosses Boroko Creek, but the span of the Moitaka area upstream (by the side of the airport) is as large as 25 m, therefore, a siphon culvert shall be installed on the bed of the creek. The span of the Gordon area downstream is 12 m and a aqueduct shall be installed. The pipeline material of the aqueduct shall be made of steel, after considering the construction, maintenance and control aspects. In front of and behind the part where the ductile cast iron pipe and steel pipe of the aqueduct are

connected, a valve chamber shall be installed, containing control valve and blow-off valve. Blow-off valve shall be installed in the siphon culvert.

(d) Existing pipe connections

The work for connecting the new transmission trunk main and existing branch pipelines shall be carried out quickly. For the connection work with the existing main pipeline (pipe diameter 600 mm), the water supply through the existing main pipeline shall be cut, and the connection work carried out quickly.

4.4.3 Construction and supervision plan

A construction and supervision plan is necessary to ensure that the water supply construction work is carried out safely, quality of the work is good, and work is completed within the specified period.

(1) Work shall be supervised and monitored all the time.
(2) If the basic design conditions and the local conditions do not match, the local permanently-based supervisor shall make design changes according to the specifications and within the scope of the contract, after receiving the approval from NCDC.
(3) Quality control related to pipeline installation work is an important aspect, therefore, water pressure tests shall be carried out based on the work contract.
(4) For land acquisition for temporary roads and detours, the position, area, and period of work shall be reported to NCDC beforehand, and the land acquired so that there is no hindrance or delay in the work.

4.4.4 Procurement plan

Materials and equipment that can be procured locally, shall be procured from PNG. All other materials shall be procured from Japan.

The important materials and equipment that need to be procured are listed below.

(1) Materials
  (a) Procured from PNG

  Aggregate, cement, reinforcing bars, simple steel sheet piles, general steel materials, plywood for formwork, concrete blocks, etc.

  (b) Procured from Japan

Ductile cast iron, standard diameter pipes, valves, air valves, and steel pipes for aqueducts. There is only one manufacturer of ductile cast iron pipes in Australia, the neighboring country. In view of the delivery period and the quality, as mentioned below, procurement from Japan is preferable, therefore, the pipes shall be procured from Japan.

* Does not manufacture pipes larger than 500 mm diameter complying with ISO standards.

* There is only one manufacturer of ductile cast iron pipes in Australia, and there is uneasiness in signing a contract with only one manufacturer for supply of the pipes and completion of the work within one year.

(2) Construction machines

(a) Procured from PNG

General construction machines can be leased from PNG, therefore, these machines shall be procured locally.

(b) Procured from Japan

Special machines that are difficult to procure from PNG and neighboring countries shall be procured from Japan.

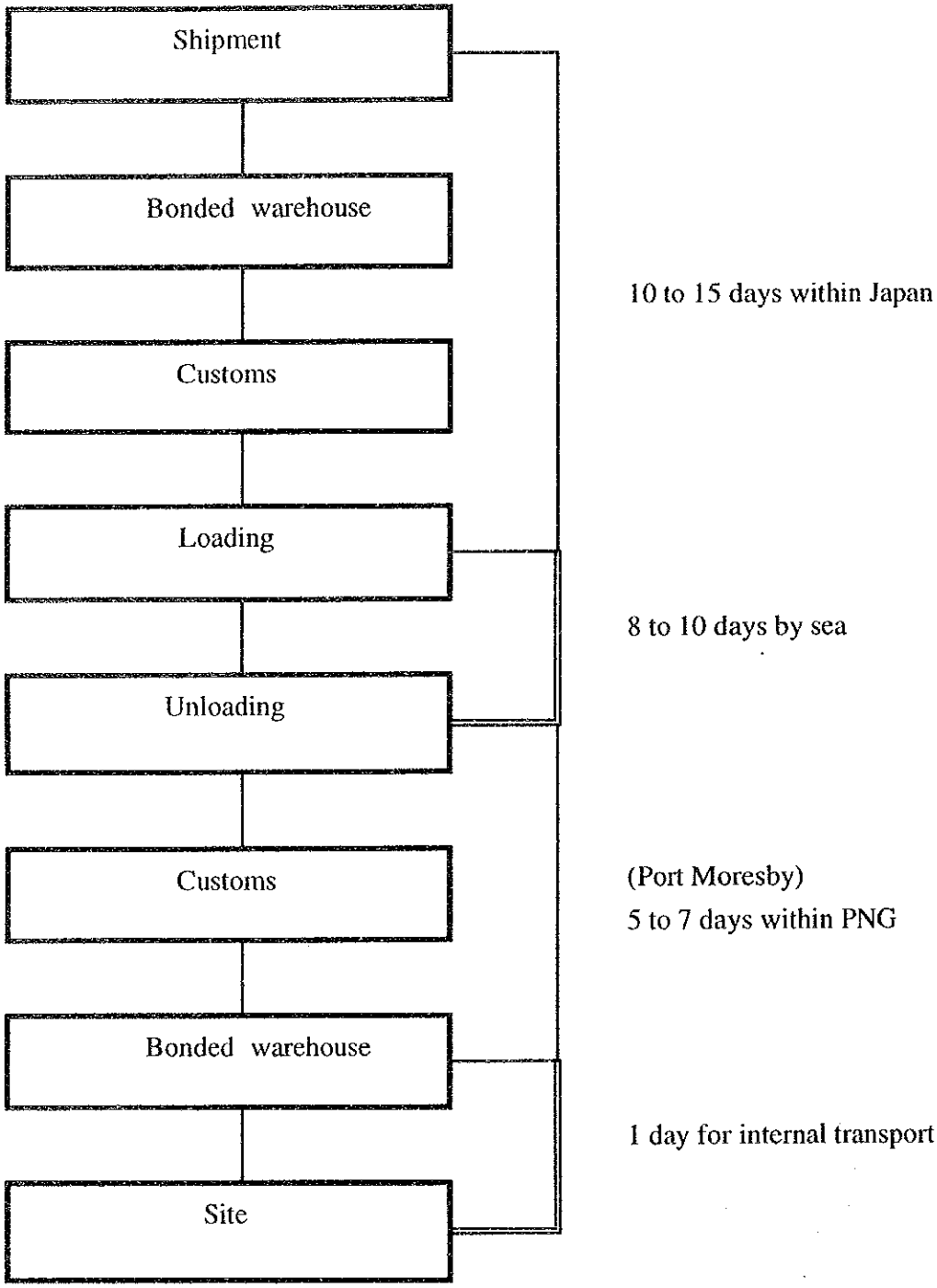
The procurement categories for main materials and equipment to be used for the project are given below.

Material / equipment	Procured from PNG	Procured from Japan	Remarks
1. Sand / gravel	O		These items are circulated continuously in PNG and can be procured easily.
2. Ordinary Portland Cement	O		
3. Reinforcing bar	O		
4. Wood	O		
5. Plywood for formwork	O		
6. Fuel and lubricating oil	O		Can be purchased in PNG.
7. Power and water	O		
8. Bulldozer	O		Owned by local subcontractors. Can be leased.
9. Wheel loader	O		
10. Back hoe	O		
11. Dump truck	O		
12. Trailer	O		
13. Power shovel	O		
14. Water tank truck	O		
15. Concrete mixer	O		
16. Truck crane	O		
17. Rammer	O		
18. Generator	O		
19. Welding machine	O		
20. Air compressor	O		
21. Submersible sand pump	O		

Material / Equipment	Procured from PNG	Procured from Japan	Remarks
22. Ductile cast iron pipe		O	The materials mentioned in the column on the left are not manufactured in PNG, therefore, they shall be procured from Japan.
23. Ductile cast iron pipes of special form		O	
24. Valves for ductile cast iron pipe		O	
25. Aqueduct materials		O	
26. Safety and maintenance materials (Barricade, indicating plates, lighting, and others)		O	

(3) Transportation plan

The transportation method and number of days required for transporting materials from Japan to the site are given below.



4.4.5 Scope of Work

The scope of work implemented by the Japanese side, shown already in section 4.3 is repeated here.

1) Dia. 1,100 mm transmission pipeline installation work

Type of pipeline	Ductile cast iron, T and K-shaped joints, mortar lining		
Length	2,596 m (From Airport to Erima point)		
Accessory equipment	Butterfly valves and equipment	Dia. 1,100 mm	4 sets
	Double orifice air valve equipment	Dia. 200 mm	1 location
		Dia. 80 mm	1 location
	Blow-off equipment		4 sets
	Creek crossing by siphon culvert		1 location

2) Dia. 600 mm transmission pipeline construction work

Type of pipe	Ductile cast iron, T and K-shaped joints, mortar lining.		
Length	7,195 m (From Erima point to 3 Mile point)		
Accessory equipment	Sluice valves and equipment	Dia. 250 mm	1 set
	Butterfly valves and equipment	Dia. 600 mm	6 sets
	Double orifice air valve	Dia. 80 mm	At 5 locations
	Blow-off equipment		8 sets
	Creek crossing by aqueduct		At 1 location
Sheeting	1) Lightweight steel sheet piles	Used in the upstream parts (not rocky). Used as contact sheets only, without setting.	
	2) Excavation without timbering	This method is used for downstream parts that are comparatively rocky.	

3) Asphalt paving

Asphalt paving work is contemplated for the areas mentioned below in the planned routes.

a) Road crossing locations (5 locations)

b) All routes through the shopping district along the Spring Garden Road.

c) A part of the route through the residential areas.

The Papua New Guinean side will undertake the following works;

(1) Access road : 300,000 Kina

(2) Water charges for water tests: 2,000 Kina

Conditions for calculation are as follows;

Calculation period: December 1993

Exchange rate: 1.00 US dollar = 108 yen

(Average value over six months before December 1993)

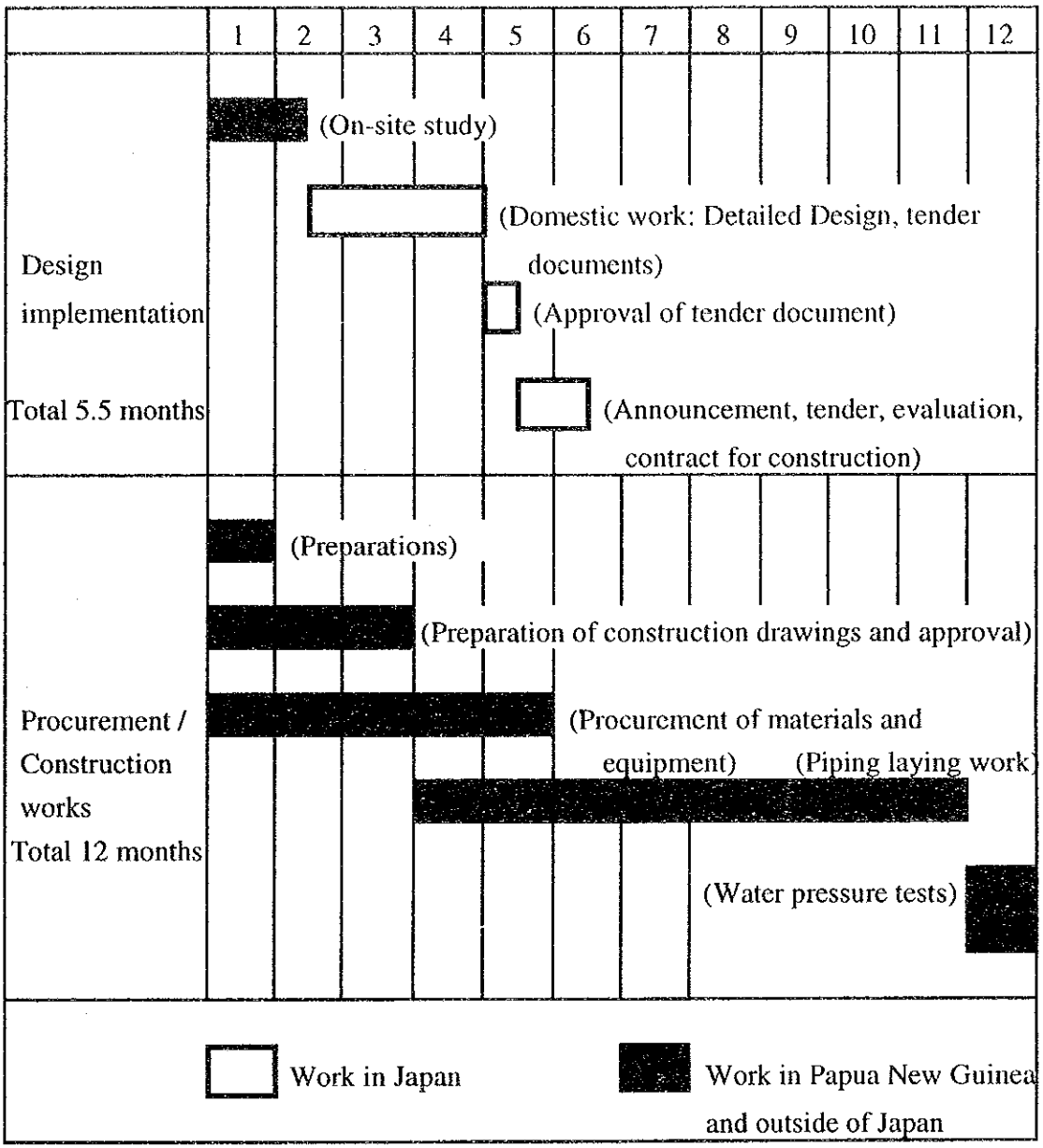
1.00 US dollar = 0.98 Kina

(Average value over six months before November 1993)

4.4.6 Implementation Schedule

After the Exchange of Notes are concluded between the governments of Papua New Guinea and Japan based on the recommendations of the Basic Design Study Report, the detailed design will start followed by the construction. Each schedule is shown in Table 4.1.

Table 4-1 Project implementation stages



CHAPTER 5 PROJECT EVALUATION AND CONCLUSIONS

(Effects and targets of the project)
To urgently rehabilitate (by reinforcement of water delivery capacity to low water pressure areas) the existing water supply system whose operation is irregular currently, and ensure that water is distributed equitably to the inhabitants by implementing the water supply rationing plan.

5.1 Effects of the project

5.1.1 Direct effects

(1) Effects on population due to improved water supply conditions

Fig. 2-6 shows the low water pressure areas and pumped water areas in the city during the dry season of 1992. According to this figure, the low water pressure areas are concentrated in areas remote from the water treatment plant in the coastal part, and in the hilly areas at a high altitude in the interior parts. The details of these areas are given below. Out of these areas, the areas where improvements in water supply conditions are anticipated after the implementation of this project, are all the low water pressure areas, except Gerehu area.

Census Division	District
Gerehu	Gerehu
Hohola/Tokarara Ensisi	June Valley, Tokarara, Hohola No. 4
Gordon/Saraga	Gordon Ridge, Saraga, 6 Mile
Boroko/Korobosea	Korobosea
Kilakila/Kaugere	Kila and Toikone, Savama
Hanuabada / Town	Baruni, Tatana, Hanuabada, Town, Elamakana, Gorobe

The population that will be relieved of water shortage due to the implementation of this project and the population in low water pressure areas mentioned above, are summarized according to Census Division (CD) in Table 5-1.

Table 5-1 Population in low pressure areas and improved supply areas

CD (Census Division) Number	CD Total population	Population in low water pressure areas	Percentage (%)		Population		Improvement percentage (%)	
			Population of CD	Population of all low water pressure areas	Unimproved	Improved	Population in low water pressure areas	Population in improved water supply areas
80 Gerehu	24,845	910	4	2	910	0	0	0
81 Waigani/ University	17,743	0	0	0	0	0	-	0
82 Hohola/ Tokalala	35,554	9,494	27	21	0	9,494	100	22
83 Gordons/ Saraga	36,202	4,827	13	11	0	4,827	100	11
84 Boroko/ Korobosea	28,839	3,251	11	7	0	3,251	100	7
85 Kilakila/ Kaugere	31,755	3,725	12	8	0	3,725	100	8
86 Town/ Hanuabada	27,694	22,063	80	51	0	22,063	100	52
87 Laloki/ Napanapa	5,744	0	0	0	0	0	-	0
88 Bomana	12,179	0	0	0	0	0	-	0
Total	220,555	44,270	20	100	910	43,360	98	100

The figures given above are for the dry season in 1992.

Almost 50% of the population in low water pressure areas is concentrated in the Town / Hanuabada areas in the coastal region. The remaining 50% reside in the high altitude areas in the interior parts. The transmission pipelines proposed in this project will pass through the high altitude areas (Hohola) in the interior parts, and reach the coastal regions. Therefore, the water supply conditions will improve for all the areas under low water pressure currently, by implementing the water rationing plan. The population that will benefit from this project is 43,360 persons or 98% of the population in the low water pressure areas.

B. Improvements in the water supply conditions of public facilities

The public facilities that will receive benefits by implementation of this project are schools and hospitals.

(Schools)
There are currently 54 schools in the city. Out of these schools, about 10 schools are confronted with low water pressures currently. By implementing this project, improvement in the water supply for all the facilities is anticipated, with benefits reaching approximately 4,600 students. Details are given below.

Table 5-2 Schools with low water pressure and number of students

Number	Name of school	Number of students
Elementary and junior high schools (in 1990)	1 Baruni	449
	2 Hagata	910
	3 Ororo	584
	4 Tokalala	608
	5 Tatana	103
	6 Hanuabada	527
	Total	3,181
High schools (in 1992)	7 Badihaga	689
	8 Tokalala	523
	Total	1,212
Occupational training schools (in 1992)	9 Kavari	103
Universities	10 Technical College	105
Total		4,601

(Hospitals)

There are no hospitals with low water pressures currently. However, the PNG General Hospital that caters to the whole of PNG, has installed a pumping facility to solve the problem of low water pressure. With the implementation of this project, apprehensions of water shortages will fade.

5.1.2 Indirect effects

Indirect benefits on financial and management aspects are anticipated by implementation of this project.

1) By implementing the water rationing plan, the all-round experience of NCDC, the implementing organization, will be supplemented and its maintenance and control aspects will be reinforced.

2) The employees of the Water Supply Unit of the NCDC will have the opportunity for experiencing on-the-job-training by participating in the piping work.

3) The costs incurred for adopting measures (water tank trucks, local valve operations at night) for the low water pressure areas until now will be eliminated. However, periodic valve operations for the water rationing plan will increase.

4) Low water pressure areas will no longer exist, therefore, there will be an increase in income by collection of water charges.

5) By setting the days for rationing of water, the awareness of the residents for saving water will be increased.

6) By identifying the 1100 mm pipeline from the airport to the Erima point as a part of the transmission pipeline for the future, and by implementing this project, the path to radical reforms of the existing system in the near future will be paved.

This project is a single plan for installation of transmission pipelines from the hardware aspects, and its effects are as described above. However, by combining this plan with the water rationing plan, the effects on the entire NCDC from software aspects, are anticipated to be significant.

5.2 Conclusions and suggestions

When this project is completed, the water supply conditions of Port Moresby city will improve, together with the financial condition of NCDC. As mentioned above, the know-how accumulated from the software aspects (maintenance, control and management aspects of the system) by NCDC through this project is anticipated to be significant.

The following are the suggestions for the smooth and effective implementation of this project:

1) The status of this project in the overall planning of the water supply system is at best an urgent measure to prevent further deterioration of the existing system. A solution to the root problem lies in the proper development of the entire water supply system.

2) NCDC is anticipated to reinforce its maintenance, control and management functions with this project. This will enable a smooth transition to the water supply rationing plan, that will be implemented in the next stage.

3) During the implementation of the water rationing plan, the water pressure in particular areas will increase, therefore, reinforcement from engineering aspects must be considered to prevent water leakages.

4) The route for installation of transmission pipelines will pass through land owned by government-related organizations. Therefore, NCDC is expected to carry out negotiations taking full responsibility.

5) One of the most important components in the water supply development project is the work of constructing the transmission pipeline. This work involves comparatively large diameter pipelines extending over a considerable length. NCDC is expected to offer opportunities for training the young employees by allowing them to participate in the work.

6) The low water pressure areas will be eliminated by implementing this project. Therefore, illegal connections must be severely dealt with, and efforts must be made to improve the water charge collection rate.

7) With the implementation of the water supply rationing plan, the awareness to save water will be inculcated in the citizens, therefore, establishing a publicity system is very important. The setting up of a monitoring system to judge the effects periodically must be given consideration.