TONGA WATER BOARD
KINGDOM OF TONGA

BASIC DESIGN STUDY REPORT

ON

THE PROJECT

FOR

NUKU' ALOFA WATER SUPPLY SYSTEM

IN

THE KINGDOM OF TONGA

December 1999

JAPAN INTERNATIONAL COOPERATION AGENCY
PACIFIC CONSULTANTS INTERNATIONAL
HOKKAIDO ENGINEERING CONSULTANTS

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PREFACE

In response to the request from the Government of the Kingdom of Tonga, the Government of Japan decided to conduct a basic design study on the project for Nuku'alofa water supply in the Kingdom of Tonga and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Tonga a study team from 6 June to 22 July, 1999.

The team held discussions with the officials concerned of the Government of Tonga, and conducted field surveys at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Tonga in order to discuss a draft basic design, and as this result, the present report was finalized.

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

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

December 1999

Kimio Fujita
President
Japan International Cooperation Agency

December 1999

LETTER OF TRANSMITTAL

We are pleased to submit to you the basic design study report on the project for Nuku'alofa water supply in the Kingdom of Tonga.

This study was conducted by Pacific Consultants International and Hokkaido Engineering Consultants, under a contract to JICA, during the period from 1 June, 1999 to 10 January, 2000. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Tonga and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

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

Very truly yours,

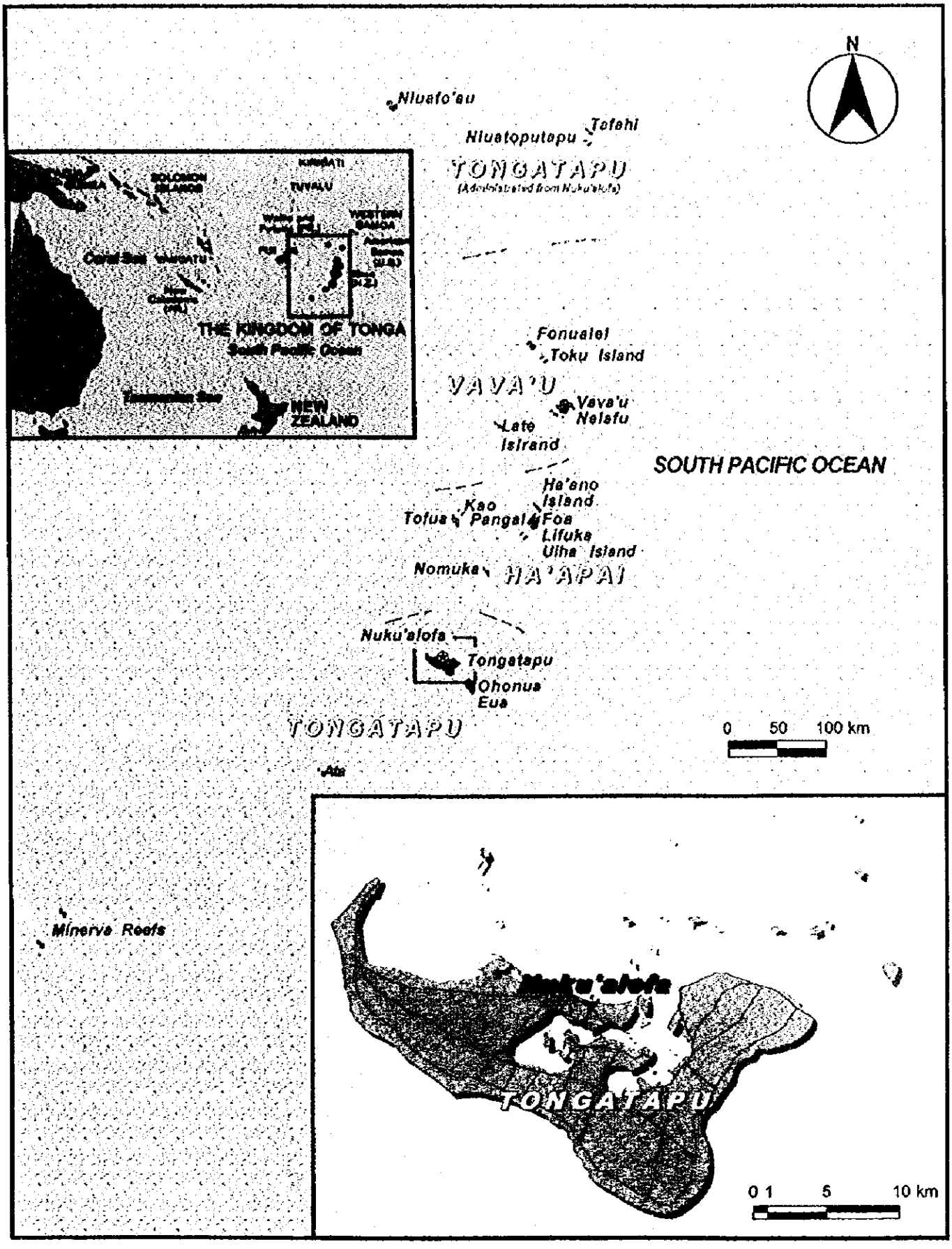
OKAGA Toshifumi

Project manager,

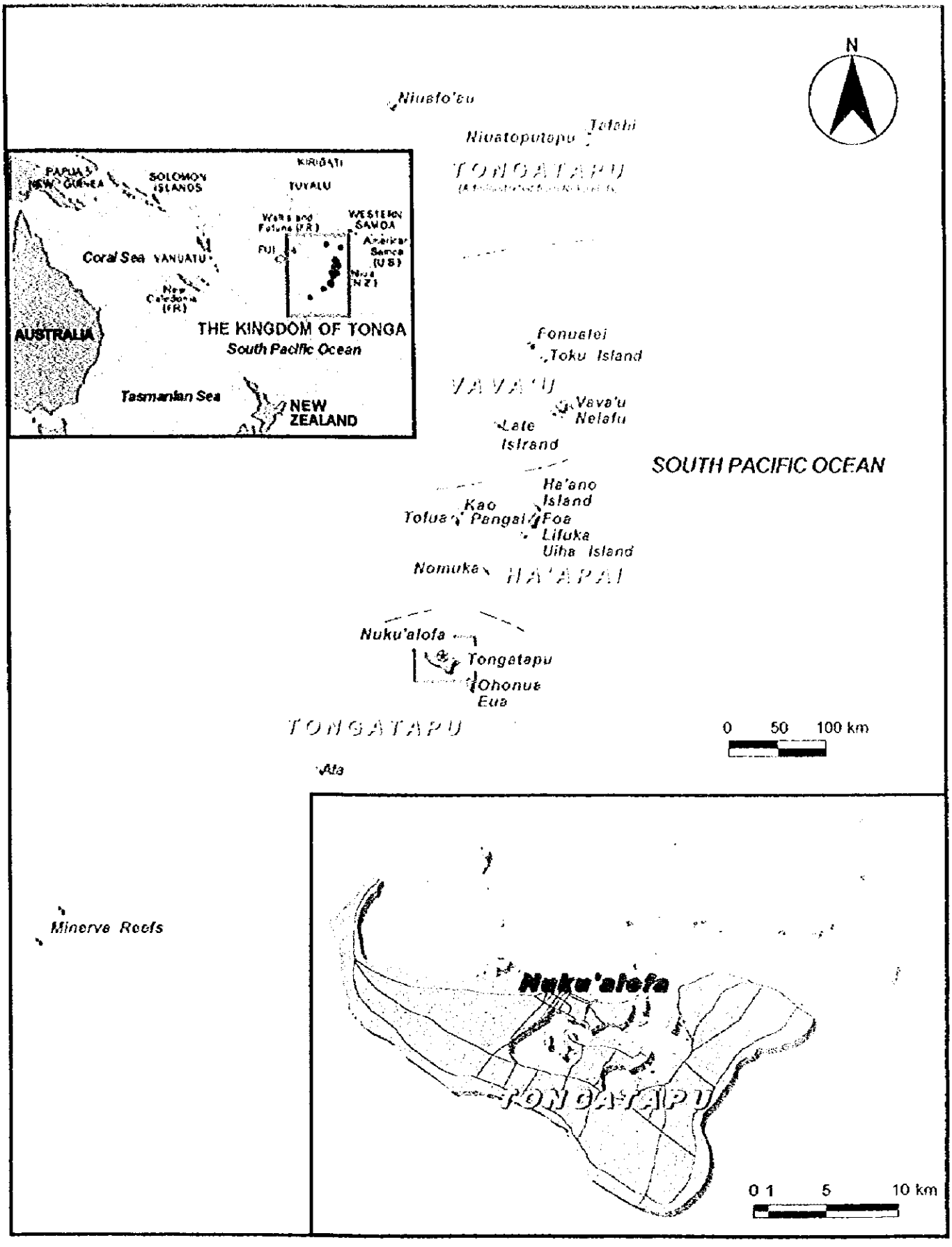
Basic design study team on
the project for Nuku'alofa water supply
in the Kingdom of Tonga

Pacific Consultants International.

Hokkaido Engineering Consultants



Location Map



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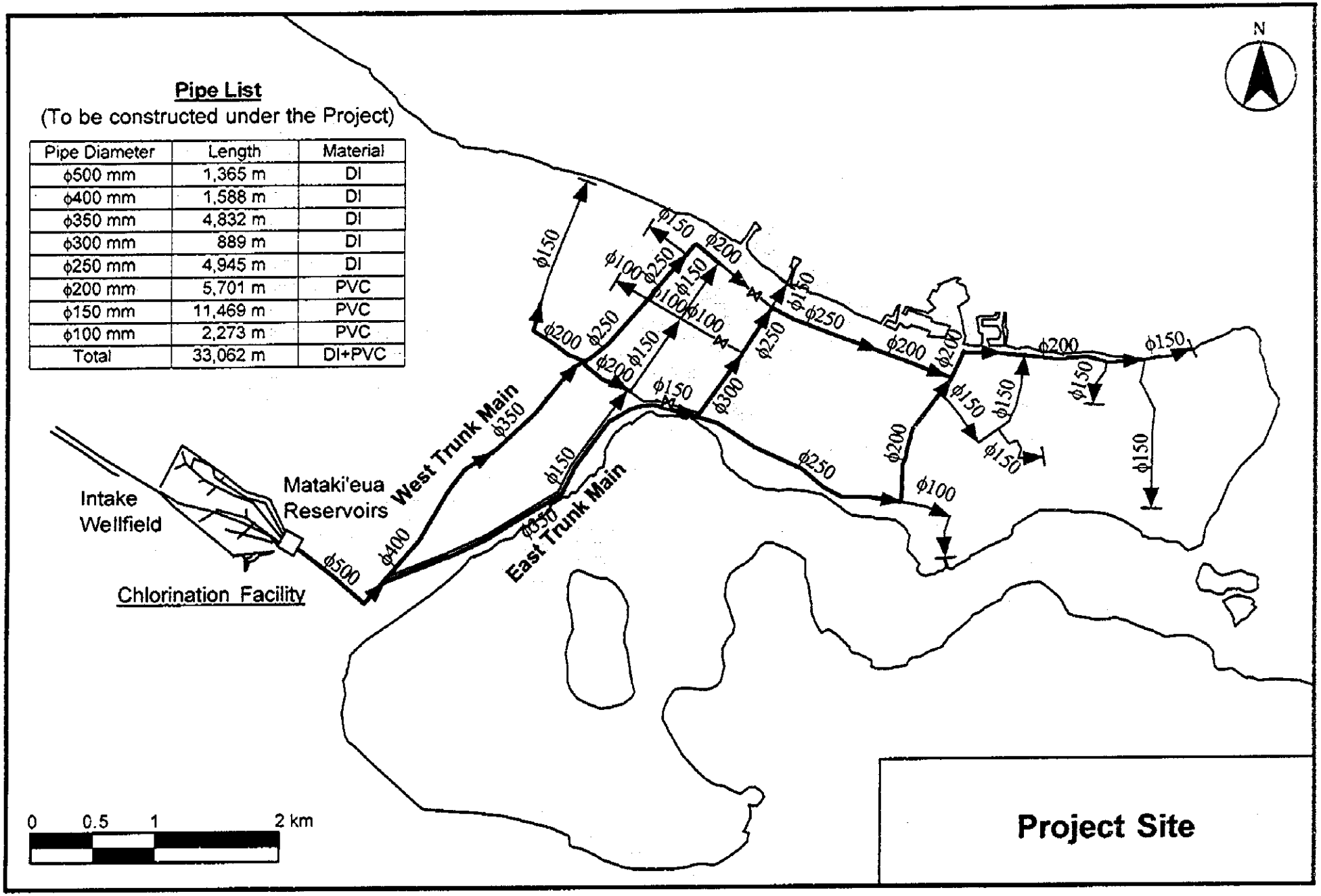
Pipe List
(To be constructed under the Project)
Pipe Diameter | Length | Material
ϕ500 mm | 1,365 m | DI
ϕ400 mm | 1,588 m | DI
ϕ350 mm | 4,832 m | DI
ϕ300 mm | 889 m | DI
ϕ250 mm | 4,945 m | DI
ϕ200 mm | 5,701 m | PVC
ϕ150 mm | 11,469 m | PVC
ϕ100 mm | 2,273 m | PVC
Total | 33,062 m | DI+PVC
N
Intake
Wellfield
Chlorination Facility
Mataki'eua
Reservoirs
West Trunk Main
East Trunk Main
0 0.5 1 2 km
Project Site

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CHAPTER 2 CONTENTS OF THE PROJECT

CHAPTER 3 IMPLEMENTATION PLAN

ABBREVIATIONS

ACP	Asbestos Cement Pipe
AFW	Accounted for Water
DIP	Ductile Iron Pipe
PVC	Polyvinyl Chloride (Pipe)
TWB	Tonga Water Board
UFW	Unaccounted-for Water

EXCHANGE RATE

1 US$	= 115 Japanese Yen
1 T$	= 73.4694 Japanese Yen
1 AS$	= 77.1560 Japanese Yen

CHAPTER 1 BACKGROUND OF THE PROJECT

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The Kingdom of Tonga is a seagirt country in the South Pacific Ocean. The Kingdom consists of approx. 170 islands between latitudes 15° South to 23.5° South and longitudes 173° West to 177° West. Total land area is approx. 700 km^2. The population is approx. 97,000 persons (1996 census). The study area is Nuku'alofa, the capital of the Kingdom. It is located in the Tongatapu, the largest island of the Kingdom that covers an area of approx. 258 km^2.

Water supply system of Nuku'alofa was launched in 1996. At present, about 95% of the population is served with water supply. However, shortage of water supply volume becomes serious in some parts of region, such as Popua district in the eastern edge and Sopu district in the western edge of the city. Water pressure is also low so that the residents are troubled with the situation that water doesn't flow from the tap in the morning and early evening. These people store the water during nighttime by installing the reservoir tank in the home. To supplement water, they also obtain water from the neighborhood. Insufficiency of water poses a big problem in their daily life.

Most residents install rain water reservoir tanks by themselves. Rain water is used not only for supplementing water shortage but also for drinking purpose, since people prefer it for its taste. However, there is a possibility that rain water is contaminated by dust and saprophyte, and that rain water might be scarce in drought season. Therefore, rain water use is not recommendable in terms of sanitation and stability of water volume.

As a waterworks, Tonga Water Board (TWB) has carried out the water supply of Tonga. Since, there is no river in this island, groundwater is the main source for water supply. TWB has increased the groundwater intake capacity with expansion of water supply volume. However, increase in groundwater intake capacity has possibility to cause salination of groundwater. Therefore, it is vitally important to conserve groundwater source in order to continue groundwater utilization as the water source.

Water supply facilities of Nuku'alofa have been deteriorated. Especially, amount of water leakage from the distribution pipelines has become considerable which is a main factor of water shortage to the consumers. TWB prepared a plan for leakage reduction so as to cover the water demand and to conserve groundwater. The plan was commenced in 1996, supported by Australian Government. However, its progress was delayed due to lack of finance and materials for implementation. Hence, the rate of unaccounted-for water (UFW) hasn't been reduced yet. And low water pressure at the edge of the service area is neither improved yet.

The delay in implementation of the plan has led further degradation of water supply. Therefore, radical improvement of the water supply system is urgently required.

Under the above circumstances, the Government of Tonga requested the grant aid for the improvement of Nuku'alofa water supply system to the Government of Japan. Japan International Cooperation Agency (JICA) conducted a preparatory study and confirmed the contents of the request and existing conditions of facilities. As a result, the concepts of basic design study were formulated as follows:

-1 Status of the Project
The Project is defined not as a project for improvement and rehabilitation of the water supply system but as a project for contributing to the aqueous environment system as well as improving water supply conditions of the capital city.

-2 Improvement of the water supply conditions
By solving unbalance of water pressure in the service area, water supply condition will be improved through increasing water supply volume to the low water pressure areas.

-3 Conservation of water resource
New groundwater development will be limited to the necessity minimum, through analyzing both demand and supply volume.

-4 Transmission and distribution pipelines, and elevated tank
Water transmission and distribution method will be examined in order to ensure balanced water pressure and water consumption. Based on the hydraulic analysis, facility design will be carried out with consideration of cost and maintenance.

-5 Replacement of asbestos cement pipes (ACP)
Since, the existing deteriorated ACP is considered to be a main cause of water leakage, the study will be carried out assuming that all ACP will be replaced.

-6 Leakage control and improvement of polyvinyl chloride pipelines (PVC)
Leakage control and improvement of PVC should be conducted by TWB. Therefore, they are not included in the scope of the Japan's grant aid scheme.

-7 Improvement and sustainability of the financial status
Financial forecast will be prepared by TWB as a status after the Project. Sustainability of the waterworks management will be confirmed.

Based upon the above concepts, the Basic Design Study was conducted, and this report was prepared.

CHAPTER 2 CONTENTS OF THE PROJECT

CHAPTER 2 CONTENTS OF THE PROJECT

2-1 Objectives of the Project

The objective of the Project is to supply sufficient and safe water to Nuku'alofa citizens by means of improving distribution conditions. The Project will also aim to conserve groundwater from environmental aspect.

To this end, the following items will be executed by the Project.

- Replacement of the existing deteriorated asbestos cement pipes (ACP)
- Enlargement of pipe's diameters.
- Division of the service area to two zones
- Renewal of disinfection system
- Provision of leakage survey equipment
- Provision of maintenance equipment for intake facilities

2-2 Basic Concept of the Project

With the result of the preliminary study carried out in 1998, the Project is defined as a project for conservation of the environment system as well as improvement of the water supply conditions of the city. The main contents of the Project are the following three items:

1) The new groundwater development will be held in necessity minimum.

2) Diameters of transmission/ distribution pipes and elevated tank system will be examined in order to improve low water pressure of the service area.

3) All the asbestos cement pipes are to be replaced for leakage reduction.

Based on the contents, the field study has been carried out in the basic design. And the basic concepts have been formulated as follows:

(1) The target year of the Project is defined as the year 2003.

(2) Since salination of groundwater must be prevented that is a peculiar problem of island countries, groundwater conservation is essential from environmental aspects. Therefore, groundwater development plan should be implemented with prudent examination. Water demand by 2003 is to be covered by the effective

utilization of the production water from the existing facility. Therefore, groundwater source will not be newly developed.

(3) Reduction of leakage ratio of the pipelines is proposed from the current 34.3% to 15% by the Project. For that purpose, replacement of the deteriorated existing ACP are planned. The total length of ACP is to be approx. 19 km.

(4) The minimum residual pressure will be 10m (target) at the peak hour so as to supply sufficient amount of water. Service areas are planned to be divided into 2 zones, the East Zone and the West Zone, in order to balance the water distribution capacities and supply pressure. A trunk main for the East Zone will be constructed to the entrance of the East Zone. Diameters for some pipes are to be enlarged according to the network analysis.

(5) The disinfection system is required to supply safe water continuously. Chlorine dosing equipment is employed for water disinfection.

(6) Although sufficient quantity of water can be obtained to cover the demand by reducing water leakage, 100% operation of intake pumps is required in the peak hours of demand. Therefore, stand-by pumps are necessary and number of the pumps is decided from the present mean rate of pump failure. For the purpose of achieving the 100% operation in the peak hours, stand-by pumps and equipment necessary for quick exchange of the malfunctioned pump are to be provided under the Project.

(7) Leakage control is essential for conservation of groundwater and financial soundness of Tonga Water Board (TWB). For these purposes, it is required to formulate a practical leakage control program and to provide leakage detection equipment. Equipment, which are locally unavailable but necessary for the TWB's plan, will be provided by the Japan's grant aid.

(8) As for other equipment requested by Tonga, such as construction equipment for the new expansion and vehicles for administration, they are procured by TWB, taking into account of TWB's management ability.

2-3 Basic Design

2-3-1 Design Concept

(1) Natural Conditions to be Considered

The water supply system of the Project would be designed from the viewpoint of energy saving on account of high electric power tariff of Tonga. The proposed gravity flow system will require neither elevated tanks nor booster pumps. High-elevated structures such as elevated tanks will not be constructed so as to minimize damages by cyclones or earthquakes.

For material of the distribution pipe along the coast, polyvinyl chloride (PVC) or plastic pipe will be employed to prevent corrosion by saline water intrusion.

(2) Local Contractors and Materials / Equipment

In the Tongan water supply sector, there is no local construction company to contract a large-scale work. Therefore, the Japanese contractor will employ skilled and unskilled workers directly from the local labor market.

Most construction materials such as sand, gravel, asphalt and cement are locally available. Mechanical, electrical devices and construction machineries are unavailable in Tonga so that they will be imported. Feasibility of procurement from the third countries such as New Zealand and Australia will be considered in viewpoint of readiness for spare parts and technical support as well as cost and time for transportation.

Lease of construction machineries is difficult in Tonga and other neighboring countries. Therefore, they are to be leased from Japan

2-3-2 Basic Design

(1) Water Demand

i) Domestic Use

The Project service area is to be the same as the present service area. The total population in the area is forecast as 31,738 in year 2003. The population served in the year 2003 will be 30,151, or a service ratio of 95%.

The unit water demand for domestic use is estimated at 140 l/c/d in 1998 and 180 l/c/d in 2011, according to the TWB Water Master Plan. On assumption that the unit

water demand increases in linear from 1998 to 2011, the demand in 2003 is calculated at 155 l/c/d. Accordingly, the total domestic water demand is to be 4,673 m³/d in 2003.

ii) Public Use

Water demand for public use in 2003 such as government offices, schools and hospitals is estimated at 337 m³/d, based on the present water demand of 326 m³/d and a population increase rate of 0.83 % a year.

iii) Public and Commercial Use

Water demand for industrial and commercial use in 2003 is estimated to be 539 m³/d, based on the present demand of 482 m³/d and increase rate of 2.5 %, which is referred to the past investment trend and the GDP growth ratio.

From the above calculations, the daily average water demand is to be 5,549 m³/d in 2003.

(2) Design Capacity

Based on the water demand forecast, design capacities for the facilities are defined as Table 2-1.

Table 2-1 Design Capacity

[A]	Daily Average Demand	5,549 m³/d	Total volume of water that is consumed by customers. [Domestic] + [Public] + [Commercial/Industry] = 4,673 m³/d+337 m³/d+539 m³/d
[B]	Daily Average Production	6,528 m³/d	Water volume delivered from the Mataki'eua Reservoirs. [A] + [Physical loss in distribution pipelines] = 5,549 m³/d / (1 - 0.85) (Leakage ratio of 15% is shown in Table 2-2)
[C]	Daily Maximum Production	8,160 m³/d	The peak daily distribution volume supplied on a peak-demand day throughout the year. This capacity will be used for designing intake facilities, treatment facilities and supply reservoirs. [B] x [Daily maximum factor: 125%] = 6,528 m³/d x 1.25 = 94.4 l/sec (Daily maximum factor of 125% is a design standard of Tonga)
[D]	Peak Hourly Flow	170 l/sec	The maximum hourly flow which will be occurred in the peak demand hour in the day of the Daily Maximum Production. This parameter determines sizing diameters of distribution pipelines. [C] x [Peak hourly factor: 180%] = 94.4 l/sec x 1.80 (Peak hourly factor of 180% is estimated based on the past record of Nuku'alofa. The peak demand hour is supposed to be around 7 a.m)

Table 2-2 Leakage Ratio

Existing Pipelines		Proposed Pipelines	
Pipe material	Leakage	Pipe material	Leakage
ACP	39.7 %	Replaced with DIP and PVC	10 %
PVC	26.3 %	PVC (Leakage control by TWB)	20 %
Total	34.3 %	Total	(14 % -->) 15 %

(Note)
The target leakage ratio in total is set as 15%, although the leakage ratio of the whole pipe line becomes about 14% as a result of calculation, taking into account of water volume borne by PVC and DIP (ductile iron pipe).

(3) Facility Design

1) Water Supply System

The water supply system under the Project is summarized in Fig. 2-1. Items to be provided/ constructed under the Project are marked with (*1, *2, *3, *4 and *5).

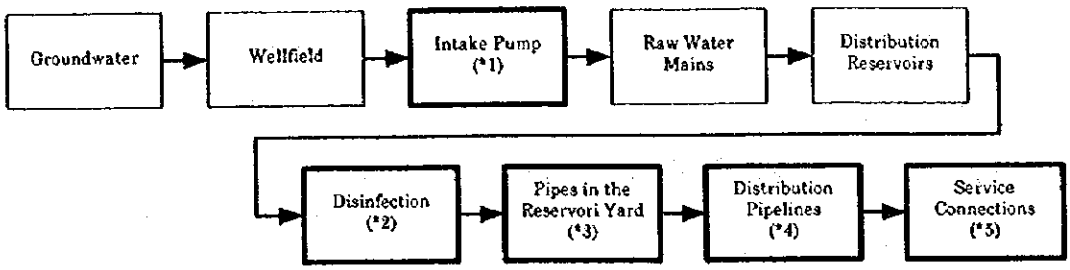


Fig. 2-1 Flowchart of the Proposed Water Supply System

Table 2-3 Items to be provided/constructed under the Project

(*1)	Intake pumps	Provision of 3 stand-by pumps with engine Provision of a truck with crane
(*2)	Disinfection	Replacement of chlorination equipment
(*3)	Pipes in the reservoir yard	Replacement of ACP and a main flow meter
(*4)	Distribution pipelines	Replacement of ACP with pipes of appropriate diameters/ materials
(*5)	Service connections	Restoration

2) Intake Facilities

Intake facilities will not be replaced nor extended in the Project on account of the followings, though the existing intake capacity will be slightly short of the calculated daily maximum production. Firstly, the intake facility is capable of supplying the daily average production throughout the year. Secondly, groundwater conservation is necessary from environmental viewpoint.

Water volume to be saved by reducing leakage ratio is estimated at Table 2-4.

Table 2-4 Water volume to be saved by reducing leakage ratio by the Project

		After Project	Without Project	Saved water volume
[A]	Leakage ratio	15 %	34.3 %	19.3 %
[B]	Daily average water demand = [Water demand of year 2003]	5,549 m^3/d	5,549 m^3/d	-
[C]	Daily average water production = [B] / (1 - [A])	6,528 m^3/d	8,446 m^3/d	1,918 m^3/d
[D]	Daily maximum water production = [C] x [Daily max. factor: 125%]	8,160 m^3/d	10,556 m^3/d	2,396 m^3/d

Taking into account that the discharging capacity of one pump is approx. 250 m^3/day, the water volume to be saved by the Project corresponds to approx. 8 units of intake pumps in daily average capacity and 10 units in daily maximum capacity, In short, construction of the intake facilities on the order of 8 to 10 could be saved by the Project.

Capacities of the intake facilities and operation ratio are tabulated in Table 2-5. Average operation ratio of the facilities is 85% throughout the year.

Table 2-5 Operation Ratio and Intake Capacities

Operation ratio	100%	95%	90%	85%	80%
Number of pumps in operation	31 nos.	30 nos.	28 nos.	27 nos.	25 nos.
Intake capacity	7,765 m^3/d	7,378 m^3/d	6,990 m^3/d	6,601 m^3/d	6,213 m^3/d

3) Reservoirs

As for distribution reservoirs, all the six existing Mataki'eua reservoirs are proposed to be used without extension work, based on the technical assessment. The reservoirs have a total capacity of 3,515 m^3 including 200 m^3 of fire-fighting water, or 9.75 hours equivalent of the daily maximum water production of 8,160 m^3/d.

4) Distribution Pipelines

i) Comparison on distribution system

Regarding the distribution system, two alternatives have been studied. They are,

Case 1: Construction of an elevated tank and a transmission pipeline to the tank
Case 2: Construction of a direct distribution trunk main of a larger diameter, without elevated tank

Considering advantages/ disadvantages of several factors shown in Table 2-6 of the both alternatives, the Case 2 is recommended in this Project. Among the comparison factors, difference in construction cost is remarkable. Concerning maintenance cost, Case 2 become little more expensive for the larger diameter than the Case 1. As the transmission capacity in Case 1 is a constant for 24 hours, the diameter of the pipe is smaller so that the pipe cost would be smaller but pipe capacity be also smaller. In Case 2, the larger diameter is required to have a capacity of peak hour (180% of the daily average distribution). Therefore, the pipe cost of Case 2 become bigger but the pipe capacity can be bigger. As for future extension work, Case 2 is more advantageous, because the points of water inflow to the pipe network can be added with flexibility in Case 2, but the points would be limited to the elevated tank in Case 1 so that the extension work would be difficult.

Table 2-6 Comparison on Distribution System

Item	Case 1	Case 2
(1) Reliability of supply	Reliable	Reliable
(2) Against disasters	Care of both cyclone and earthquake	Care of earthquake
(3) Maintenance work	Water level control and tank cleaning	Not required
(4) Maintenance cost for pipes	Less expensive (smaller diameter)	More expensive (larger diameter)
(5) Main pipe capacity	Q = Daily maximum flow	Q x 180% flow
(6) Flexibility of extension work	Rather difficult	Flexible
(7) Land use	Tank occupies some land area	Land not required
(8) Construction cost (Tentative)	More expensive (T$ 4,381,700-)	Less expensive (T$ 3,245,200-)

(Note)
The construction cost for Case 1 is estimated on assumption that one elevated tank in the east zone and transmission pipeline from the Mataki'eua reservoir to the elevated tank is constructed.
The construction cost for Case 2 is estimated on assumption that a direct distribution trunk main is constructed from the Mataki'eua reservoir.

ii) Replacement of the existing asbestos cement pipes (ACP)

All the existing ACP are proposed to be replaced with DIP (diameter 250 mm or larger) or PVC (diameter 200 mm or smaller). As DIP will be newly constructed, the ISO standard or equivalent is to be employed for DIP. As for PVC, the AS standard is to be employed, which is the same as the existing PVC pipes.

The existing ACP is to be abandoned at the present position after construction of new pipes in consideration of the followings. Namely, environmental impact to the soil is unforeseeable by the left ACP. Costs for ACP removal and restore of the pavement would be higher, compared to the case of leaving ACP buried. And furthermore, harmful pollution caused by ACP disposal can be prevented by leaving ACP buried and period of water supply cutoff can be shorten.

iii) Enlargement of pipe diameters

Diameters of some pipelines are planned to be enlarged to larger diameters, based on the result of the hydraulic analysis for the distribution networks. In the case of the existing PVC pipelines, new supplemental pipes, if needed, with appropriate diameters will be installed in parallel with and adjacent to the existing ones, to which new ones will be connected through new valves at appropriate points.

iv) Restoration of the house connections

In the service area of ACP pipelines replaced, the existing house connections as well as connections to the fire hydrants are proposed to be restored where the connections are switched to the new pipelines. The restoration work would be borne by the Japanese Side.

v) Selection of pipeline route

As new distribution pipelines aim to supply water to the existing service areas, routes for the new pipelines are proposed to be on same routes as the existing pipelines. As for a new trunk main (350 mm DIP) exclusive for the East Zone, its route was decided with the minimum distance from the Mataki'eua Reservoirs to the East Zone on the existing road.

vi) Pipe embedding/ restoration of road pavement

The soil covering depth from road surface to the top of pipe is designed as 120 cm. Both DIP and PVC pipes will be lapped with sand for protection purpose after installation. The sand thickness will be 15 cm above from the top of the pipe and 10 cm below from the bottom of the pipe. Above the sand layer, the excavated soil will be back filled. "Warning tape", indicating existence of water supply pipeline below the

tape, will be installed approx. 30cm above the top of pipes to be constructed under the Project. In the case the existing road pavement be removed, it will be also restored by the Japanese side.

vii) Construction of 50mm dia. side pipe

The house connections are not directly connected to the DIP (250 mm or larger), for easiness of installing the connections and prevention of troublesome leakage at tapping bands on DIP. To this purpose, so-called "side-pipe" is proposed to be installed together and in parallel with the new DIP. House connections will be tapped from the side-pipe. The side-pipe will be 50 mm dia. PVC and connected to the DIP at appropriate points.

viii) Hydraulic calculation result

For the peak hours' supply of the year 2003, the hydraulic analysis of the distribution networks was carried out by use of the TWB's computer with the network analysis software of Cybernet with MapInfo. The conditions for the analysis are as below:

Hydraulic formula for pipelines	Hazen-Williams formula
Coefficient of velocity	DIP : C=120 PVC : C=140
Minimum residual pressure (Residual pressure in the peak hourly flow)	10 m
Fire-fighting water	Discharging water from fire hydrant is considered. (Two strategic points at 7:00 a.m. Fire-fighting water : 1.0m³/min for one place)

As a result of the hydraulic analysis (refer to Appendix 10), the pipeline networks which assure appropriate water supply was established. In the several areas, the targeted pressure of 10m is not satisfied at the peak hour of 7 a.m. These areas are, (a) high elevated and (b) located in the end of pipelines. Although the pressure drops to about 5m at the peak hour, it is considered to be acceptable on account of the followings. Firstly, the targeted pressure would be satisfied in the off-peak hours. Secondly, necessary water volume can be supplied without interruption. Finally, water pressure of 5m is considered to be useful in practical use. Furthermore, as gravity flow system is employed in the Project, larger pipe diameter is required in order to raise the pressure for the areas. However, it is not economical because of the higher construction cost required.

viii) Pipelines to be constructed by Japan

Among the pipelines finalized by the hydraulic analysis, the proposed pipelines to be recommended for the portion of the Government of Japan are summarized in the Table 2-7 and shown in Fig. 2-2.

Table 2-7 List of Pipelines to be Constructed by Japan

Diameter	Material	Length	Remarks
500 mm	DIP	1,365 m	
400 mm	DIP	1,588 m	
350 mm	DIP	4,832 m	
300 mm	DIP	889 m	
250 mm	DIP	4,945 m	Total of DIP = 13,619 m
200 mm	PVC	5,701 m	
150 mm	PVC	11,469 m	
100 mm	PVC	2,273 m	Total of PVC = 19,443 m
Grand Total (DIP+PVC) =		33,062 m	
Side-pipe (50 mm PVC) =		8,824 m(*)	Additional to DIP

(Note)
(*) Total length of the side pipe:
= (DIP total: 13,619 m) - (East Trunk Main: 3,675 m) - (Mataki'eua road: 1,120 m) = 8,824 m

ix) Pipelines to be constructed by TWB

The following pipelines (7 lines) are to be constructed by TWB which is shown in Fig. 2-3 and listed in Table 2-8.

Item	Reason for selection	Pipeline No.
(a)	New pipelines for current non-service areas	(3), (7)
(b)	Pipelines for locally terminated areas	(1), (5), (6)
(c)	Isolated pipelines from the pipelines of scope of Japan	(4)
(d)	Other reason (TWB has already scheduled to implement)	(2)

Table 2-8 List of TWB Portion

Diameter	Material	Length	Remarks
150 mm	PVC	215 m	1 route
100 mm	PVC	1,598 m	5 routes
75 mm	PVC	195 m	1 route
Total (PVC) =		2,008 m	7 routes

Pipe List

(To be constructed under the Project)

Pipe Diameter	Length	Material
ϕ500 mm	1,365 m	DI
ϕ400 mm	1,588 m	DI
ϕ350 mm	4,832 m	DI
ϕ300 mm	889 m	DI
ϕ250 mm	4,945 m	DI
ϕ200 mm	5,701 m	PVC
ϕ150 mm	11,469 m	PVC
ϕ100 mm	2,273 m	PVC
Total	33,062 m	DI+PVC

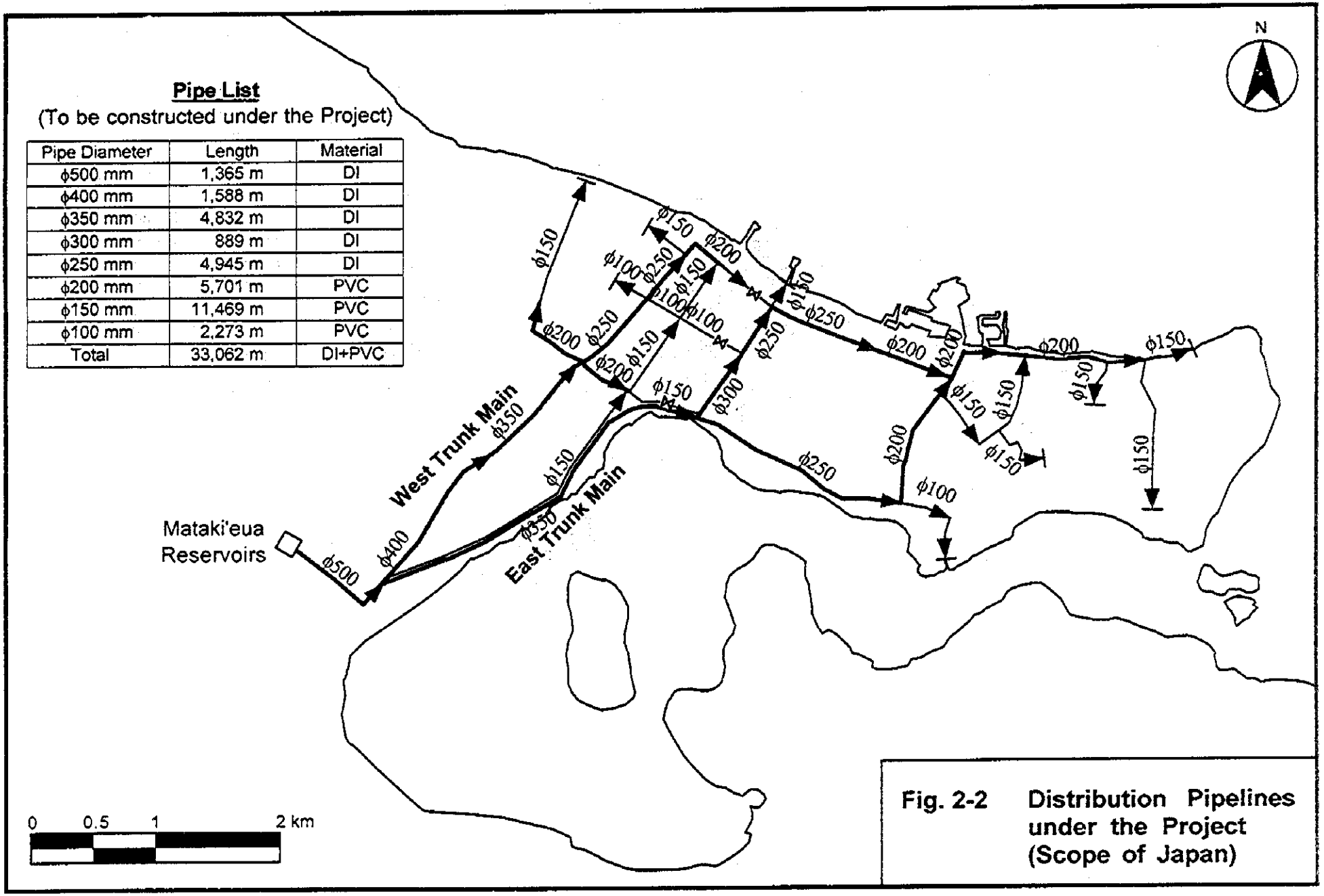
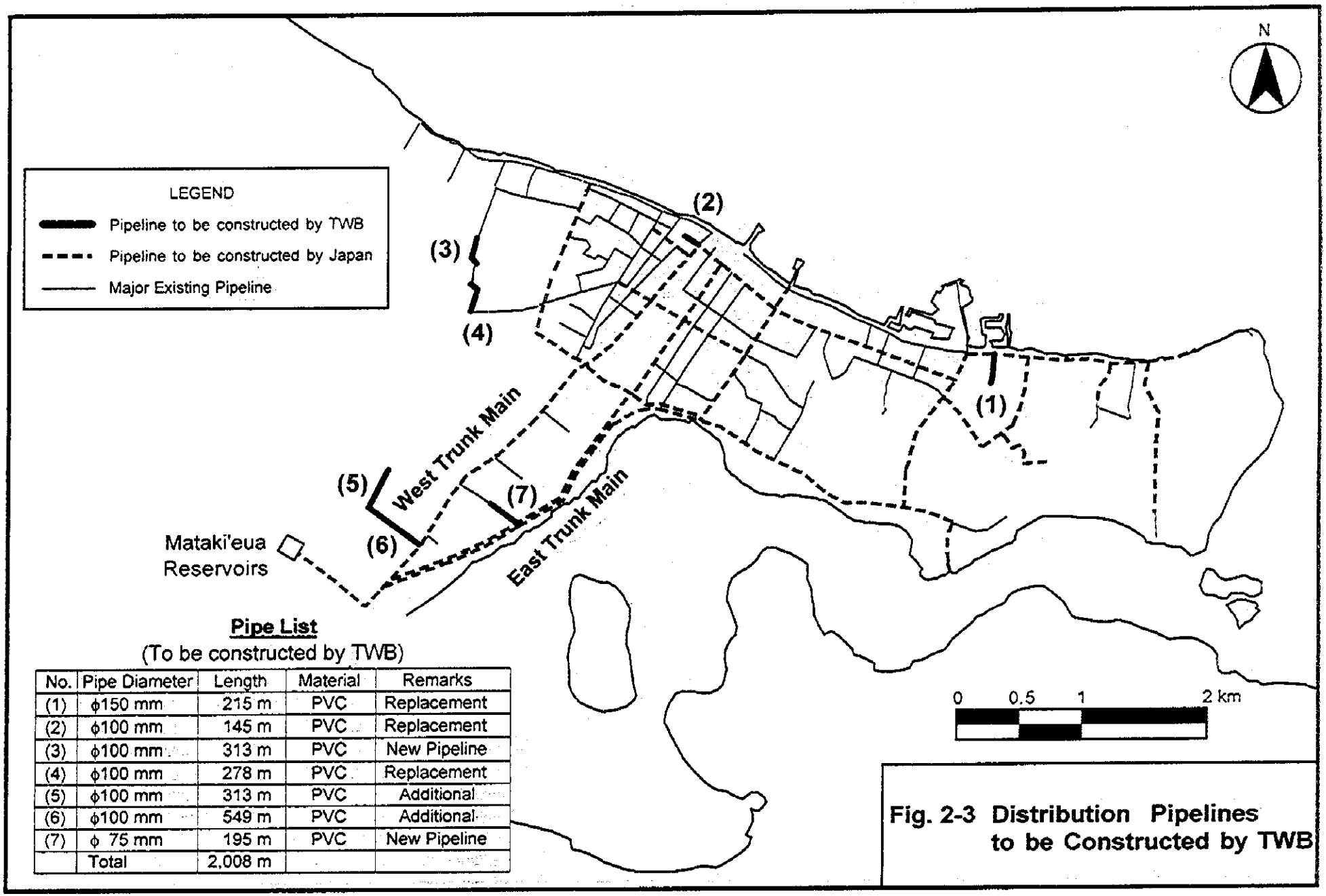


Fig. 2-2 Distribution Pipelines under the Project (Scope of Japan)



Pipe List

(To be constructed by TWB)

No.	Pipe Diameter	Length	Material	Remarks
(1)	ϕ150 mm	215 m	PVC	Replacement
(2)	ϕ100 mm	145 m	PVC	Replacement
(3)	ϕ100 mm	313 m	PVC	New Pipeline
(4)	ϕ100 mm	278 m	PVC	Replacement
(5)	ϕ100 mm	313 m	PVC	Additional
(6)	ϕ100 mm	549 m	PVC	Additional
(7)	ϕ 75 mm	195 m	PVC	New Pipeline
	Total	2,008 m		

Fig. 2-3 Distribution Pipelines to be Constructed by TWB

5) Mataki'eua Reservoir Yard

In the yard of the Mataki'eua Reservoirs, the following works will be carried out, they are, i) replacement of disinfection equipment and ii) replacement of pipes.

i) Replacement of Disinfection Equipment .

A. Chemical to be used

Granular calcium hypochlorite is selected as disinfectant, taking into account of the experience of TWB, easiness of mechanical handling, safety of chemical handling, construction cost, maintenance cost and etc. The following table summarizes the comparison between liquid chlorine and calcium hypochlorite (Refer to Appendix-13).

Table 2-9 Comparison on Chlorination Materials

	Liquid Chlorine	Calcium Hypochlorite
Properties	Confined in a container If unconfined, it rapidly vaporizes to gas that reacts with most elements and causes respiratory irritation	Granular powder Absorbent Readily soluble in water
Handling	Transportation shall be performed by the authorized personnel	Easy to handle by anyone with short instruction
Additional facility	Neutralizing equipment Thermostatic apparatus Personnel protective equipment	Any special apparatus is not required.
Structure (for storage)	Seismic design shall be considered Fire resistant building	Normal building structure
Special Care in Operation and Maintenance	To store away from other materials and facilities To perform daily test for leaks To prevent moisture To prepare spare parts for lead gasket, injector, etc.	To store in dry room (cooler) To store separate from other chemicals To use clean dry apparatus
Personnel	Special trained staff is necessary for the safe performance of the work.	Today's staff can manage
Availability	Possible (import)	Currently in use by import
Laws and Regulation	Not regulated in Tonga but strictly regulated in Japan	Not regulated
Capital Cost	T$45,000 (TWB report)	T$45,000 (TWB report)
Chemical Cost	T$7,723 per annum (4.63T$/kg)	T$12,085 per annum (4.71T$/kg)

B. Chlorine Dosing System

Calcium hypochlorite is to be manually put into the solution tank. The chlorine solution will be transferred to the storage tank by a chemical transfer pump and dosed into the distribution main pipe by way of a chemical dosing pump. In order to keep residual chlorine at an appropriate level constantly, step control is employed which enables to adjust the dosage to distribution flow fluctuation by changing number of the operating dosing pumps. Flowchart of the chlorination process is shown in Fig. 2-4.

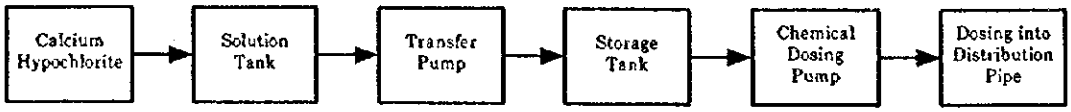


Fig. 2-4 Flowchart of the Chlorination Process

C. Chlorine Dosing Rate

Based on the chlorination dosing test result, dosing rates are to be 0.7 mg-Cl_2/liter on average and 1.5 mg-Cl_2/liter at maximum. The dosage is to be 0.246 liters/min*1), where chlorine solution would be of 5%-Cl_2.

The storage tank capacity would be approx. 335 liters*2), or two-days capacity equivalent, in consideration of release of chlorine during storage. Adjustment of pump dosing rate and points for step controll will be properly done by monitoring the residual chlorine at service taps in the service area during trial operation.

*1) [Hourly peak production:8.61 m^3/min] x [Maximum dosing rate: 1.5 mg-Cl_2/L] / [Effective chlorine: 5%] / [Specific gravity: 1.05]

*2) [Daily maximum production: 8,160 m^3/day] x [Average dosing rate: 0.7 mg-Cl_2/L] / [Effective chlorine: 5%] / [Specific gravity: 1.05] x 2 days

ii) Replacement of Pipes

Some sections of the existing ACP in the yard will be replaced with DIP of larger diameter than the existing ACP. Sizing of diameters is based on the hydraulic analysis result. In addition, the main flow meter will be replaced with new electro-magnetic flow meter which is able to present the instant flow rate as well as the accumulated flow. It will be utilized for chlorination dosing operation as well as water distribution management.

(4) Provision of Equipment

The component of equipment to be provided under the Project are summarized in Table 2-10. The equipment is for maintenance of the intake facilities and leakage control activities. As for spare parts, they are provided for two years operation, setting the period for overhaul of equipment as two years.

Table 2-10 List of Equipment to be Provided

Purpose	Name of Equipment	Q'ty	Necessity of Equipment
Leakage control	A) Ultra-sonic flow meter B) Correlation leakage detector C) Sound type leakage detector D) Box- locator	2 sets 1 set 1 set 1 set	TWB's leakage control program will be carried out by two teams. Leakage survey procedures: i) Location of pipeline ii) Measurement of leakage volume iii) Detection of leakage area iv) Location of leakage point
	Small backhoe	1 no.	For quick repair works To be used for distribution pipelines on public roads
	Trencher	1 set	For quick repair works To be used for service pipes in narrow space
	Pick-up truck (4 WD Dual cab)	1 car	Necessary for two leakage control teams in addition to the current shared one vehicle
	PVC pipe-cutter	2 sets	For quick repair work To be used not only for distribution pipes but also for house connection pipes
	Concrete cutter	2 sets	To minimize obstruction to traffic on public roads where leakage occurs
	Compaction Machine	1 set	For land finishing
	Spare parts	L.S.	For 2 years operation
O & M* for intake facility	Borehole pump with diesel engine	3 sets	For full capacity operation of 31 pumps by stocking stand-by pumps in preparation to pump troubles 3 sets, or 10% of all pumps, are required from the past record on pump troubles
	Small crane-truck	1 car	For improvement of pump replacement works so as to secure 31 pumps operation
	Spare parts	L.S.	For 2 years operation

* O&M: Operation and Maintenance

TWB has carried out a leakage control program, that is so-called "step-test", with assistance of the Australian Government (AusAID). However, its implementation was delayed due to lack of finance and equipment such as water flow meters and valves. So far TWB has conducted the test for one block only (as of July 1999). Although step test enables approximation of a leakage flow and separating a leakage area, it is difficult to detect a specific leakage point.

Leakage control equipment to be provided by the Project is proposed for the following purposes; (i) Measurement of leakage water volume, (ii) Locating leakage points and (iii) Quick activities for repair works for leakage pipes. Proposed implementation schedule of the leakage control program is summarized as Table 2-11 and its flowchart is shown as Fig. 2-5.

Table 2-11 Proposed implementation schedule for the TWB's leakage control program

Present to year 2001	Completion of step test (7 blocks)
From year 2001 to 2003	Leakage survey in each block and repair works
After year 2003	Successive implementation of step test, leakage survey and repair works

Priorities for repair will be given to the blocks in accordance with the survey results. Based on the given priorities, succeeding leakage survey in a block will be carried out by using the equipment provided under the Project. On-the-job training (OJT) of these equipment would be conducted by the manufacturer's/ supplier's supervisor before handing over to TWB.

To achieve the above implementation schedule, another leakage control team is necessary to form in addition to the present one.

After the Project, the step test will be carried out on eight zones. At present, the zone No. 8 isn't included in the above 7 blocks because it is in the center of the city so that it is technically difficult to

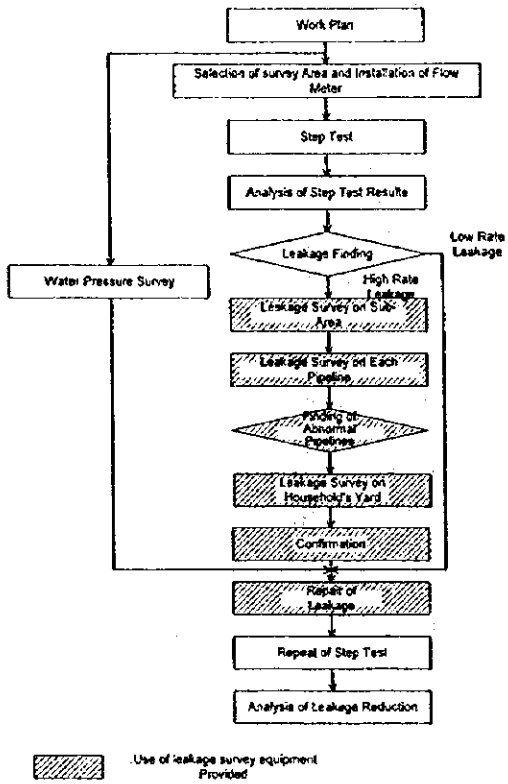


Fig. 2-5 Flowchart of leakage control

conduct the step test. By the Project, valves will be installed in all pipeline routes and portable ultrasonic flowmeter will be provided. Hence, problems of water supply cut off and traffic jam in the zone are unforeseeable in execution of the step test.

Since the present leakage control team doesn't use vehicle exclusively for their activities, one pickup truck is proposed to be provided. Work schedule of the vehicle for leakage control is given as Table 2-12.

Table 2-12 Work schedule of the vehicle for leakage control

	Work item	Day 1st	Day 2nd	Day 3rd	Day 4th	Day 5th
1	Site surveying of the area to be tested					
2	Identify the pipeline of a particular section					
3	Locate the leaking point					
4	Repair / replace the leaked pipes					

(Notes)

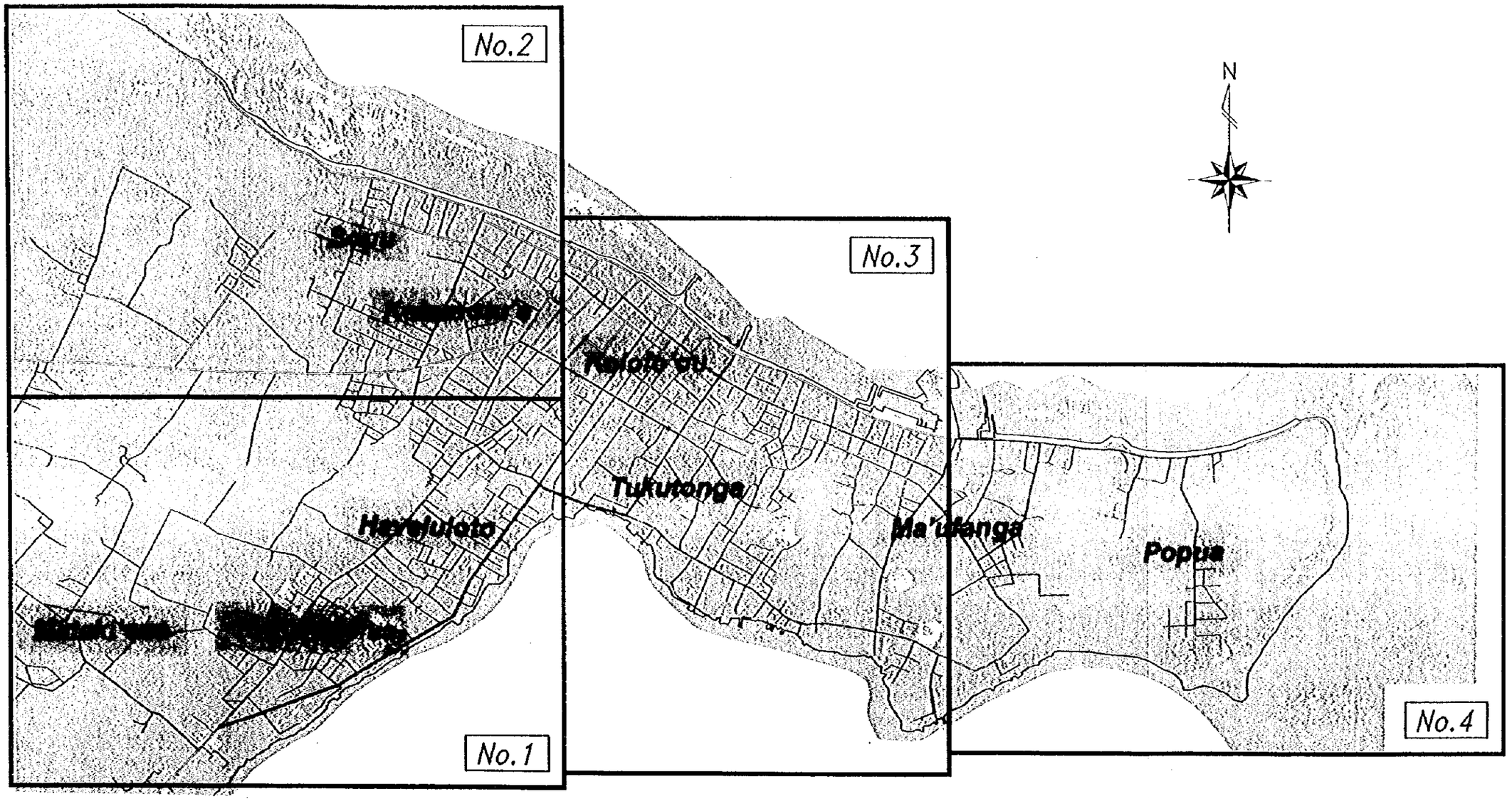
- The process of the table shows the representative process of leakage investigation and repair work. Car is used for transportation of leakage survey equipment and reparative equipment as well as of the leakage control team.
- Work item [3], locate the leaking point, includes the flow measurement work in the midnight so that vehicle is used from the first day afternoon to the third day morning.
- When no water leakage is detected as a result of the leakage survey, the process from work item [1] is repeated in order on next survey area.

(5) Basic Design Drawings

For the implementation of the project, basic design drawings were prepared and presented in the following pages.

List of Basic Design Drawings

Draw No.	Title of Drawing
No. 1	Proposed Distribution Pipelines : Key Plan
No. 2	Proposed Distribution Pipelines : No. 1
No. 3	Proposed Distribution Pipelines : No. 2
No. 4	Proposed Distribution Pipelines : No. 3
No. 5	Proposed Distribution Pipelines : No. 4
No. 6	Longitudinal Profile of Pipelines (1) : East-No. 1
No. 7	Longitudinal Profile of Pipelines (2) : East-No. 2
No. 8	Longitudinal Profile of Pipelines (3) : East-No. 3
No. 9	Longitudinal Profile of Pipelines (4) : West-No. 1
No. 10	Longitudinal Profile of Pipelines (5) : West-No. 2
No. 11	Trench Work Standard : PVC Pipelines
No. 12	Trench Work Standard : DIP Pipelines
No. 13	Trench Work Standard : DIP with Side-pipe
No. 14	Site Plan of Mataki'eua Reservoirs
No. 15	Chlorination Equipment : Process Flow Diagram
No. 16	Chlorination Equipment : Piping Arrangement Plan



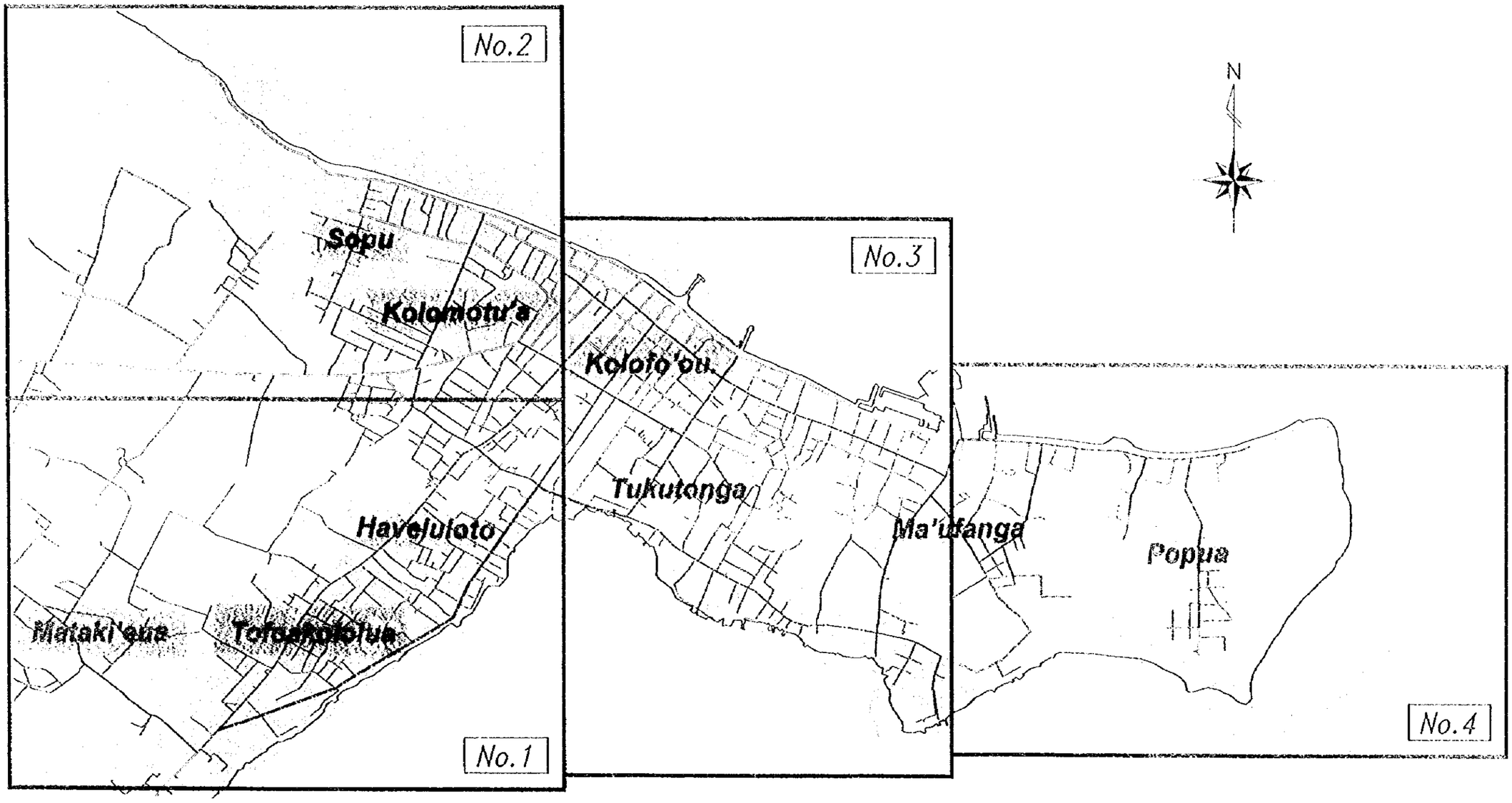
N

KEY PLAN

1:30,000

0m 100m 200m 300m 400m

TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Title: Proposed Distribution Pipelines Key Plan		
Date: Aug. 1999	Scale: 1:30000	Drow. No.: 1
JAPAN INTERNATIONAL COOPERATION AGENCY		



KEY PLAN

1:30,000

0m 100m 200m 300m 400m

TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Title: Proposed Distribution Pipelines Key Plan		
Date: Aug. 1999	Scale: 1:30000	Drew. No.: 1
JAPAN INTERNATIONAL COOPERATION AGENCY		

N

Mataki'eua Reservoirs

ø500 DIP L=1,365 m

ø400 DIP L=1,588 m

ø350 DIP L=1,157 m

ø200 PVC L=478 m

ø200 PVC L=510 m

ø150 PVC L=1,412 m

ø150 PVC L=1,586 m

ø150 PVC L=1,237 m

ø350 DIP L=3,675 m

1:10,000

0m 100m 200m 300m 400m

TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Title: Proposed Distribution Pipelines No.1		
Date: Aug. 1999	Scale: 1:10000	Draw. No.: 2
JAPAN INTERNATIONAL COOPERATION AGENCY		

TONGA WATER BOARD
THE KINGDOM OF TONGA

BASIC DESIGN STUDY ON THE PROJECT
FOR NUKU'ALOFA WATER SUPPLY

Title: Proposed Distribution Pipelines No.2

Date	Scale	Draw. No.
Aug. 1999	1:10000	3

JAPAN INTERNATIONAL COOPERATION AGENCY

1:10,000
0m 100m 200m 300m 400m

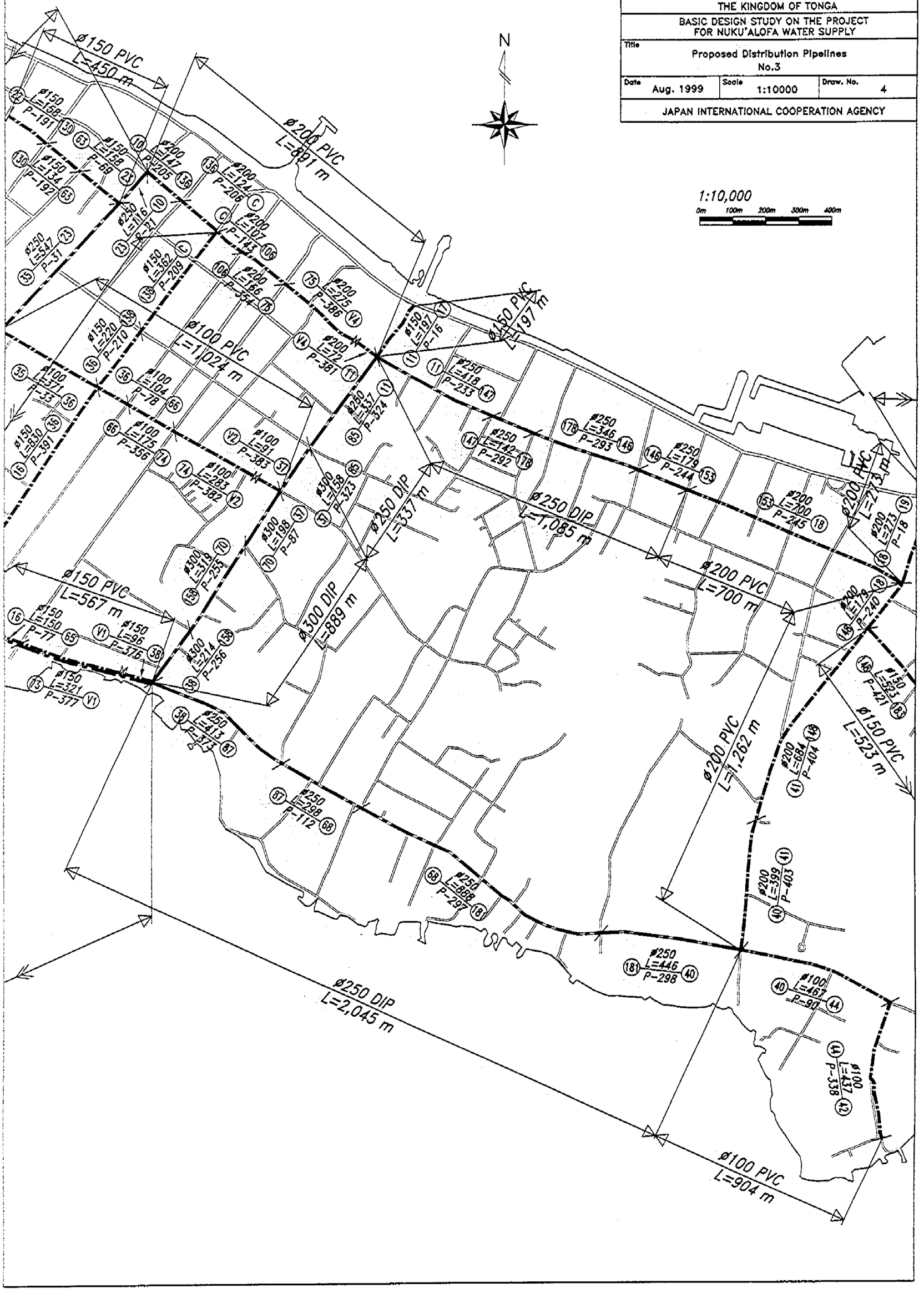
TONGA WATER BOARD
THE KINGDOM OF TONGA

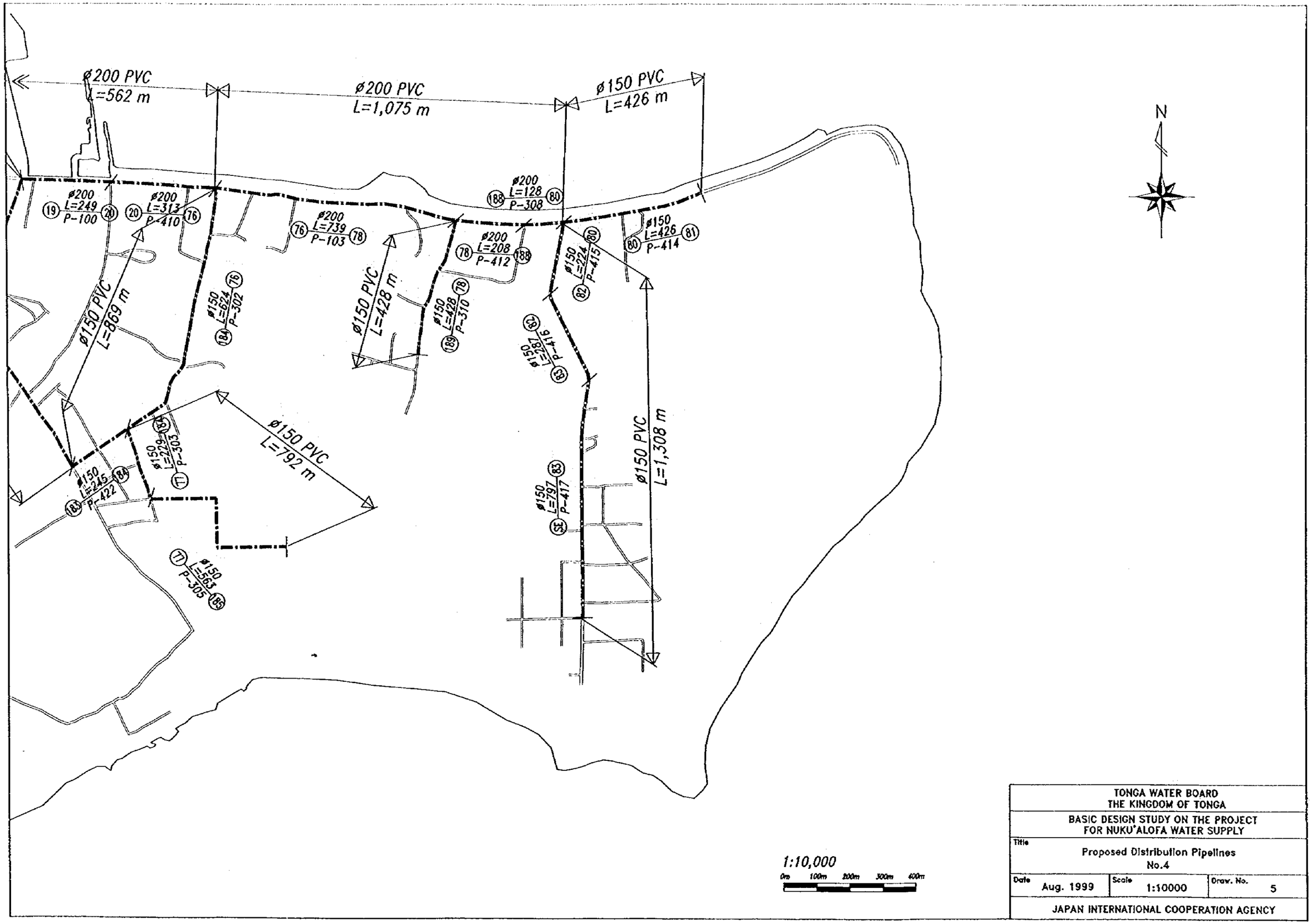
BASIC DESIGN STUDY ON THE PROJECT
FOR NUKU'ALOFA WATER SUPPLY

Title: Proposed Distribution Pipelines No.3

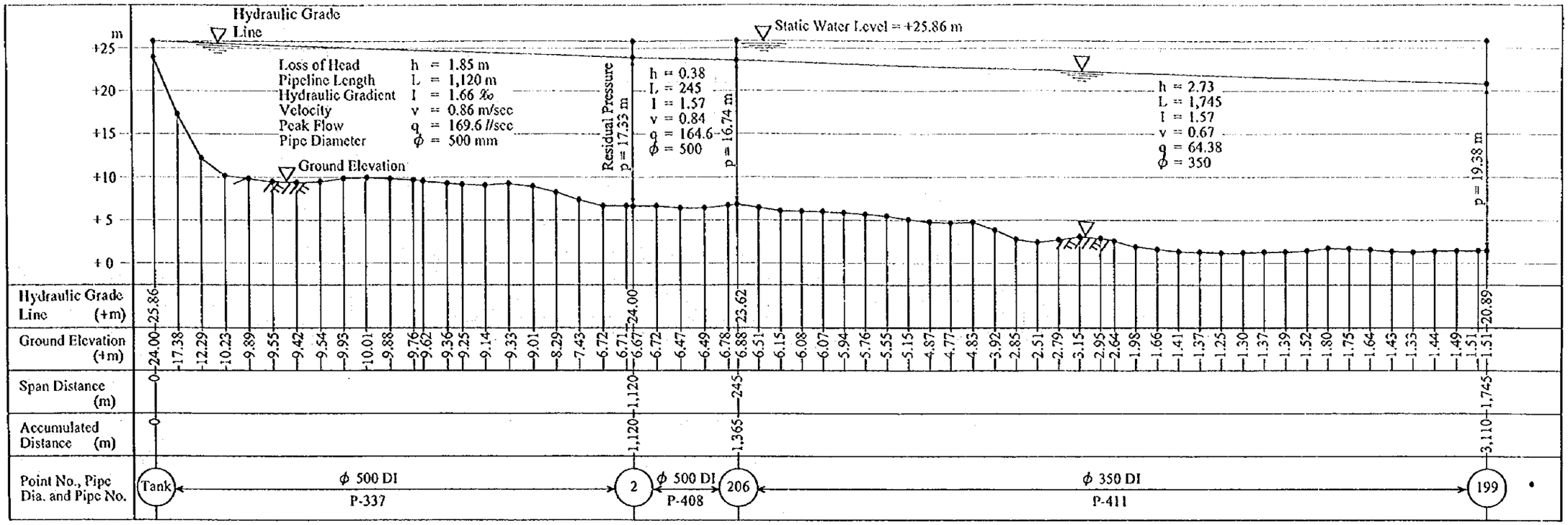
Date	Scale	Draw. No.
Aug. 1999	1:10000	4

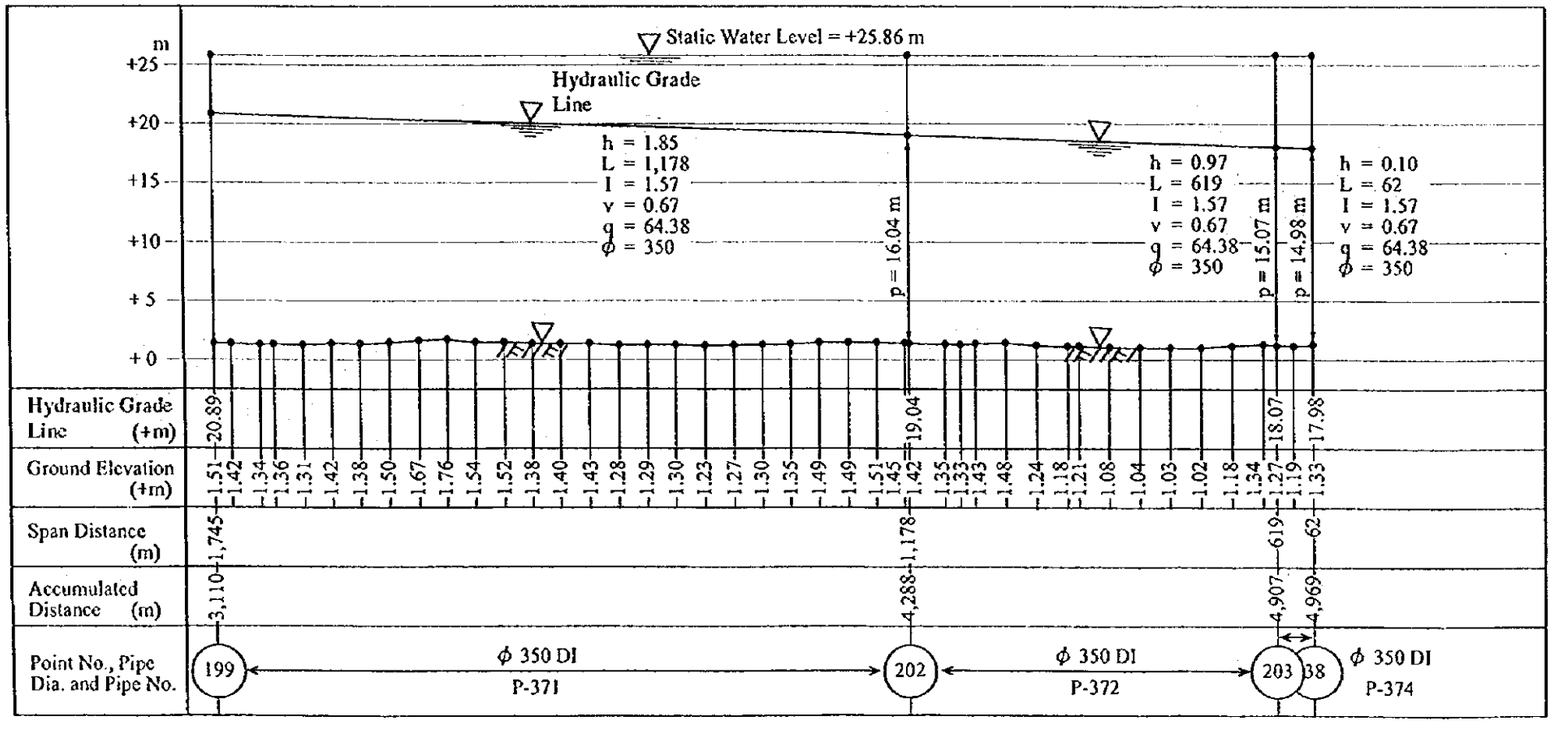
JAPAN INTERNATIONAL COOPERATION AGENCY

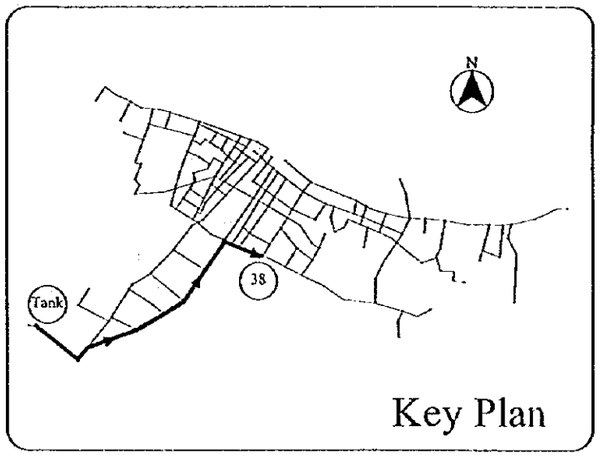




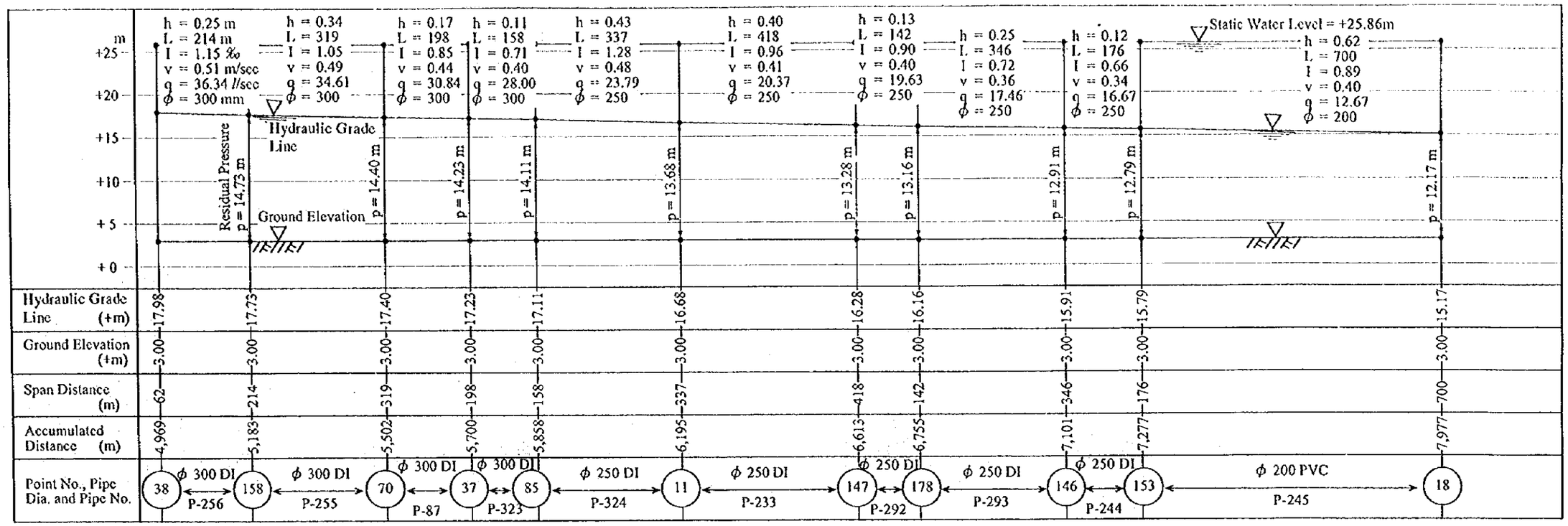
TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Title: Proposed Distribution Pipelines No.4		
Date: Aug. 1999	Scale: 1:10000	Draw. No.: 5
JAPAN INTERNATIONAL COOPERATION AGENCY		

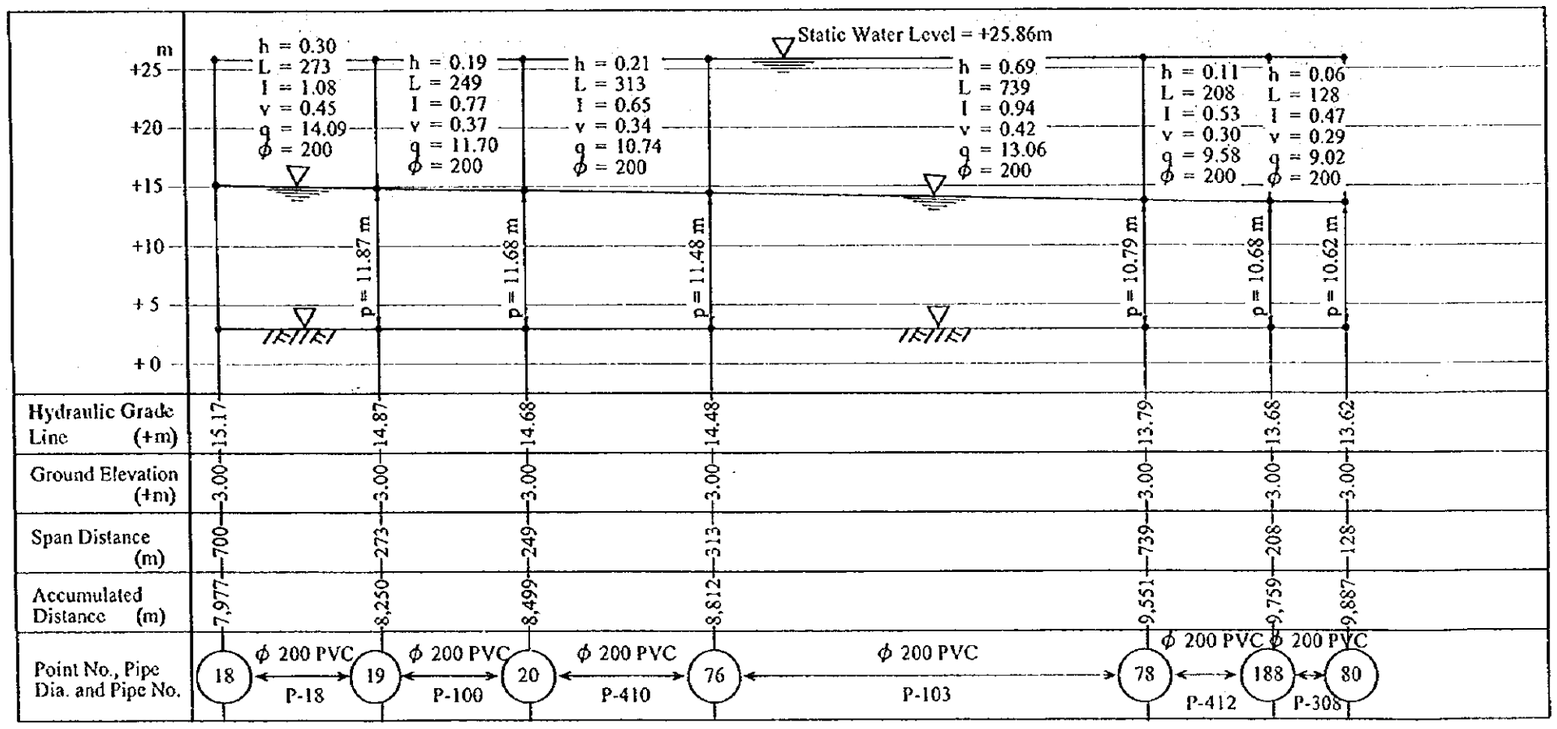


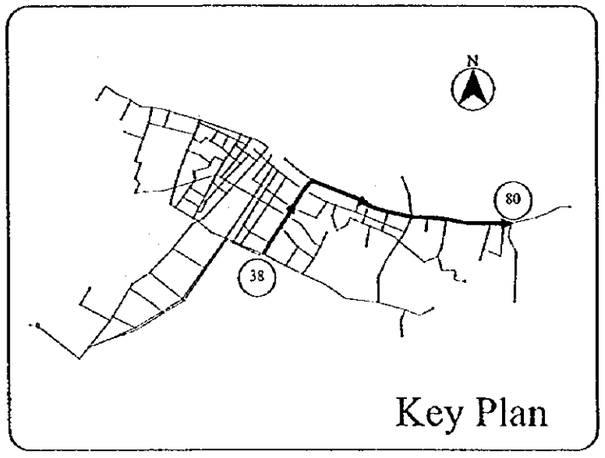




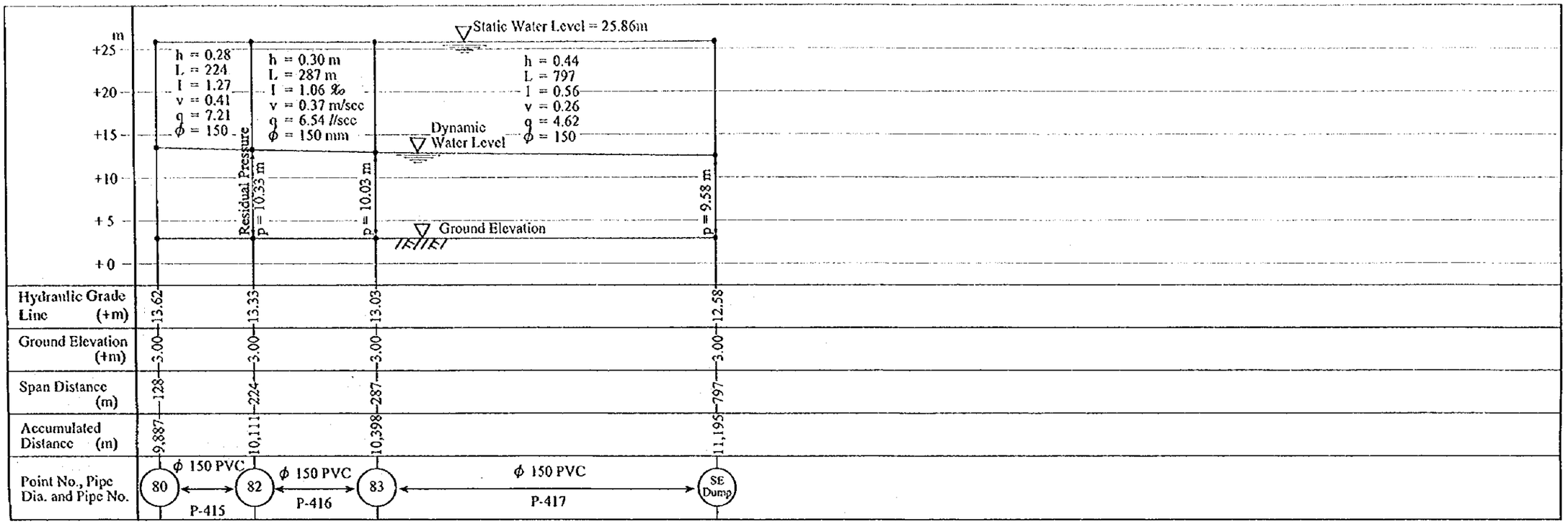
TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Longitudinal Profile of Pipelines (1) East - No. 1		
Aug.-1999	V=1/500, H=1/10,000	6
JAPAN INTERNATIONAL COOPERATION AGENCY		

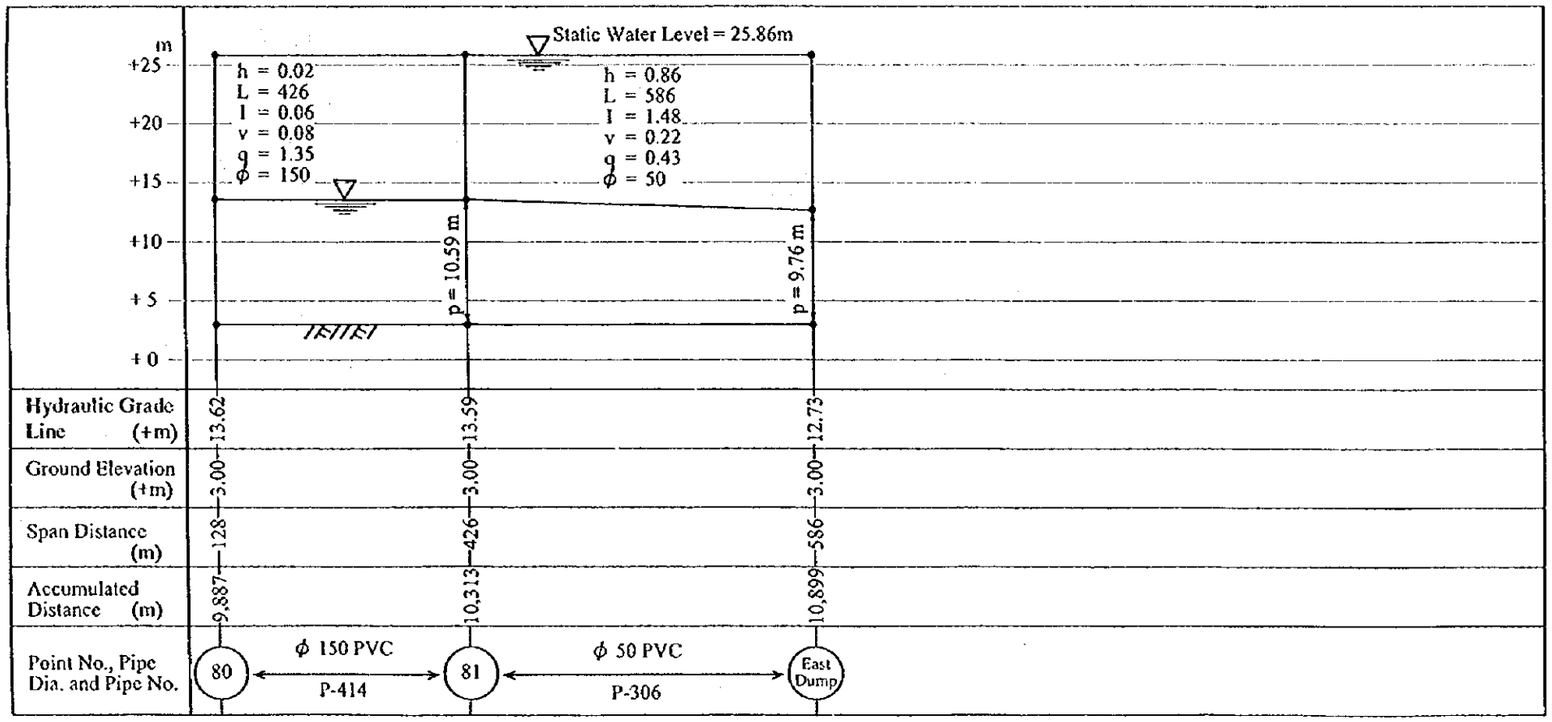


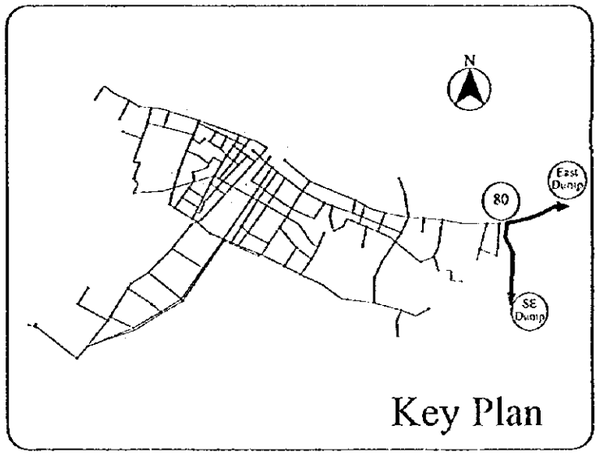




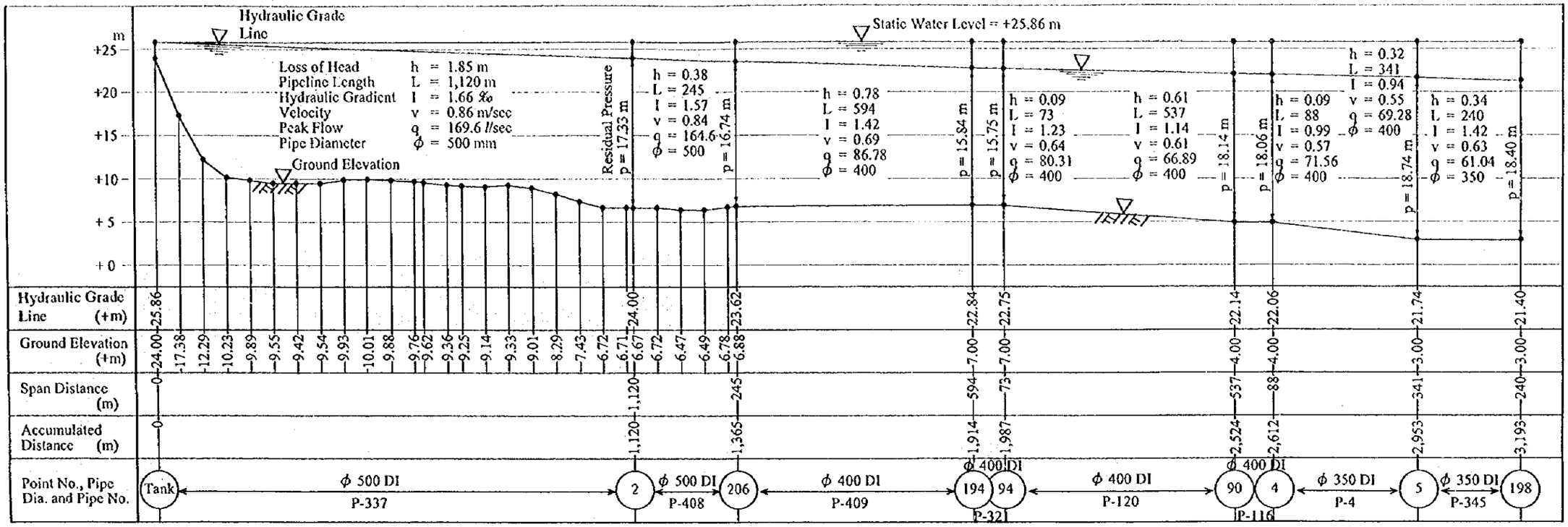
TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Longitudinal Profile of Pipelines (2) East - No. 2		
Aug -1999	V=1/500, H=1/10,000	7
JAPAN INTERNATIONAL COOPERATION AGENCY		

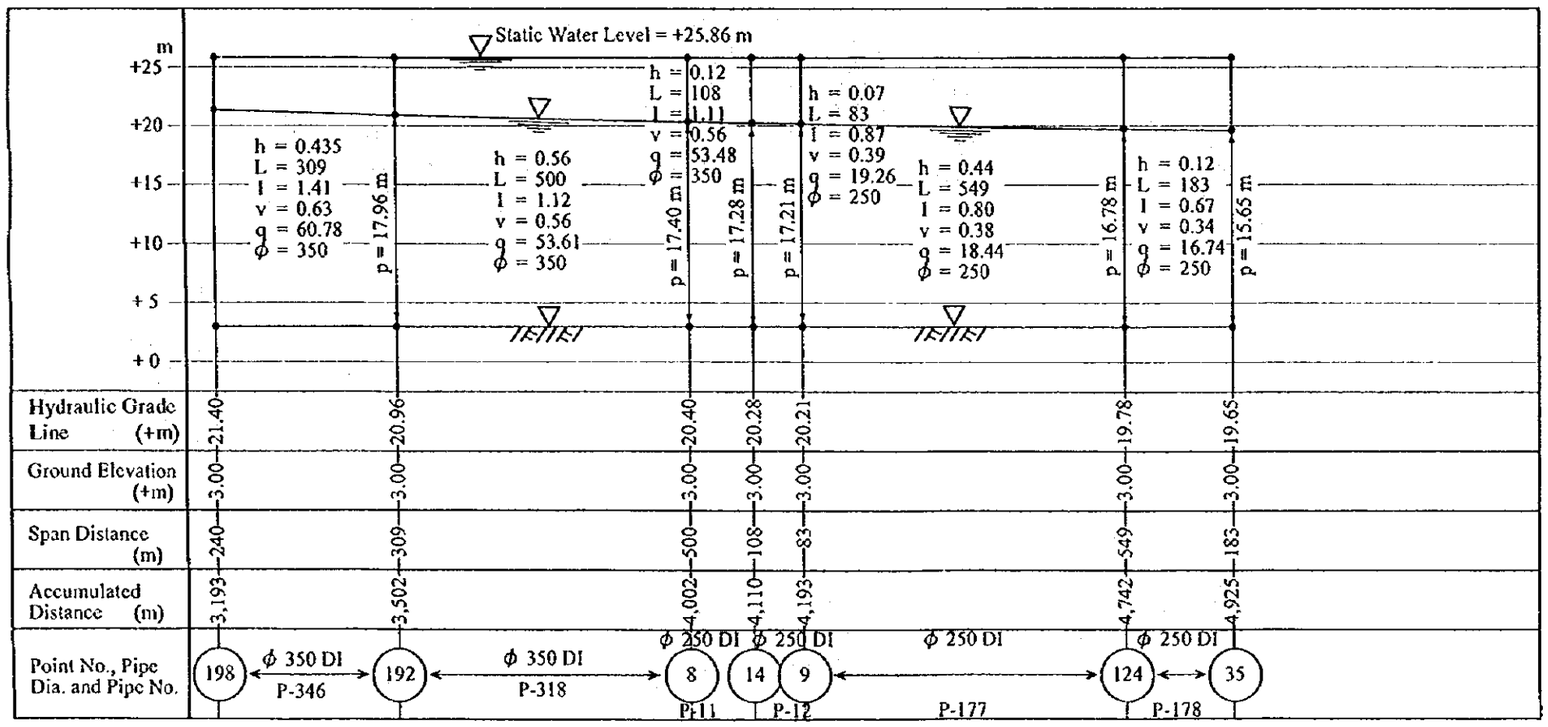


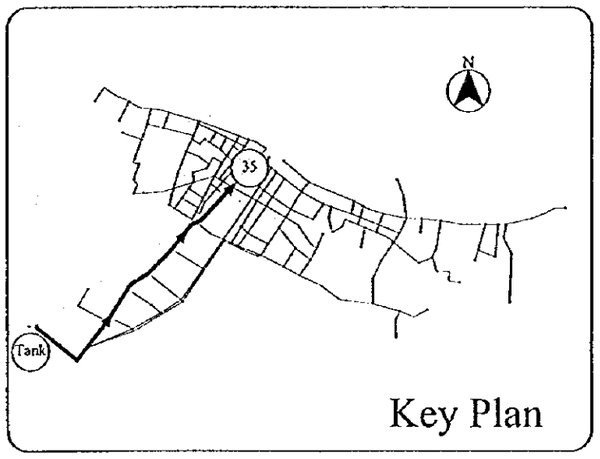




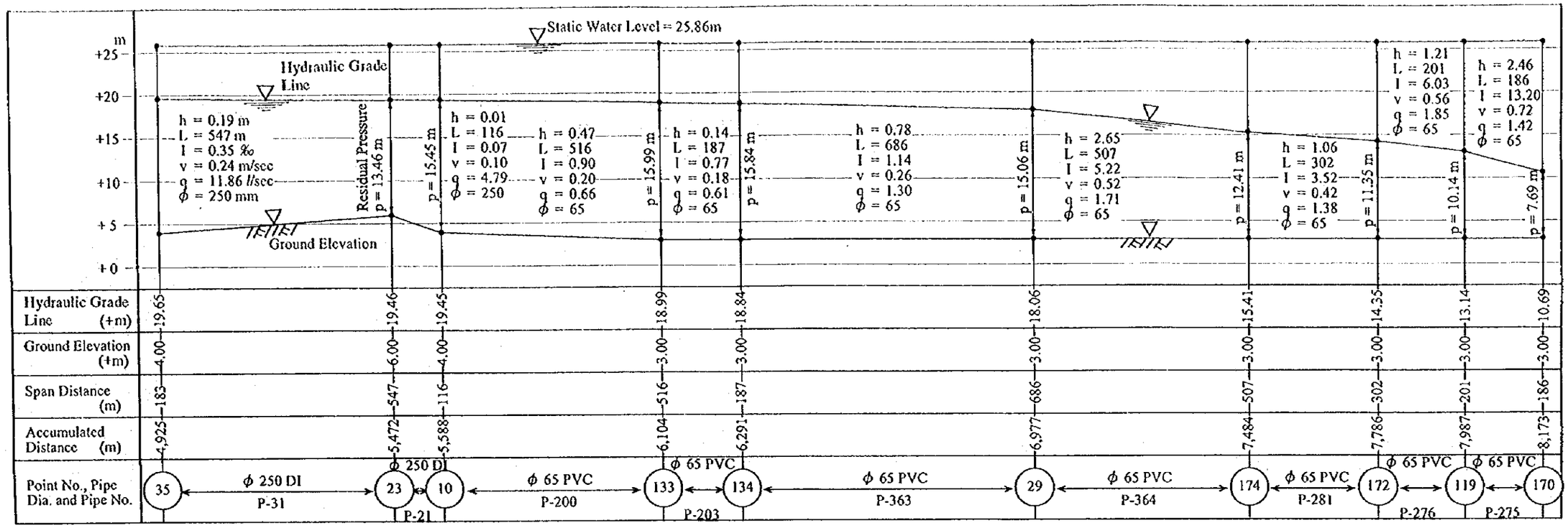
TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Longitudinal Profile of Pipelines (3) East - No. 3		
Aug.-1999	V=1/500, H=1/10,000	8
JAPAN INTERNATIONAL COOPERATION AGENCY		

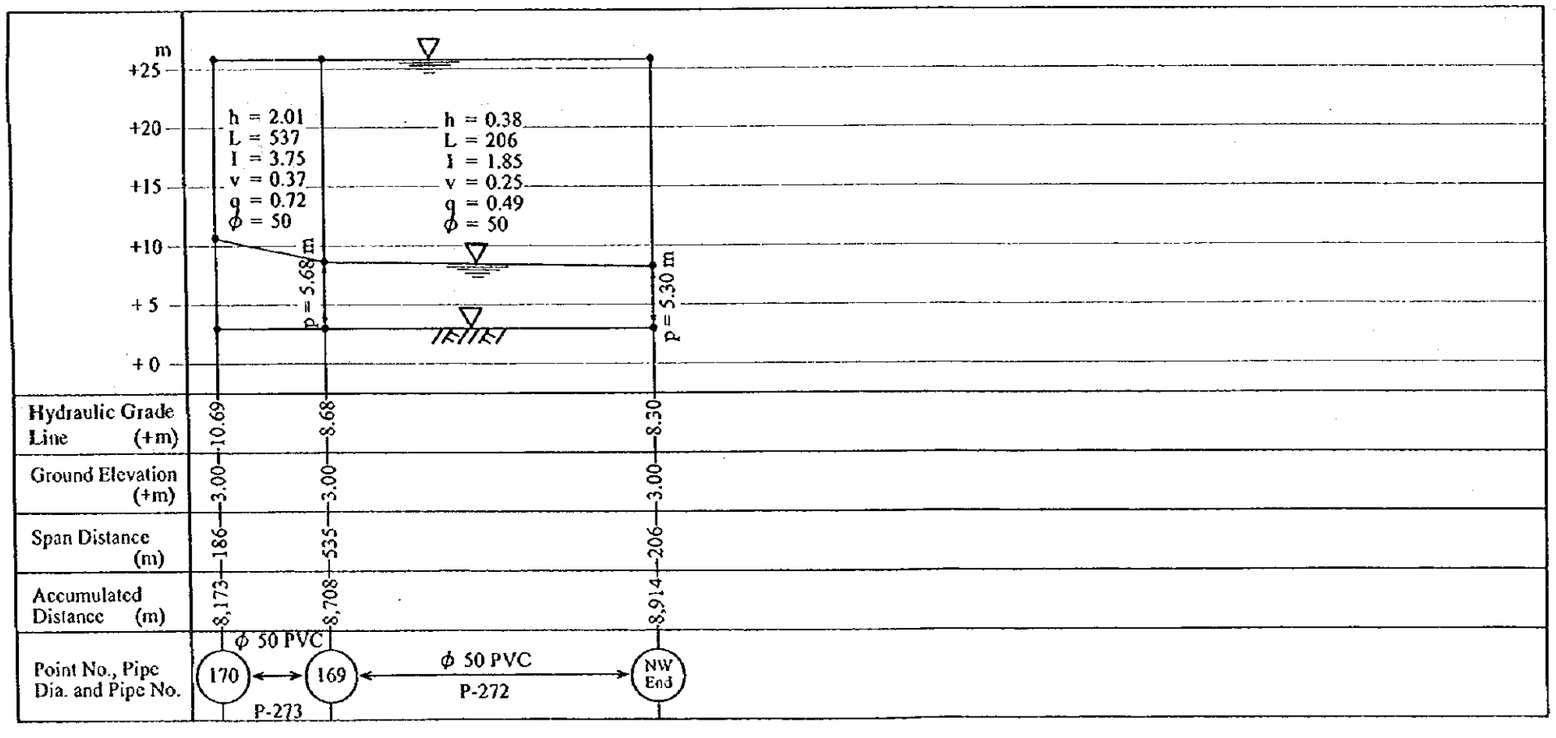


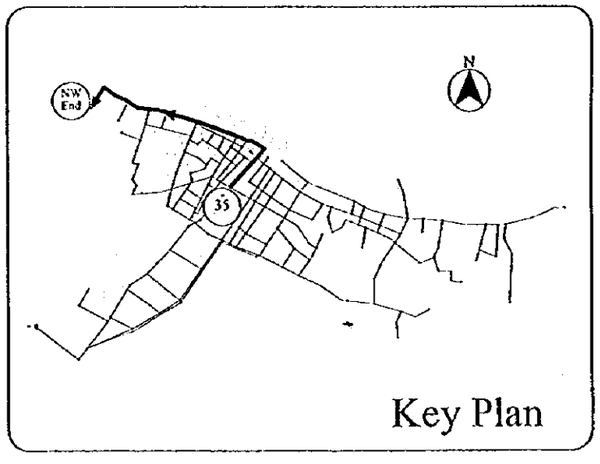




TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Longitudinal Profile of Pipelines (4) West - No. 1		
Aug.-1999	V=1/500, H=1/10,000	9
JAPAN INTERNATIONAL COOPERATION AGENCY		







TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Longitudinal Profile of Pipelines (5) West - No. 2		
Aug.-1999	V=1/500, H=1/10,000	10
JAPAN INTERNATIONAL COOPERATION AGENCY		

PVC Pipeline Trench Work Standard

(Unit : mm)

Dia. (ϕ)	200 mm	150 mm	100 mm	75 mm	50 mm
A	820	794	782	778	772
B	516	500	500	500	500
C	152	147	141	139	136
D	609	583	573	568	562
E	216	165	114	89	60
F	150	168	193	206	220
G	100	100	100	100	100
J	150	150	150	150	150
K	1,050	1,050	1,050	1,050	1,050
M	1,200	1,200	1,200	1,200	1,200
N	466	415	364	339	310
H	1,516	1,465	1,414	1,389	1,360

Work Item and Volume

(Unit : m3/m)

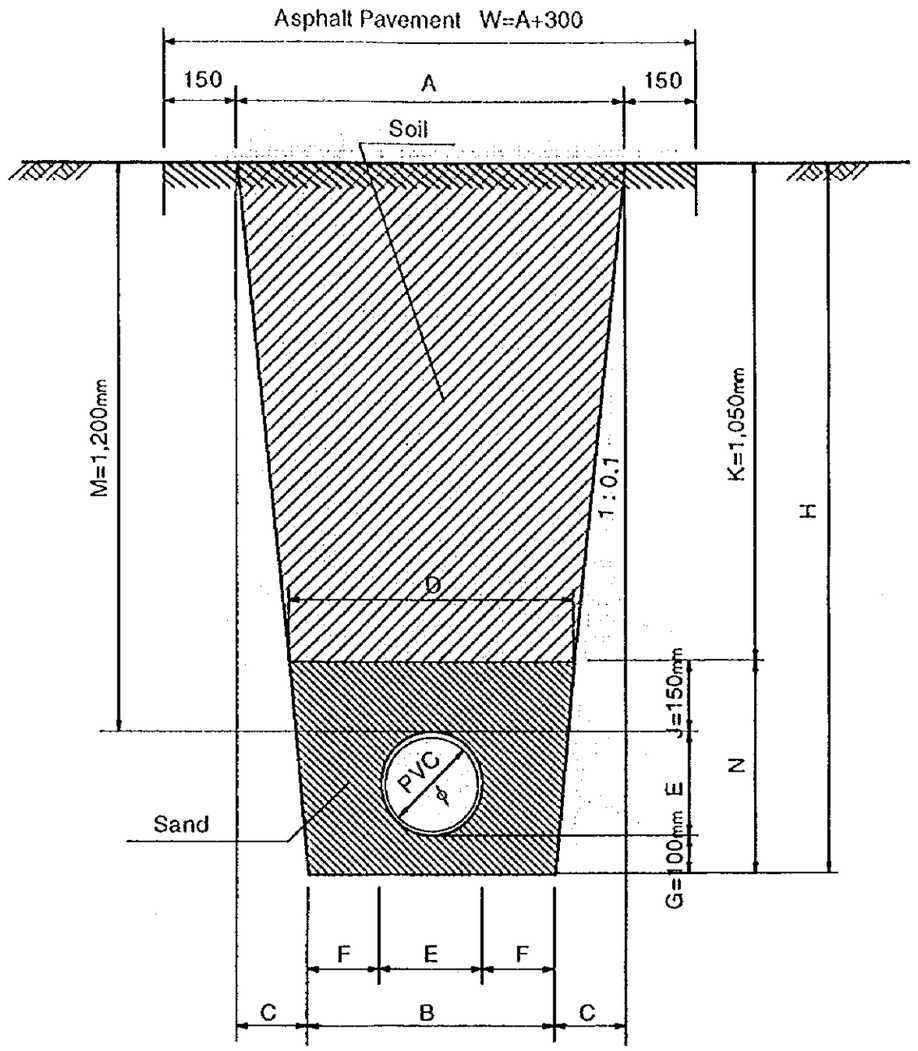
Diameter (ϕ)	200 mm	150 mm	100 mm	75 mm	50 mm
Excavation	1.013	0.948	0.906	0.888	0.865
Sand Backfill	0.225	0.204	0.185	0.175	0.162
Soil Backfill	0.750	0.723	0.711	0.707	0.700
Soil Disposal	0.262	0.225	0.195	0.181	0.165

Restoration Width of Asphalt Pavement

(Unit : mm)

Diameter (ϕ)	200 mm	150 mm	100 mm	75 mm	50 mm
Width (W)	1,120	1,094	1,082	1,078	1,072

Trench Standard
(PVC Pipeline)



TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU' ALOFA WATER SUPPLY		
Title: Trench Work Standard PVC Pipeline		
Date: Aug. 1999	Scale: None	Draw. No. 11
JAPAN INTERNATIONAL COOPERATION AGENCY		

DIP Pipeline Trench Work Standard

(Unit : mm)

Dia. (ϕ)	500 mm	450 mm	400 mm	350 mm	300 mm	250 mm
A	1,194	1,133	1,072	1,008	947	886
B	828	777	726	674	623	572
C	183	178	173	167	162	157
D	984	922	861	799	738	676
E	528	477	426	374	323	272
F	150	150	150	150	150	150
G	100	100	100	100	100	100
J	150	150	150	150	150	150
K	1,050	1,050	1,050	1,050	1,050	1,050
M	1,200	1,200	1,200	1,200	1,200	1,200
N	778	727	676	624	573	522
H	1,828	1,777	1,726	1,674	1,623	1,572

Work Item and Volume

(Unit : m3/m)

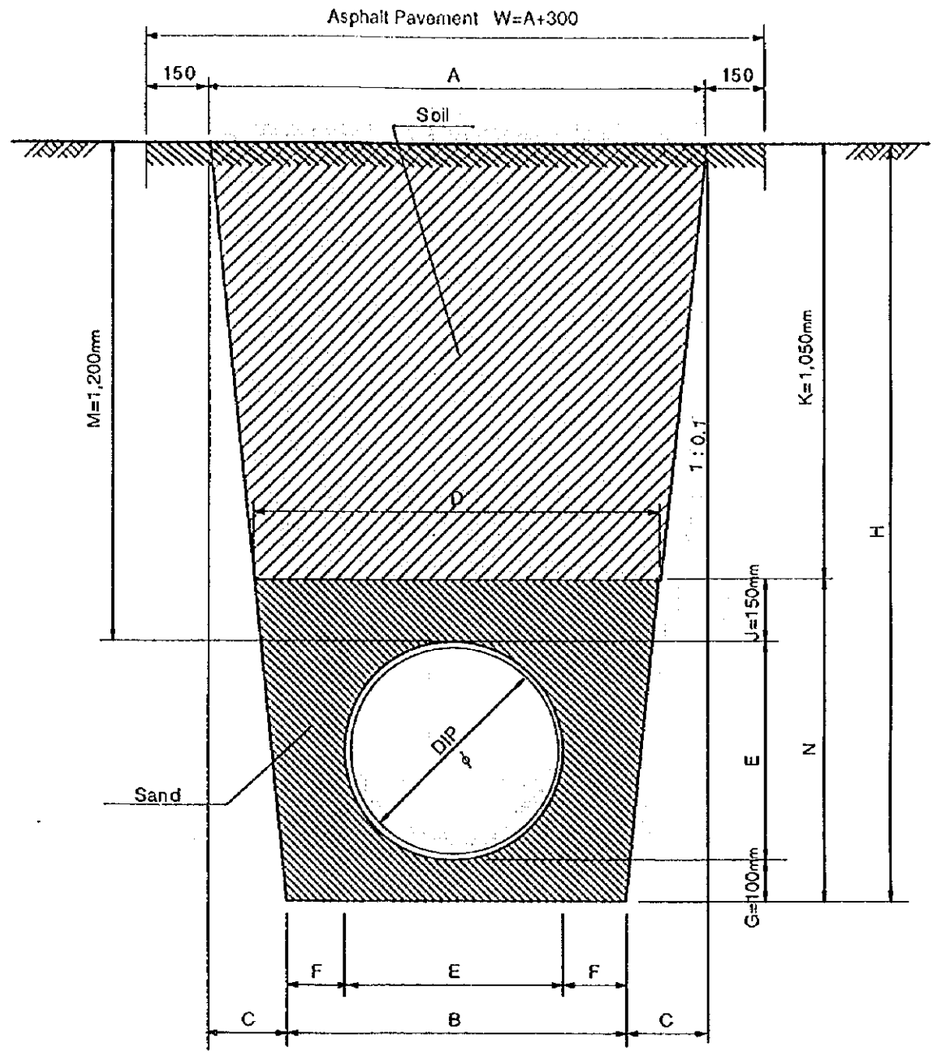
Diameter (ϕ)	500 mm	450 mm	400 mm	350 mm	300 mm	250 mm
Excavation	1.848	1.697	1.552	1.408	1.274	1.146
Sand Backfill	0.486	0.439	0.394	0.350	0.308	0.268
Soil Backfill	1.143	1.079	1.015	0.949	0.885	0.820
Soil Disposal	0.705	0.618	0.536	0.460	0.390	0.326

Restoration Width of Asphalt Pavement

(Unit : mm)

Diameter (ϕ)	500 mm	450 mm	400 mm	350 mm	300 mm	250 mm
Width (W)	1,494	1,433	1,372	1,308	1,247	1,186

Trench Standard
(DIP Pipeline)



TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Title: Trench Work Standard DIP Pipeline		
Date: Aug. 1999	Scale: None	Draw. No. 12
JAPAN INTERNATIONAL COOPERATION AGENCY		

DIP with Side-Pipe Trench Work Standard

(Unit : mm)

Dia. (ϕ)	500 mm	450 mm	400 mm	350 mm	300 mm	250 mm
A	1,194	1,133	1,072	1,008	947	886
A'	1,420	1,359	1,298	1,234	1,173	1,112
B	828	777	726	674	623	572
C	183	178	173	167	162	157
D	1,210	1,148	1,087	1,025	964	902
E	528	477	426	374	323	272
F	150	150	150	150	150	150
G	100	100	100	100	100	100
J	150	150	150	150	150	150
K	1,050	1,050	1,050	1,050	1,050	1,050
M	1,200	1,200	1,200	1,200	1,200	1,200
N	778	727	676	624	573	522
H	1,828	1,777	1,726	1,674	1,623	1,572

Work Item and Volume

(Unit : m3/m)

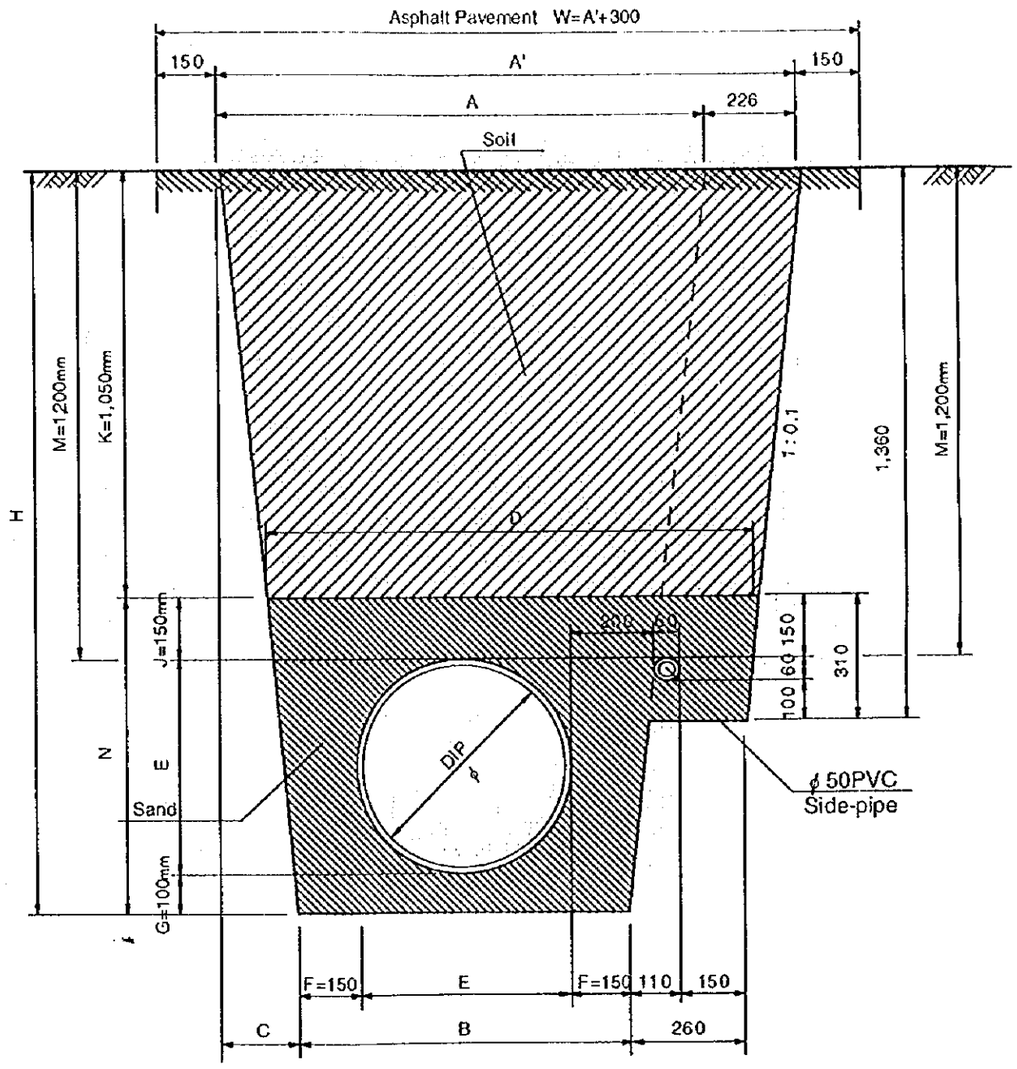
Diameter (ϕ)	500 mm	450 mm	400 mm	350 mm	300 mm	250 mm
Excavation	2.155	2.004	1.859	1.715	1.581	1.453
Sand Backfill	0.553	0.506	0.461	0.417	0.375	0.335
Soil Backfill	1.380	1.316	1.252	1.186	1.122	1.057
Soil Disposal	0.775	0.688	0.606	0.530	0.460	0.396

Restoration Width of Asphalt Pavement

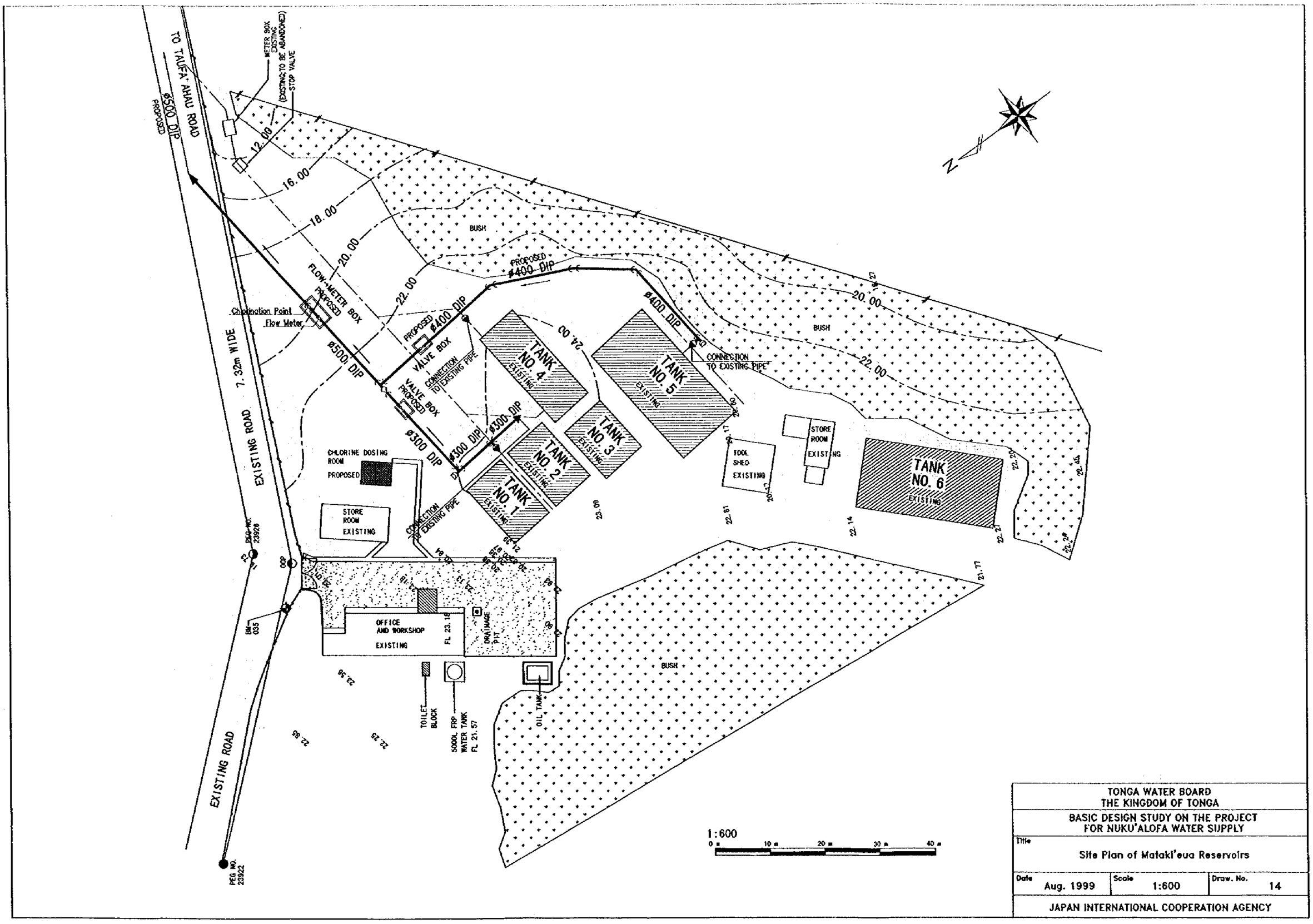
(Unit : mm)

Diameter (ϕ)	500 mm	450 mm	400 mm	350 mm	300 mm	250 mm
Width (W)	1,720	1,659	1,598	1,534	1,473	1,412

Trench Standard
(DIP with Side-pipe)



TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Title: Trench Work Standard DIP with Side-pipe		
Date: Aug. 1999	Scale: None	Draw. No. 13
JAPAN INTERNATIONAL COOPERATION AGENCY		

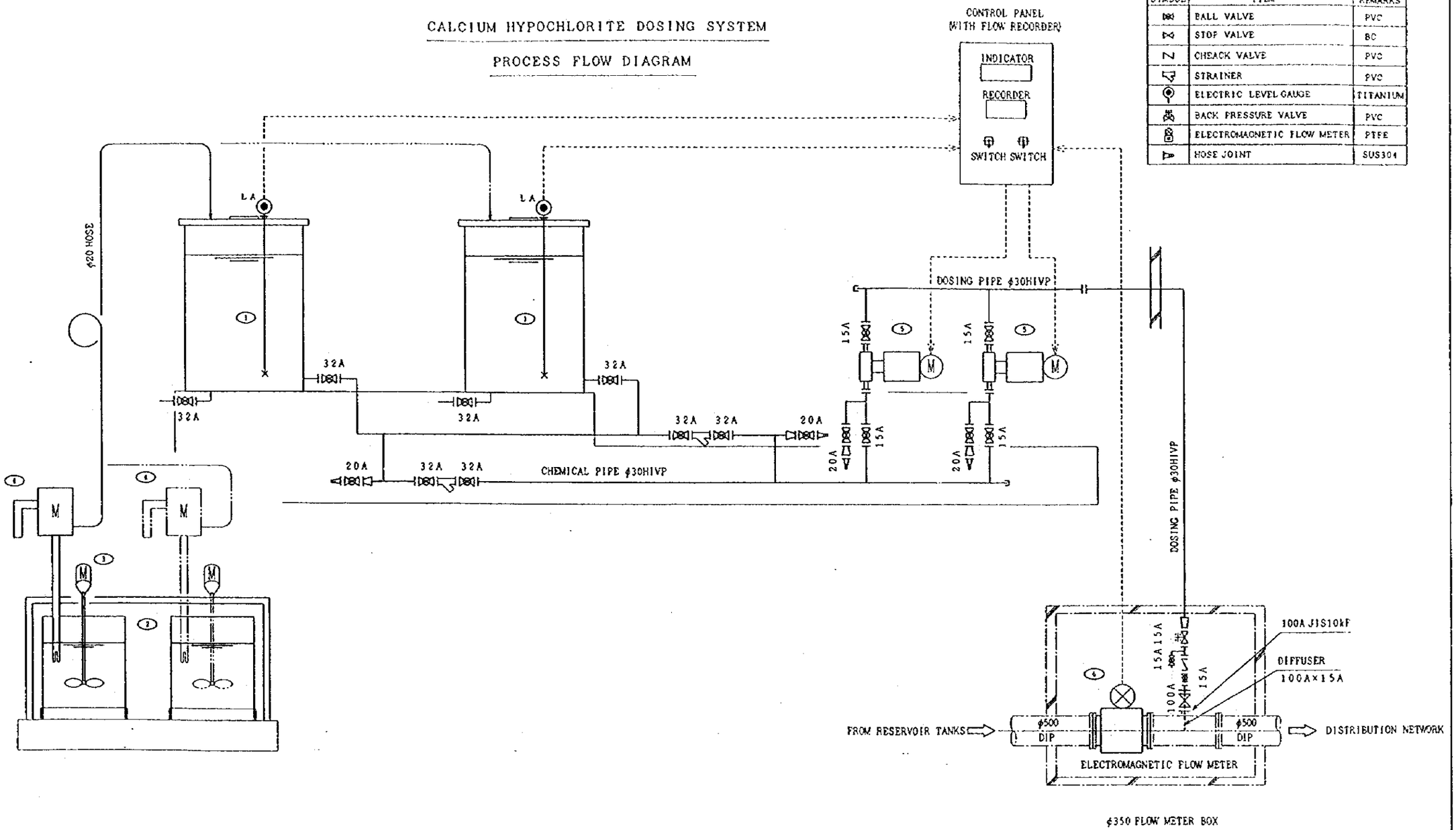


TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Title Site Plan of Matakl'eua Reservoirs		
Date Aug. 1999	Scale 1:600	Drow. No. 14
JAPAN INTERNATIONAL COOPERATION AGENCY		

CALCIUM HYPOCHLORITE DOSING SYSTEM

PROCESS FLOW DIAGRAM

SYMBOL	ITEM	REMARKS
⋈	BALL VALVE	PVC
⋈	STOP VALVE	BC
⋈	CHEACK VALVE	PVC
⋈	STRAINER	PVC
⋈	ELECTRIC LEVEL GAUGE	TITANIUM
⋈	BACK PRESSURE VALVE	PVC
⋈	ELECTROMAGNETIC FLOW METER	PTFE
⋈	HOSE JOINT	SUS304



ϕ350 FLOW METER BOX

NO	①	②	③	④	⑤	⑥
ITEM	STORAGE TANK	DISSOLVING TANK	AGITATOR	CHEMICAL TRANSFER PUMP	CALCIUM HYPOCHLORITE DOSING PUMP	ELECTROMAGNETIC FLOW METER
MODEL	CYLINDRICAL TYPE	CYLINDRICAL TYPE	PORTABLE TYPE	HANDY TYPE	METERING CHEMICAL PUMP WITH DIAPHRAGM	FLANGE TYPE
CAPASITY	300 ℓ	100 ℓ	ϕ20r.p.m	25ℓ/min	0.1ℓ/min ~ 0.025ℓ/min	12m³/min ~ 1.7m³/min
MATERIALS	POLYETHYLENE	POLYETHYLENE	STAINLESS STEEL	POLYVINYL CHLORIDE	POLYVINYL CHLORIDE	POLYTETRAFLUOROETHYLENE
MOTOR RATING	——	——	0.1kW×1ϕ×AC200V×50Hz	0.05kW×1ϕ×AC100V×50Hz	0.2kW×3ϕ×AC200V×50Hz	0.025kW×1ϕ×AC100V×50Hz
DIMENSIONS	ϕ750×800H	ϕ430×765H	——	——	——	ϕ350
QUANTITY	2	2	1	1	2 INCLUDING 1 STANDBY	1

TONGA WATER BOARD
THE KINGDOM OF TONGA

BASIC DESIGN STUDY ON THE PROJECT
FOR NUKU'ALOFA WATER SUPPLY

Title: Calcium Hypochlorite Dosing System
Process Flow Diagram

Date	Scale	Drow. No.
Aug. 1999		15

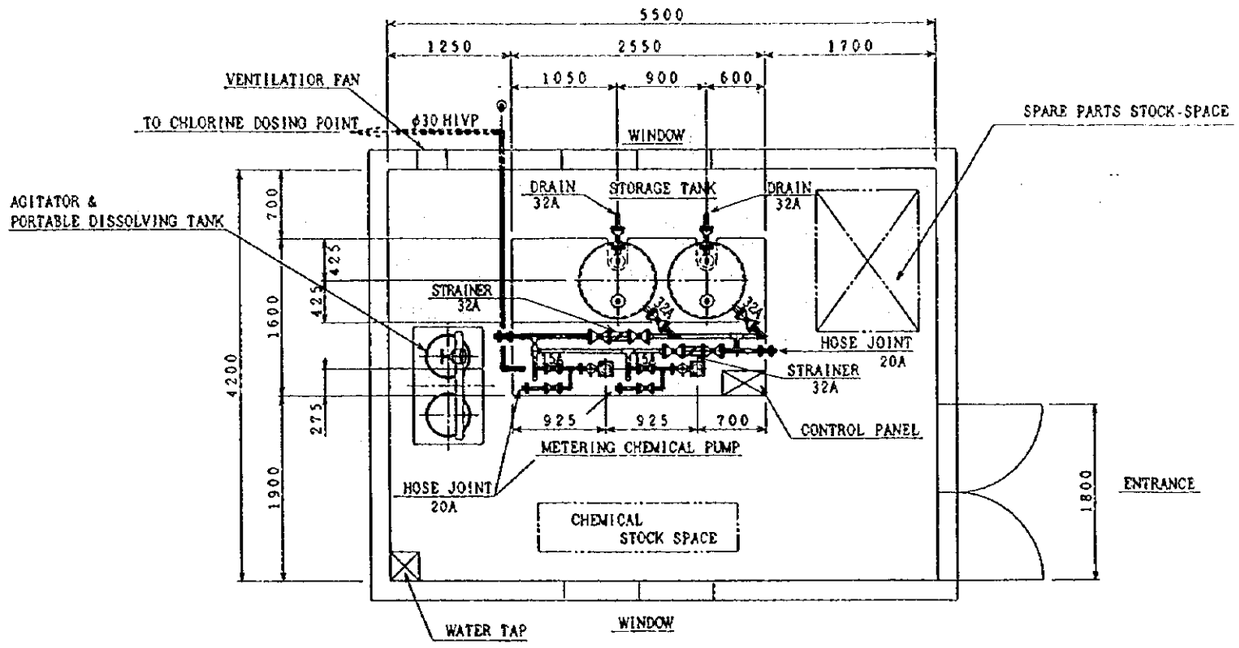
JAPAN INTERNATIONAL COOPERATION AGENCY

CALCIUM HYPOCHLORITE DOSING SYSTEM

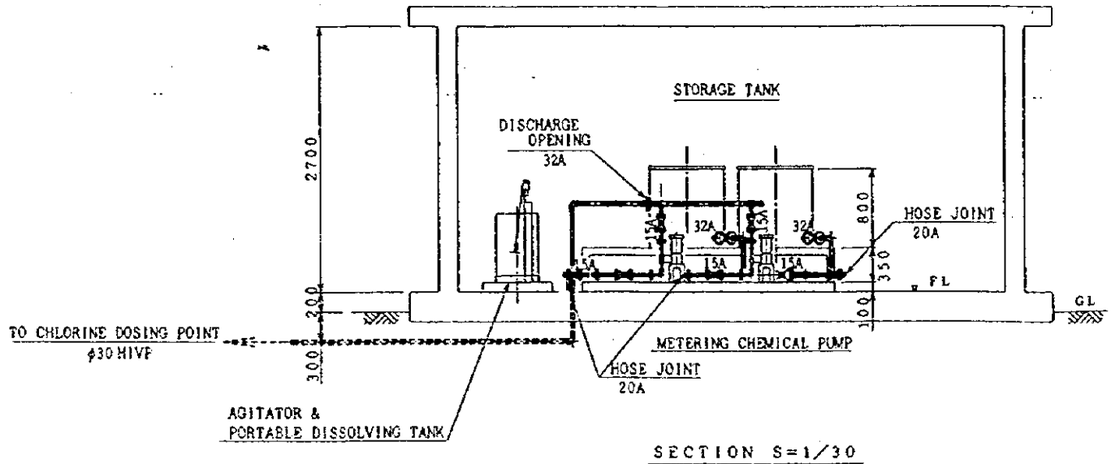
PIPING ARRANGEMENT PLAN

(UNIT:mm)

DESIGN CONDITIONS
- DAILY AVERAGE CAPACITY = 6,528 m³/day
- DAILY MAXIMUM CAPACITY = 8,160 m³/day
- HOURLY PEAK CAPACITY = 12,407 m³/day = 8.61m³/min
- CHEMICAL SOLUTION DENCITY = 5.0% (as Cl₂)



PLAN S=1/30



SECTION S=1/30

TONGA WATER BOARD THE KINGDOM OF TONGA		
BASIC DESIGN STUDY ON THE PROJECT FOR NUKU'ALOFA WATER SUPPLY		
Title: Calcium Hypochlorite Dosing System Piping Arrangement Plan		
Date: Aug. 1999	Scale:	Drow. No.: 16
JAPAN INTERNATIONAL COOPERATION AGENCY		

CHAPTER 3 PROJECT IMPLEMENTATION

CHAPTER 3 IMPLEMENTATION PLAN

3-1 Implementation Plan

3-1-1 Implementation Concept

(1) Basic Conditions for Implementation

Project components are summarized in Table 3-1, while it is stated in 2-3-2.

Table 3-1 Scope of Works and Project components

Scope of works	Facility	Items to be conducted
Government of Japan	Intake facility	Provision of standby intake pumps Provision of equipment for maintenance
	Disinfection facility	Renovation of disinfection facility
	Pipes in reservoir yard	Installation of flow meter Replacement of ACP* with DIP**
	Distribution pipelines	Construction of distribution pipelines (approx. 33km) Construction of dia.50mm PVC*** side pipe (approx. 9km)
		Provision of leakage control equipment
	Service pipes	Restoration of connections
Government of Tonga	Distribution pipelines	Construction of PVC pipelines (approx. 2km)
	Garage	Construction of garage for vehicles to be provided under the Project
	Leakage control	Implementation of the step test Reduction of leakage ratio of PVC to 20%

* ACP: Asbestos cement pipe
** DIP: Ductile iron pipe
*** PVC: Polyvinyl chloride

For pipeline construction of the scope of Japan, six groups are planned to work simultaneously. In the case that road is occupied for work, bypass road should be secured so as to avoid negative impacts such as traffic jam, etc..

Restoration of service connections is required where distribution pipes are replaced. Approx. 800 individual connections are estimated to require the restoration. In construction, special care shall be taken for selection of the construction method and scheduling in order to minimize period of water supply cutoff.

(2) Local Contractor

It is difficult to sublet to local contractors the works of such scale of the Project in Nuku'alofa. It is therefore assumed that experienced engineers/ technicians and skilled/ unskilled workers be recruited directly by the Japanese contractor. Engineers of various expertises are required to be sent from Japan or other countries.

(3) Expatriate Engineers

The Japanese contractor has to conduct technical transfer through OJT in construction period, especially in terms of the following categories.

- Installation of ductile iron pipe (DIP)
- Operation of leakage survey equipment
- Installation for chlorination facility

(4) Executing Organization of Tongan Side

Tonga Water Board (TWB) is to be executing agency of the Project. General Manager of TWB would be responsible for implementation of the Project, and TWB Engineering Department will supervise the works with assistance of a Japanese consultant.

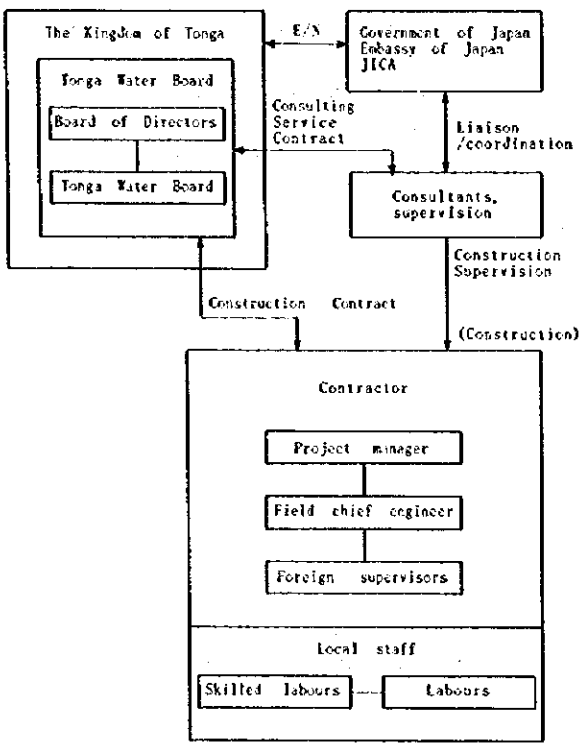


Fig.3-1 Conceptual Structure for Project Implementation

3-1-2 Implementation Conditions

(1) Natural Conditions on Construction

Geology

Tongatapu Island is composed of thick Pleistocene lime layer, the thickness of that reaches approx. 250m. Surface soils are hard clay in the east and silty clay in the west.

Climate

The climate of Tonga is of subtropical. The temperature fluctuates from 21°C in winter to 33°C in summer with minor year-to-year vacation.

Rainfall

In general, rain falls more in summer than in winter. In summer, from November to April, it is relatively humid. Average annual rainfall in recent years is 1,033mm.

Earthquake

Around 4 or 5 times of felt earthquakes per year in average occur in Tonga. Since year 1910, 19 big earthquakes were recorded with magnitude ranging from 7.0 to 8.3 on Richter scale. Aseismatic design has to be employed for every structure in Tonga so that Australian design standard, AS1170.4-1993 Minimum design loads structures Part 4: Earthquake loads, is applied (design horizontal seismic factor: 0.25)

Cyclone

Cyclone is yearly observed in Tonga, and the one attacked Niuafo'ou Island in 1997 was the biggest in these 20 years. Maximum wind velocity was 87m/sec and 90% of whole houses of the island were disappeared. Large cyclones of 60-70 m/sec is recorded almost every year. In many cases, cyclone accompanies tornado that causes serious damages.

(2) Related Laws and Regulations

Tonga's drinking water standards are to follow the WHO's guideline for drinking water quality (WHO: World Health Organization). Standards for designing structures and other water supply facilities are in general to follow the Australian standards (AS).

3-1-3 Scope of Works (Demarcation)

Work Item	Government of Tonga	Government of Japan
Construction of distribution pipes (2km)	☑	
Construction of garage (for vehicles to be provided by the Project)	☑	
Construction of distribution pipelines (33km)		☑
Construction of disinfection facility		☑
Provision of equipment (for leakage control and maintenance of intake pumps)		☑

3-1-4 Detail Design and Construction Supervision

(1) Detail Design

In the detailed design study, following works will be carried out:

- In the field study, followings are conducted; site reconnaissance of the pipeline routes, investigation of underground installations and other obstacles (pole, overhead wire, etc.), investigation of existing pipes, etc., investigation of positions for the connection restoration of existing water supply pipes and branch pipes, topographic survey, trial pit investigation.
- Basic design should be reviewed on the basis of the field study.
- Comparison on construction method, structural planning and temporary planning are carried out so as to decide implementation plan.
- The structural calculation as well as temporary calculation, etc. are carried out.
- Drawings are prepared, such as location map, plans, longitudinal section drawings, detail drawings (plan, longitudinal, cross section, etc.) and structural drawings.
- Calculation sheets are made on all that are necessary for construction.
- Basic conditions, the comparison examinations, etc. are confirmed. Validity of the design plan, consistency of the drawings and the calculation sheets are probed so as to examine the content of the design.

- Cost estimation of the basic design is reviewed on the basis of the decided scale of facilities and quantities.

- Tender document is prepared in accordance with the guideline of JICA (Japan International Cooperation Agency).

- For the selection of the contractor, the consultants will assist the TWB in line with the tendering procedures stipulated in the guideline of JICA.

(2) Construction Supervision

Following the detail design, the construction supervision will be undertaken. Major items of the construction supervision services are summarized below:

- Close coordination with parties concerned for completing the construction work as scheduled in the implementation program of the Project

- Precise and timely advises to the contractor and the executing agency to construct the facilities consistent to design drawing / contract document

- Proper transfer of knowledge to the staff of TWB on construction methods and techniques to maximize the expected effects of the Grant Aid Project in the form of on-the-job training

- Adequate advice and guidance on operation and maintenance of the constructed facilities to facilitate the proper operation of the Project

- During the pipe laying works in the service area, it is important to minimize interference to the residents, such as suspension of water supply, by cooperation with TWB.

- In order to achieve project objectives from the early stage, the consultants would pay attention to the progress of TWB portion, construction of distribution pipelines, from the preparatory to construction stages. The consultants will assist its designing and planning to coordinate whole progress of the Project.

- Operation and Maintenance (O&M) manual for equipment and pipelines is to be prepared by the consultants during the construction period. Each manual for equipment or facility would be made by the manufactures. And the consultants will combine the manuals into a comprehensive O&M manual. It will be used for training in commissioning. Necessary modifications shall be made, if any.

The above supervision works include the following duties and responsibilities:

- Supervision of construction program and quality control, such as approval and inspection of construction materials and works
- Inspection and approval of dimensions, and numbers of the constructed works and facilities
- Change order to the contraction as required
- Preparation of reports and papers required as specified by JICA

The above consulting services will be required from the commencement of the construction to the completion of the all construction works. Throughout the construction period, a resident engineer will be assigned who coordinates the construction works. The resident engineer will be a civil engineer. Experts in several disciplines will be dispatched to the site in addition to the resident engineers for smooth implementation of the work.

3-1-5 Procurement Plan

(1) Labors

Labors and foremen are locally available. Engineers/ technicians such as pipe engineers, surveyors, mechanics and etc. will be employed in the neighboring countries, such as Australia and New Zealand.

(2) Materials and Equipment

Among the construction materials, locally available materials are sand, gravel, asphalt, cement, aggregate and wood. Ductile iron pipes, PVC pipes, pumps, controlling equipment, vehicles, construction machinery are not produced in Tonga so that they are to be imported from Japan or the neighboring countries. Since exploitation of sand and gravel are controlled by the Ministry of Land Survey and Natural Resource, their prices are officially set up. As for ductile iron pipes and PVC pipes, about 4 months will be required from order to the first delivery.

(3) Construction Machinery

Most construction machineries in Tonga are secondhand from Japan, Australia and etc. It seems that they are old and number of them is small so that procurement in local area is unpractical. Lease from the neighboring countries is also difficult due to the suppliers intentions that 18 months of the construction period might be too short. Therefore, they would be leased from Japan.

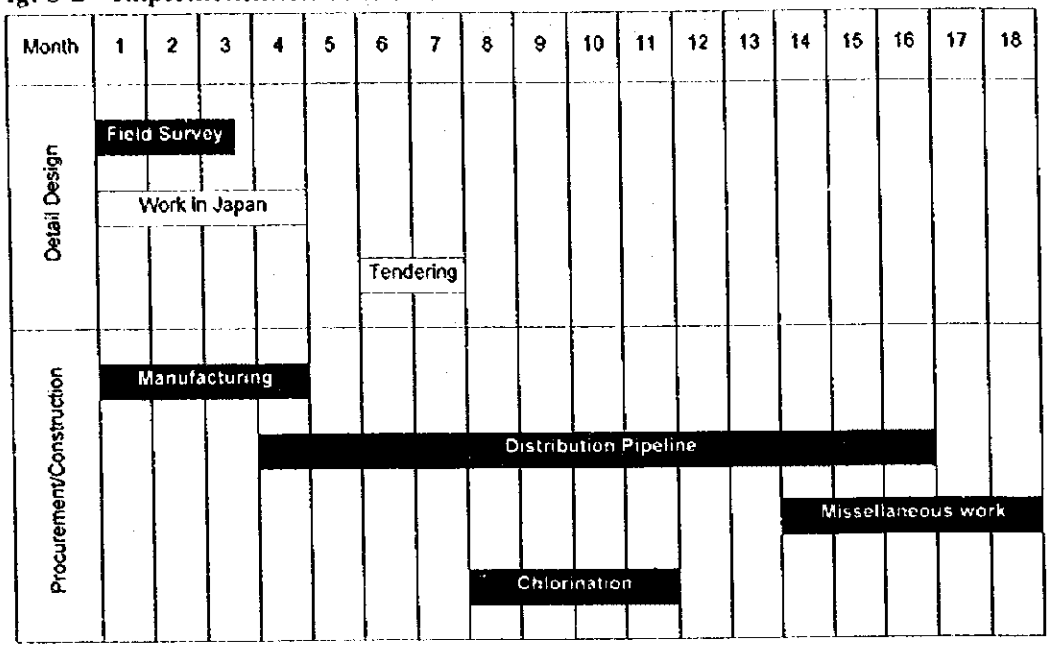
Table 3-2 List of Procurement Plan

Item	Specification	Country		
		Tonga	Japan	3rd Country
Labors				
Technicians				AS/NZ
Foreman		☑		
Common labor		☑		
Construction materials				
Ductile iron pipe	φ500～φ250mm		☑	
PVC pipe	φ200～φ75mm			AS
Valves	φ500～φ250mm		☑	
	φ200～φ75mm			AS
Stop valve with saddle			☑	
Sand for backfill		☑		
Concrete		☑		
Steel bar		☑		
Sand		☑		
Asphalt		☑		
Aggregate		☑		
Light oil		☑		
Gasoline		☑		
Water flow meter			☑	
Chlorination equipment			☑	
Manhole cover	Cast iron		☑	
Cover for valve	Cast iron		☑	
Provision of equipment				
Ultrasonic water flow meter			☑	
Leakage detector			☑	
Correlation leakage detector			☑	
Box locator			☑	
Backhoe			☑	
Trencher			☑	
Pickup truck		☑		
Pipe cutter			☑	
Concrete cutter			☑	
Tamper			☑	
Truck with crane			☑	
Borehole pumps	Diesel type			AS

AS : Australia, NZ : New Zealand

3-1-6 Implementation Schedule

Fig. 3-2 Implementation Schedule



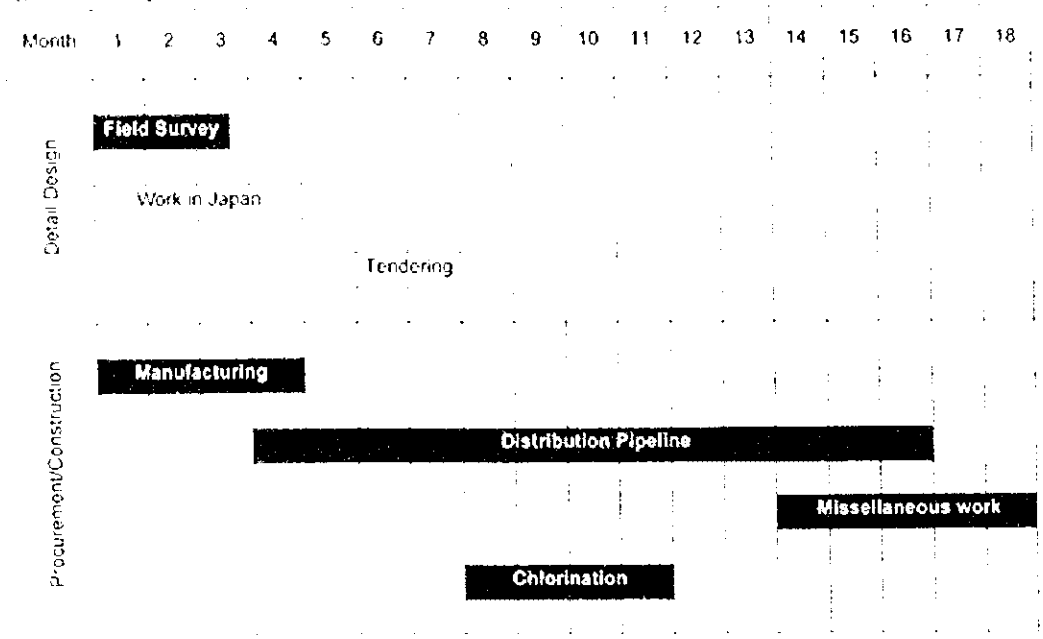
3-1-7 Undertakings of the Government of Tonga

Following necessary measures should be taken by the Government of Tonga on condition that Grant Aid of Japan be extended to Tonga for implementation of the Project.

1	To bear commissions to the Japanese foreign exchange bank for its banking services based upon the Banking Arrangement
2	To ensure prompt unloading, tax exemption, customs clearance at the port of disembarkation in Tonga
3	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 Tonga and stay therein for the performance of their work
4	To obtain necessary permissions, licenses and other authorizations for implementing the Project
5	To assign appropriate budget and administrative staff members for proper and effective operation and maintenance of equipment and instruments provided under the Grant Aid scheme
6	To use and maintain properly and effectively all the facilities constructed and equipment provided under the Grant Aid scheme
7	To bear all the expenses, other than those to be borne by the Japan's Grant Aid, which are necessary for construction of the facilities as well as transportation and installation of the equipment

3-1-6 Implementation Schedule

Fig. 3-2 Implementation Schedule



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