The Population of Tonga

1891 to 1986

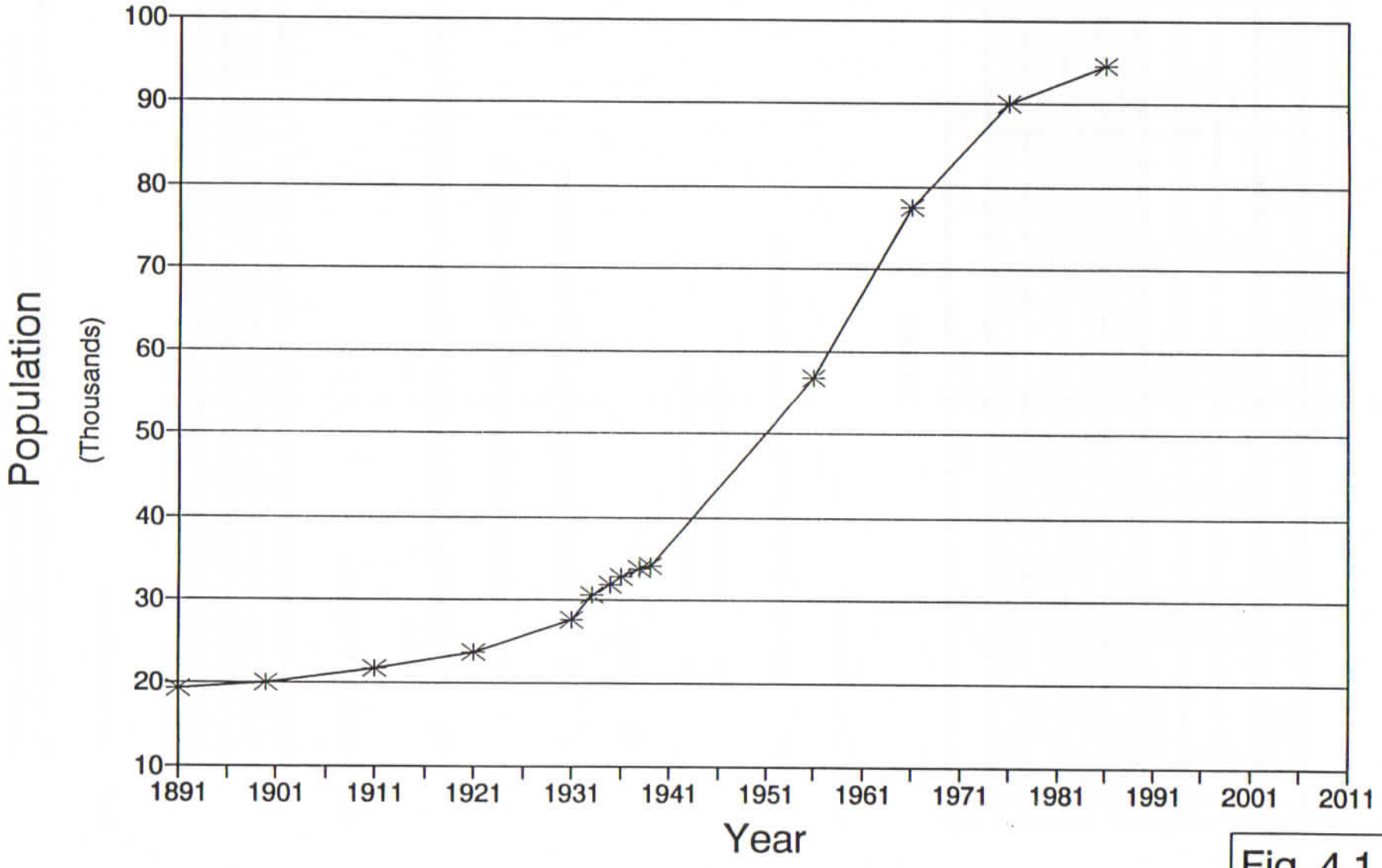


Fig. 4.1

Population by Region 1966 - 1986						
Region	1966	%	1976	%	1986	%
Tongatapu	47,920	61.9	57,411	63.7	63,614	67.3
Nuku'alofa	15,683	20.3	21,327	23.7	28,899	30.6
Balance of Tongatapu	32,235	41.6	36,084	40.1	34,715	36.7
Vava'u	13,533	17.5	15,068	16.7	15,170	16.0
Ha'apai	10,591	13.7	10,792	12.0	8,979	9.5
'Eua	3,391	4.4	4,486	5.0	4,393	4.7
Niuas	1,994	2.6	2,328	2.6	2,379	2.5
TONGA	77,429	100	90,085	100	94,535	100

Table 4.3

4.1.3 Tonga Summary

(i) Population reducing (in the presence of migration).

a) high estimates - 2.9% p.a.
b) crude estimates - 1.0% p.a.

(ii) Causes are:

a) high male migration in the 23-55 year age groups.

b) subsequent reduction in number of births per female.

(iii) The Master Plan Project has assumed a ceiling population of 100,000 in twenty years (2011).

4.2 Niuafo'ou Projections

Niuafo'ou Island population evacuated in 1947 prior to an eruption of the volcano. Most of the population were relocated to 'Eua. Since that time there has been a gradual return of some of the original inhabitants. This has accelerated in the last 10 years. There are limited resources and space for growth on Niuafo'ou and it would not be expected that the enormous growth rates over the last 10 years will continue.

4.2.1 Population Changes

The combined villages of Niuafo'ou had a census population of 375 in 1976. The population in 1986 was 763. This represents a very rapid growth of 103.47% over the ten year period.

It is anticipated (from discussions with CPD) that growth rates will peak around the year 2000 and the resulting year 2011 population will be approximately 915.

This is an effective annual growth rate from 1986 of 0.7293% per annum.

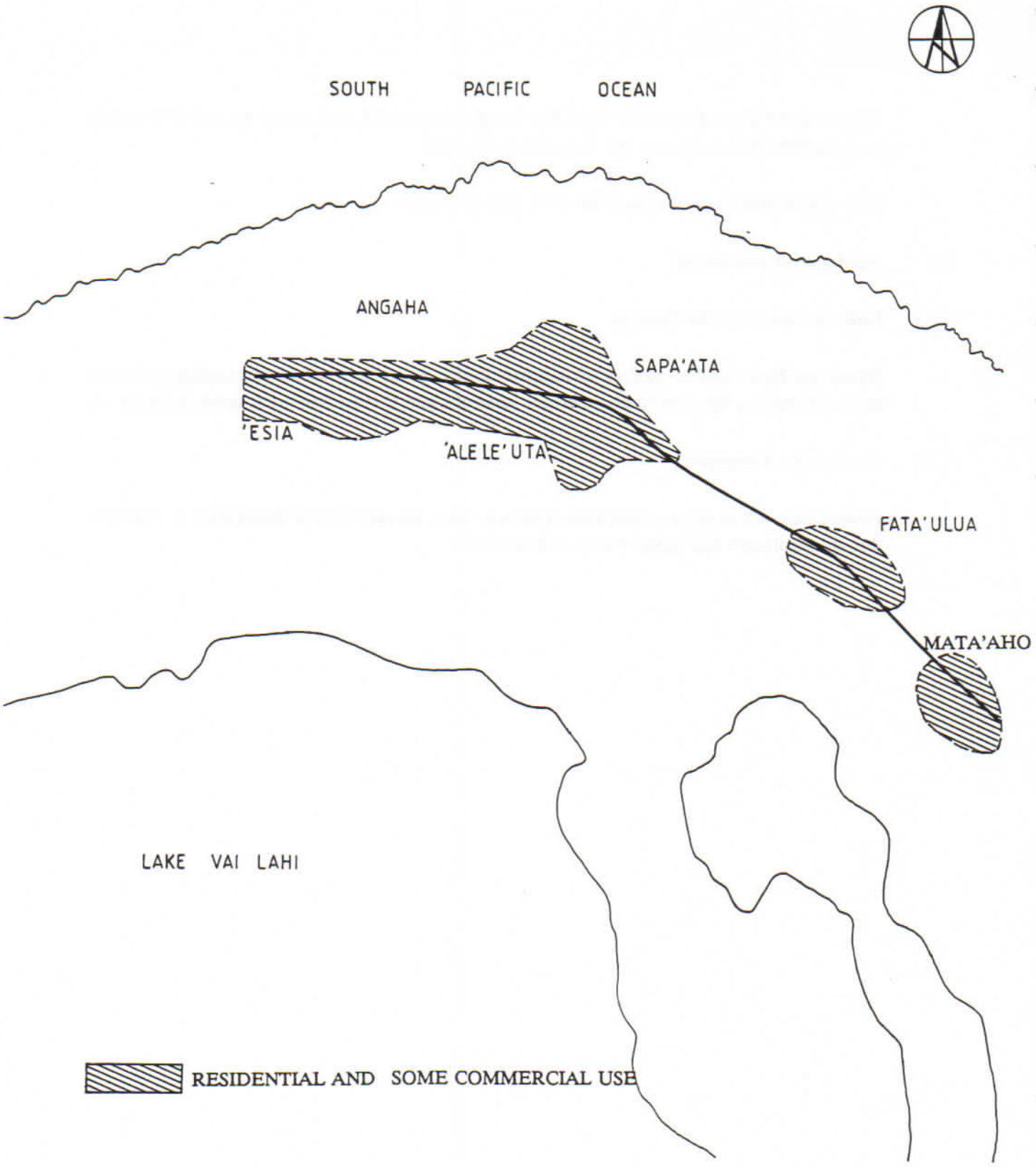
4.3 Development Projections

4.3.1 Land Use and Land Use Planning

Present and Future land use patterns are important in determining the locations of changing populations and in determining locations of non-domestic users of water. Current land use is shown in Figure 4.4.

4.3.2 Development Projections

Development will be minimal within the study area during the period of the Master Plan. It is unlikely that any significant new users of water will develop.



LAND USE
FIGURE 4.4

5 WATER DEMANDS

5.1 General Consumption Pattern

The water consumption pattern in Niuafo'ou is characterised by a number of significant factors:–

* All consumers use rainwater from private or community tanks and about 50% of consumers carry water from a neighbours rainwater tank.

* During extended low rainfall periods water is used at or, carted from, the Lakes for non–drinking, and to a lesser extent for drinking, purposes.

* Internal plumbing is minor.

* Garden watering is not practised.

5.2 Population Served

In 1991 there were approximately 750 people living on Niuafo'ou. All use rainwatere as the main source of water.

5.3 Present Water Consumption

5.3.1 General

The average daily domestic water consumption in 1991 is estimated to be 38kL/d or 50L/person/day.

The existing consumption is estimated from discussions with residents and from assessment of available rainfall/storage capacity.

5.3.2 Domestic Consumption:

The current domestic water consumption is approximately 50 L/person/day. During low rainfall periods the consumption is estimated to drop to around 15L/person/day.

5.3.3 Non Domestic Demand

No water consumption data is available for non–domestic users although usage would be similar to domestic consumption as high volume water consuming activities are not undertaken.

5.4 Future Water Demands

5.4.1 General

Future water demands will be affected by growth in the number of domestic and non–domestic consumers, establishment of a reticulated water supply and social and economic changes in the community.

5.4.2 Domestic Demand

The future domestic water demand will be affected by an increase in water consumption resulting from construction of a reticulated supply and a rise in the general standard of living. Installation of internal plumbing within houses will increase water demand.

As the demand in Niuafo'ou is limited by the limited capacity of the rainwater supplies it is necessary to consider consumption data measured at other locations. Such an analysis is necessary to establish what the Niuafo'ou water demand or the consumption would be if a reticulation system of adequate capacity was available. A system of adequate capacity would, for example, make limited use of rainwater tanks, and would generally provide a continuous supply of adequate quality and quantity water.

The unsuppressed demand for Vaini, a large village on Tongatapu, has been calculated as ranging from 100L/person/d in 1991 to 140 L/person/d in 2011. In comparison Niuafo'ou has and a lower degree of water consuming fixtures.

As discussed in Section 4 Niuafo'ou is unlikely to experience significant expansion within the next 20 years hence the domestic piped water demand is assumed to be limited to 100 L/person/d at least until the year 2011. Rainwater is assumed to provided an additional 40 L/person/day.

5.4.3 Non–Domestic Demand

Total non–domestic demand is expected to be 10% of domestic demand.

From the land use map, Fig 4.4, it has been assessed that there is ample available land for commercial and general non–domestic development. This would be subject to the availability of those lands for development purposes.

5.5 Unaccounted for water

When a reticulated supply system is installed in Niuafo'ou the unaccounted for water is estimated to be at least 25% of water produced. Unaccounted for water would be attributed to a number of causes including leakage, pipe bursts, or illegal connections.

5.6 Demand Pattern

A design demand pattern typical for domestic and non–domestic users in similar villages that have a reticulated water supply has been adopted and is shown in Figure 5.1.

Both domestic and non domestic demands are likely characterised by a very sudden rise in consumption in the early morning.

5.7 Projected Water Production

The average daily water production requirements for the Niuafo'ou water supply system has been projected to the year 2011 utilising the demographic projections given in Section 4 and are shown in Table 5.3.

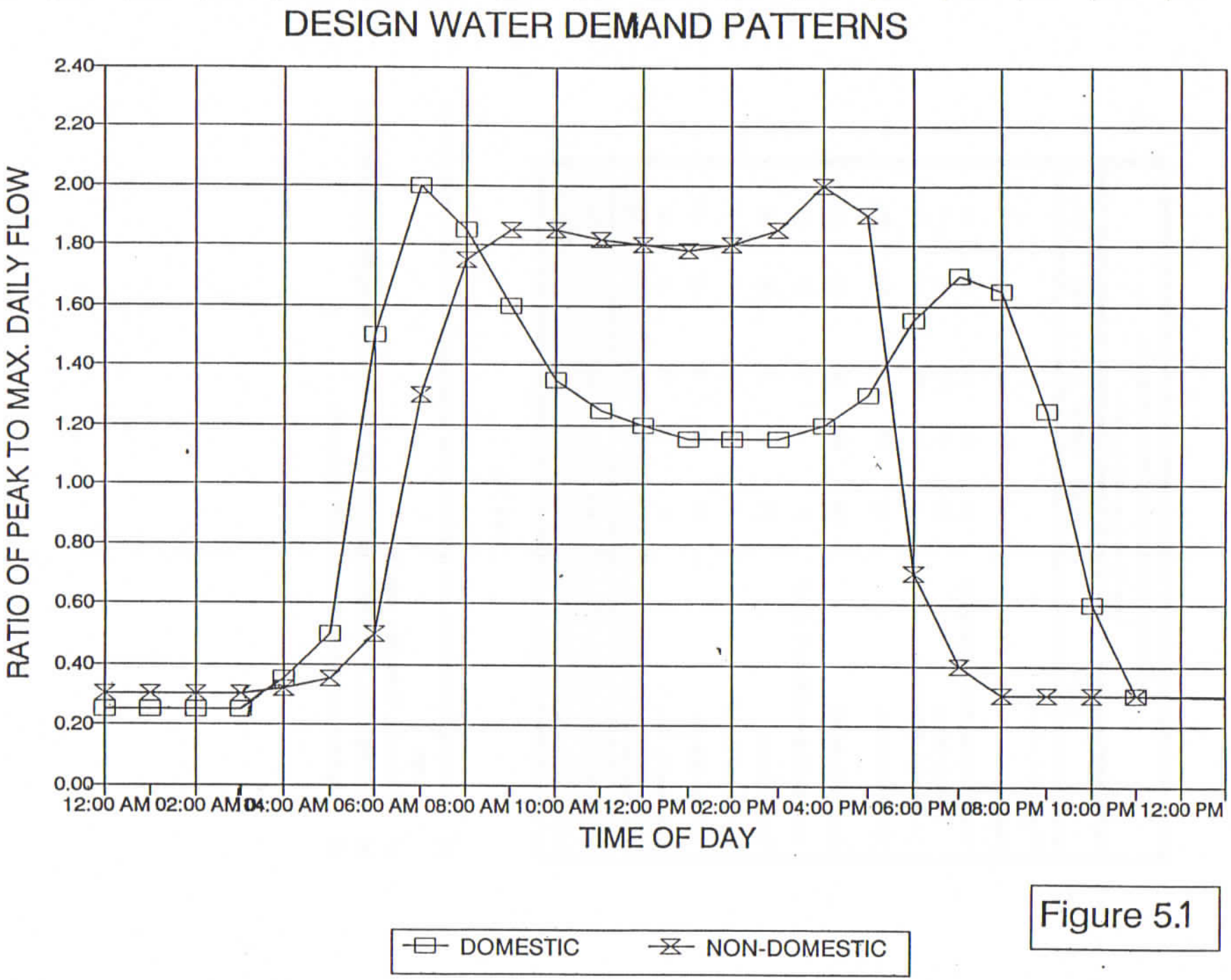

DESIGN WATER DEMAND PATTERNS
RATIO OF PEAK TO MAX. DAILY FLOW
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
12:00 AM 02:00 AM 04:00 AM 06:00 AM 08:00 AM 10:00 AM 12:00 PM 02:00 PM 04:00 PM 06:00 PM 08:00 PM 10:00 PM 12:00 PM
TIME OF DAY
DOMESTIC
NON-DOMESTIC

Figure 5.1

PROJECTED WATER PRODUCTION REQUIREMENTS Units =(kL/d) unless otherwise stated					
YEAR	1991(a)	1992(b)	1996	2001	2011
Niuafo'ou Urban Area (c)					
Population	750	515	640	720	915
Total Unit Domestic Demand (L/person/day)	50	80	95	110	140
- Rainwater Demand	50	40	40	40	40
- Reticulated Water Demand	0	40	55	70	100
Population Served (%)	100	100	100	100	100
Population Served (N°)	750	515	640	720	915
Unaccounted Reticulated Water (% of total)	0	25	25	25	25
Domestic Demand	38	21	35	50	92
Non-Domestic Demand	4	2	64	5	9
Total Metered Supply	42	23	39	55	101
Unaccounted for Water	0	8	13	18	34
Water Production Required	42	31	52	73	134
Max Day Water Production (kL/d)	N.A	39	65	91	168
Max Day Water Production (L/s)	N.A	0.5	0.8	1.1	2.0

Table 5.3

(a) Existing conditions have been presented and the values given are based on assumed rainwater usage.

(b) Following Master Plan upgrade.

(c) Excludes Mu'a, Tongamama'o and Petani which will continue to be supplied by rainwater only.

(d) Assumes nondomestic demand is 10% of domestic

6 WATER RESOURCES

6.1 General

A detailed evaluation of the water resources in Niuafo'ou is given in the Water Resources Development Master Plan.

The existing Niuafo'ou water usage is primarily based on rainwater with some use of the lake water to supplement supply during droughts. The lake water is first used for washing clothes and other non drinking purposes. During more severe droughts the water from Vai Fo is also used for drinking.

6.2 Rainfall

Due to limited rainfall data availability for Niuafo'ou rainfall on Niuatoputapu is considered as the rainfall pattern is expected to be similar.

For Niuatoputapu, monthly rainfall records are available continuously from January 1947 to the present except for 14 months. The annual rainfall pattern for the period 1947 to 1990 is shown in Figure 6.1. Some years have missing data.

The mean annual rainfall derived from the available record for the period 1947 to 1990 is 2301mm which is 30% higher than at Nuku'alofa on Tongatapu and 3% higher than at Neiafu in Vava'u.

The variability of rainfall on Niuatoputapu is discussed in section 4.2.3 of the Water Resources Development Master Plan Report.

6.3 Geology

The island of Niuafo'ou is a basalt shield volcano surmounted by an andersitic cone which has collapsed to form a large water filled caldera about 4km wide (Vai Lahi). Niuafo'ou is still geologically active with the last major eruption in 1946. Approximately 20% of the island is covered by recent lava flow material.

Soils of Niuafo'ou island include free draining sandy loams originating from volcanic ash. In general the surface and subsurface geology of Niuafo'ou Island is highly permeable. Therefore there are no perennial streams due to the rapid infiltration of rainwater.

6.4 Water Resources: Lakes

Description of Lakes

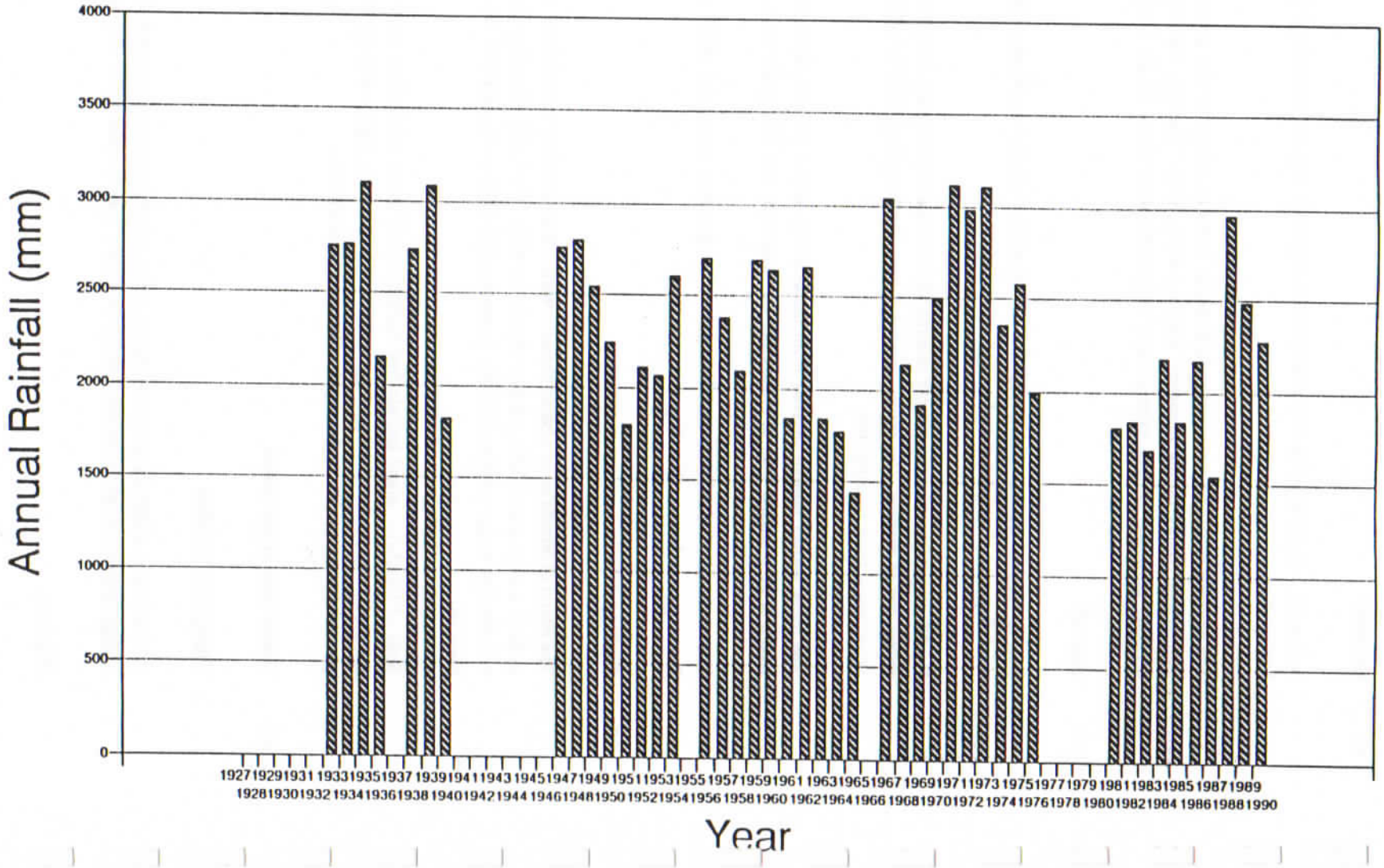
All lakes have relatively steep catchments which infers that once the upper soil layers are saturated then a large proportion of the excess rainfall will flow into the lake rather than infiltrate.

Vai Lahi

Vai Lahi is the largest lake with an approximate catchment area of 1250 ha and a water surface of 860 ha.

Niuatoputapu

Annual Rainfall from 1933 to 1990



ANNUAL RAINFALL 1933-1990

Figure 6.1

Reference is made in the file report ('Reconnaissance soil survey of Niuafo'ou island, Preliminary report and map' based on fieldwork undertaken between 24 August and 7 September 1970) to tests in 1966 by the World Health Organisation of the potability of the water in the lakes on Niuafo'ou. These tests were not sighted during the course of this study.

The file report offers other relevant information about Vai Lahi. It is approximately 80m deep and its surface is about 2.5m above sea level. Apparently, the lake has dropped about 1.5m since 1930. The water is 'slightly' alkaline tasting but potable being used by cows and horses though not by people. Water temperature at a depth of 0.3m is the same as air temperature. The lake is yellow–green in colour with a secchi transparency of less than one metre. There are numerous small red fish that live in Vai Lahi.

The topography of the lake floor consists of a closely spaced craters formed in the loamy volcanic ash. Each crater varies from 20cm to 1m deep with widths from 40cm to 2m.

Vai Si'i

Vai Si'i is the second largest lake with an approximate catchment area of 108 ha and a water surface of 28 ha. The taste of the lake water was the least objectionable of all lakes at the time of the August 1991 site visit by TWSMP staff. The fish life appears similar to that in Vai Lahi. The topography of the lake floor is similar to that of Vai Lahi. There is a potential hydraulic link between Vai Si'i and Vai Lahi during extreme rainfall periods and this is normally prevented by a land bridge, approximately 1.5m high, located on the southern extremity of Vai Si'i. The electrical conductivity of Vai Si'i water was measured as 3850 uS/cm for each of two samples. This is above the acceptable limit for drinking water.

Vai Fo

Vai Fo is the third largest lake with an approximate catchment area of 10 ha and a water surface of 2.2 ha. The taste of the lakes water was more objectionable than Vai Si'i at the time of the August 1991 TWSMP site visit. The fish life appears similar to that in Vai Lahi. There is a potential hydraulic link between Vai Fo and Vai Lahi during heavy rainfall periods and this is normally prevented by a land bridge, approximately 600mm high, located on the western extremity of Vai Fo. The electrical conductivity of Vai Fo water was measured as 640uS/cm.

Vai Inu

Vai Inu is a small relatively shallow lake with an approximate catchment area of 5.8 ha and a water surface of 0.6 ha. The water was not tasted and the lake had a dark red–brown colour as of the August 1991 TWSMP site visit. The colour may be due to clay – silt deposits in eroded hill cuttings to the south east of the lake. This lake is of inadequate capacity to serve as a reliable water supply to Niuafo'ou.

Vai Molemole

Vai Molemole is a small lake located on Motu Molemole. The catchment area is approximately 1.6 ha and the water surface is 0.2 ha. The WHO report indicated the lake water was "clear and fresh". This lake is of inadequate capacity to serve as a reliable water supply for Niuafo'ou. Access to the lake is complicated by a 300m wide section of Vai Lahi.

There are several small lakes adjacent to the southern edge of Vai Lahi. These include Vai Sulifa which apparently has a high sulphur content.

6.5 Water Quality

A water sample was obtained from the surface of Vai Lahi in March 1991 by visitors to the island. On return to Tongatapu, the sample was tested for electrical conductivity and a high value of 7160 uS/cm was obtained. The sample was subsequently laboratory tested in Sydney and the results are shown in Table 6.1.

Water quality of sample from Vai Lahi, Niuafo'ou

Parameter	Unit	Value
Electrical conductivity (@ 25°C)	uS/cm	6380
pH		8.6
Total dissolved solids	mg/L	3749
Ions		
Chloride (Cl)	mg/L	1710
Sulphate (SO_4)	mg/L	142
Carbonate (CO_3)	mg/L	243
Bicarbonate (HCO_3)	mg/L	366
Potassium (K)	mg/L	1.2
Magnesium (Mg)	mg/L	173
Sodium (Na)	mg/L	989
Calcium (Ca)	mg/L	10.7
Magnesium (Mg)	mg/L	173
Iron (Fe)	mg/L	<0.1
Manganese (Mn)	mg/L	<0.1
Total hardness as $CaCo_3$	mg/L	994

The main conclusion from the recent tests is that the water in Vai Lahi has been confirmed as brackish and well beyond the limit for potable water (2500 umhos/cm) and for irrigation of crops. The water could, however, be used for some non-potable applications.

The electrical conductivity of other lakes were measured from samples taken in August 1991 and results are as follows:-

Location	Electrical Conductivity (uS/cm)
Vai Si'i, sample 1	3840
Vai Si'i, sample 2	3850
Vai Fo	640

The salinity limit adopted for freshwater (suitable for drinking water) is taken as 2500 uS/cm (also referred to as umhos/cm) equivalent in small limestone islands to a chloride ion concentration of 600 mg/L which is the maximum permissible limit shown in the former World Health Organisation guidelines for drinking water quality (WHO,1971). The more recent WHO guidelines (WHO, 1984) give a more stringent guideline value of 250mg/L. WHO recognise that this limit for chloride is not based on health considerations but rather on taste considerations. The higher limit of 600mg/l is considered appropriate given the setting of these islands. Other small islands and nations (for example, Kiribati) have also adopted the higher limit. In most cases, the salinity of supplies used for potable purposes will be less than this upper limit.

7 EXISTING WATER SUPPLY SYSTEM

7.1 Historical Background

The Niuafo'ou population has always used rainwater from roof catchments and during drought periods water from the lakes is used.

The sophistication of rainwater catchments has improved from unreinforced concrete inground pits to reinforced above ground tanks with header tanks and hand pumps. Extensive upgrade of the rainwater tanks and catchments has occurred in the last 10 years.

Water from the lakes would have originally been carried by hand over a distance of several kilometres. This water is now carried in containers on trailers pulled by tractors.

7.2 Rainwater Supplies

The majority of rainwater tanks are of reinforced concrete construction and a minority of the smaller tanks being corrugated galvanised iron. The concrete tanks are in moderate condition and any leakage through the tank walls is relatively minor. In general, the condition of guttering systems and down pipes are very poor and the resulting efficiency of rainwater collection is reduced.

A recent programme of ferrocement tank construction has produced several new community facilities which include a central roof catchment and a series of reinforced concrete storage tanks. This programme utlisied funding from the village, GOT and external aid donors and relies on village labour for tank construction.

A summary of the existing rainwater collection and storage systems was made during the TWSMP site visit (August 1991) and is presented below in Table 7.1.

TABLE 7.1
RAIN WATER CATCHMENT AND STORAGE
(AUGUST 1991)

VILLAGE	TYPE OF STORAGE	DESCRIPTION OF COMPONENTS	STATE OF REPAIR
Petani	Community Facility	-260m² of roof catchment -8N° 10kL R.C. tanks of which 4 are not connected to roof	- tanks in moderate repair - no tank outlet taps work - guttering and downpipes in poor condition
	Part Inground Tank	-1 N° 40kL Tank is adjacent to Community facility but not connected to roof.	- moderate repair
	Part Inground Tank	-1 N° 40kL Tank connected to church with 120m² roof area	- moderate repair
Primary School	GI sheet Tanks	-4 N° 4.5kL tanks on 1.5m high timber stands. Total roof area of 300m².	- acceptable

Tongamama'o	Community Facility	-260m² of roof catchment -8 N° 10kL R.C tanks of which 4 are not connected to roof	- tanks in moderate repair - no tank outlet taps work - guttering & downpipes in poor condition
	Part Inground Tank	-1 N° 40kL Tank is adjacent to Community facility but not connected to roof	- moderate repair
	Part Inground Tank	-1 N° 40kL Tanks with no external roof catchment	- poor condition
	Above Ground Tanks	-2 N° 20kL tanks	
Mu'a	Community Facility	-140m² of roof catchment -3 N° 15kL R.C. tanks -280m² church roof catchment connected to one tank	- tanks in moderate repair - one tap outlet works - guttering & downpipes in moderate condition
	Part Inground Tank	-1 N° 40kL Tank is adjacent to Community facility but not connected to roof.	- moderate condition
	Part Inground Tank	-2 N° Tanks without any catchments - not used	- disused
Mata'aho	Community Facility	-140m² of roof catchment -1 N° 18kL R.C. tank	- 50% of gutter u/S
	Part Inground Tank	-1 N° 40kL Tank is adjacent to Community facility but not connected to roof	- moderate repair
	Above Ground Tank	-1 N° 15kL R.C. tank connected to church with 200m² roof area.	- 50% of gutter u/S
Ha'atu'a	Community Facility	-300m² of roof catchment -3 N°15kL R.C. tanks	- moderate condition
	Above Ground Tanks	-1 N° 180m² and 2 N° 100m² of roof catchments -3 N° 10kL R.C. tanks	- good condition
	Above Ground Tanks	-150m² of roof catchment -2 N° 10kL R.C tanks.	- good condition
	Part In Ground Tank	-1 N° 40kL tank with no external roof catchment	- poor condition
Fata'ulua	Community Facility	- 300m² of roof catchment - 3 N° 15kL R.C. tanks	- moderate condition
	Above Ground Tanks	- 1 N° 180m² and 2 N° 100m² of roof catchments - 3 N° 10kL R.C tanks	- good condition
	Above Ground Tanks	- 150m² of roof catchment - 2 N° 10kL R.C. tanks	
	Part In Ground Tank	- 1 N° 40kL tank with no external roof catchment	- poor condition

Sapa'ata	Community Facility	-170m² of roof catchment -3 N° 25kL R.C. tanks -40kL Partially inground tank with 150m² catchment	- 40% of guttering U/S
	School	-40kL Partially inground tank with 600m² catchment -15kL above ground tank with 450m² roof catchment -15kL above ground tank with 300m² roof catchment	- good condition
	Various	-2 N° partially 40kL inground tanks -2 N° above 12kL ground tanks with 200m² roof catchments	
Angaha	Community Facility	-280m² of roof catchment -3 N° 12kL R.C. tanks	- 40% of guttering is U/S
		-2 houses of 220m² catchment also drain into tanks	- 50% of guttering is U/S
	Church	-625m² roof catchment -2 N° 12kL above ground tanks with 240m² roof catchment	- 30% of guttering is U/S
		-1 N° 15kL above ground tank with 200m² roof catchment	- good condition
		28kL Government type tank with 150m² roof catchment	- good condition
	Various	-2 N° 40kL partially inground tank -1 N° 15kL above ground tank with 150m² roof catchment	- poor condition
'Alele'uta	Eastern Community Facility	-40kL Partially Inground Tank -Community Hall with 300m² roof catchment 25kL above ground tank connected to hall.	- 50% of guttering is U/S
	Community Facility	-120m² roof catchment 12 N° 22kL above ground tank	- 30% of guttering is U/S
	School	900m² roof catchment -2N° 4.5kL GI tanks and 1 N° 22kL above ground tank	- 20% of guttering is U/S
		-2 N° 12kL above ground tanks with 150m² roof catchments	- 40% of guttering is U/S
		-2 N° 12kL above ground tanks with 150m² roof catchments	

'Esia	Community Facility	600m² roof catchment on hall 22kL above ground tank 200m² roof catchment 40kL Partially inground tank	- moderate condition
	Commodities Board	800m² roof catchment 28kL Government type tank	
	Church	450m² roof catchment 2 N° 22kL above ground tanks	- 50% guttering is U/S
		-225m² roof catchment with 15kL above ground tank	- remainder is in good condition
		-225m² roof catchment with 15kL above ground tank	
	Main Government Building	-450m² roof catchment with 28kL government type tanks	- good condition
	Minor Government Quarters	3 N° 300m² roof catchments with 3 N° 20kL government type tanks	- good condition
	Clinic	300m² roof catchment with 28kL government type work	
	Government Quarters	3 N° 300m² roof catchments with partially 40kL inground tanks	- good condition

Note: i) Above ground tanks have associated approximated roof catchment areas of 80m² each.
ii) U/S unserviceable.

7.3 Water Quality and Treatment

7.3.1 Chemical Quality

There has been limited chemical analysis undertaken on Niuafo'ou lake water with available results listed in Section 6.6. The most significant chemical water quality issue is high salinity.

7.3.2 Microbiological Quality

Microbiological testing has not been performed.

7.4 Distribution System

There is no reticulated water supply on Niuafo'ou.

7.5 Operation, Control and Recording

Operation

There is no VWC on Niuafo'ou and each village attends to their own facilities. Government facilities are maintained by government personnel.

7.6 Capacity of Existing System

The majority of roof catchments are not fully guttered and the existing guttering is in a generally poor state of repair.

The total existing volume of the all Niuafo'ou rainwater tanks is approximately 50% of the required volume based on a consumption of 100L/person/d and the assumption that a period of 50 days may occur during which no rain falls.

8 MASTER PLAN

8.1 General

The Master Plan for the water supply system for Niuafo'ou has been developed to meet present and projected water needs through 1991 to the year 2011. The Master Plan has assumed that works will be carried out over two sequential time periods,

* An Immediate Improvements Programme to over come inadequacies in the existing system by 1996 and
* A Long Term Improvement Programme

The only viable improvement option to develop Niuafo'ou water resources is based on the continued use of rainwater for potable water and the use of reticulated water obtained from lakes for non potable.

Given the relatively high cost of providing a reticulated water supply system to the villages of Mu'a, Tongamama'o and Petani it is recommended that these villages continue to use rainwater supplies. The approach should be reviewed within the next ten years to reassess the applicability of this recommendation. The design of improvements to these villages rainwater supplies is beyond the scope of this study which is confined to reticulated water supplies. However the extent of the existing supplies is summarised in Section 7.

The capital expenditure programme for the upgrading of Niuafo'ou Water Supply is presented in Figure 9.1.

8.2 Water Sources and Headworks

8.2.1 Use of Rainwater

A reticulated supply for domestic purposes is recommended for 'Esia, Angaha, 'Alele'uta, Angaha, Sapa'ata, Ha'atu'a and Fata'ulua to supplement rainwater. Pressure from groundlevel rainwater tanks is around 2m compared to at least 10m for a reticulated supply. Quality of rainwater mitigated by the lack of flushing equipment and limited construction and maintenance standards. Common pollutants in rainwater, tanks include wind blown dust from the road, leaves, micro organisms, insects, bird droppings and small animals.

Following the Master Plan Improvements rainwater use will be mainly for drinking and cooking.

The villages of Mu'a, Tongamama'o and Petani will continue to use rainwater at least for the next 20 years.

It is necessary to allow for the protection of the rainwater supplies and of reticulated water from contamination by rainwater supplies.

Regulations to allow for, and to control, conjunctive use of rainwater are recommended and are outlined in the TWSMP, Proposed Water Resources and Water Supply Legislation.

Specific control measures include:

* Prohibition of cross connection between rainwater and reticulated water supply.
* Establishment of an information programme by the MOH in conjunction with any future VWC and possibly the TWB which should consider design and maintenance procedures to limit entry of contaminants into rainwater tanks and investigation and where necessary rehabilitation of existing rainwater supply systems.

Further information on rainwater supplies can be found in the bibliography in Appendix B.

8.2.2 Lake Water Source

There is an adequate quantity of water for non potable uses available from Lake Fo.

8.2.3 Water Demand and Production

A summary of reticulated water demand and production requirements is given in Table 8.1.

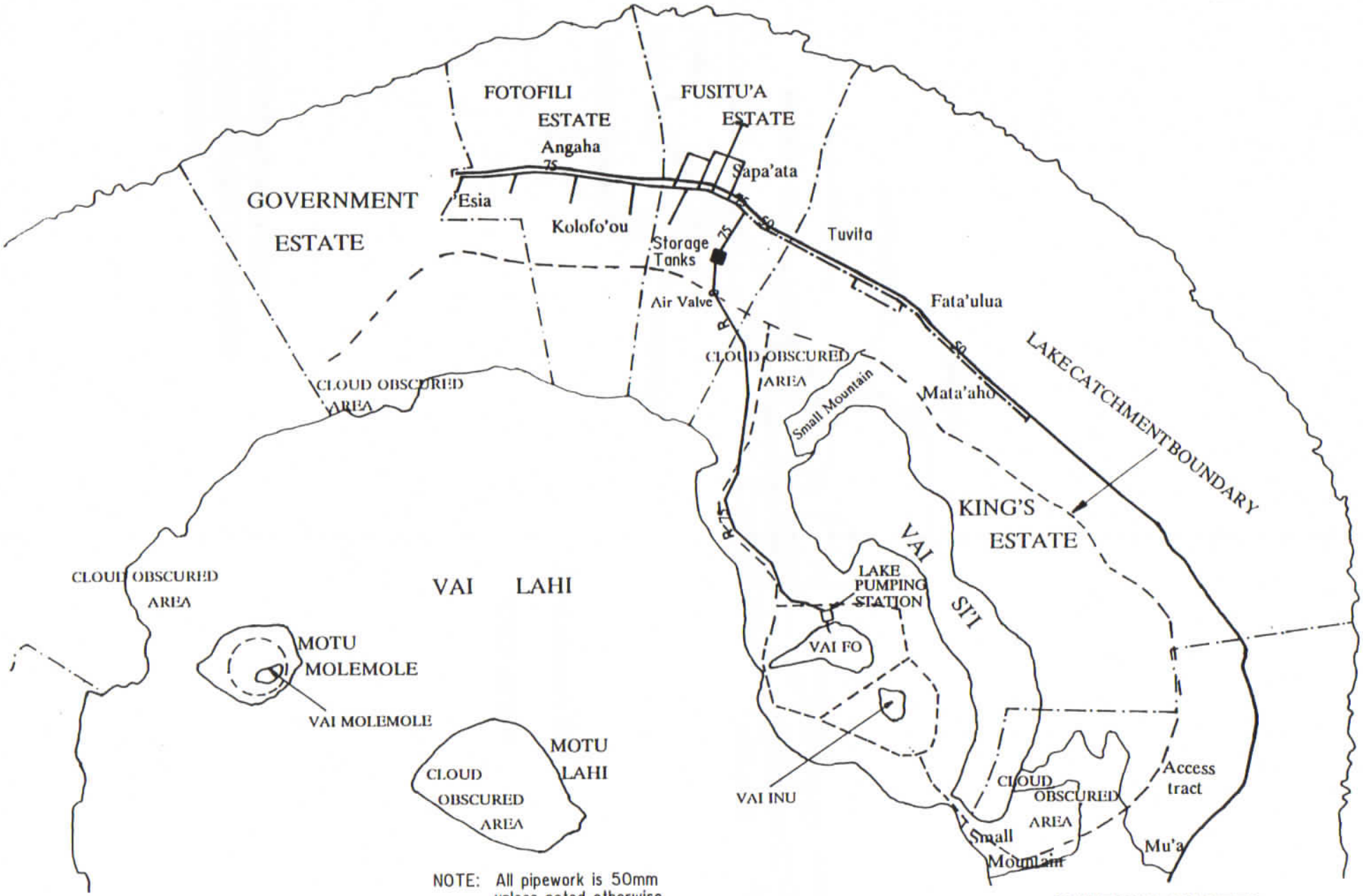
Year	Average Daily Demand (kL/d)	Maximum Daily Demand (kL/d)	
		(kL/d)	(L/s)
1991	31	39	0.5
1996	52	65	0.8
2001	73	91	1.1
2011	134	168	2.0

Table 8.1

8.2.4 Lake Pumping Station

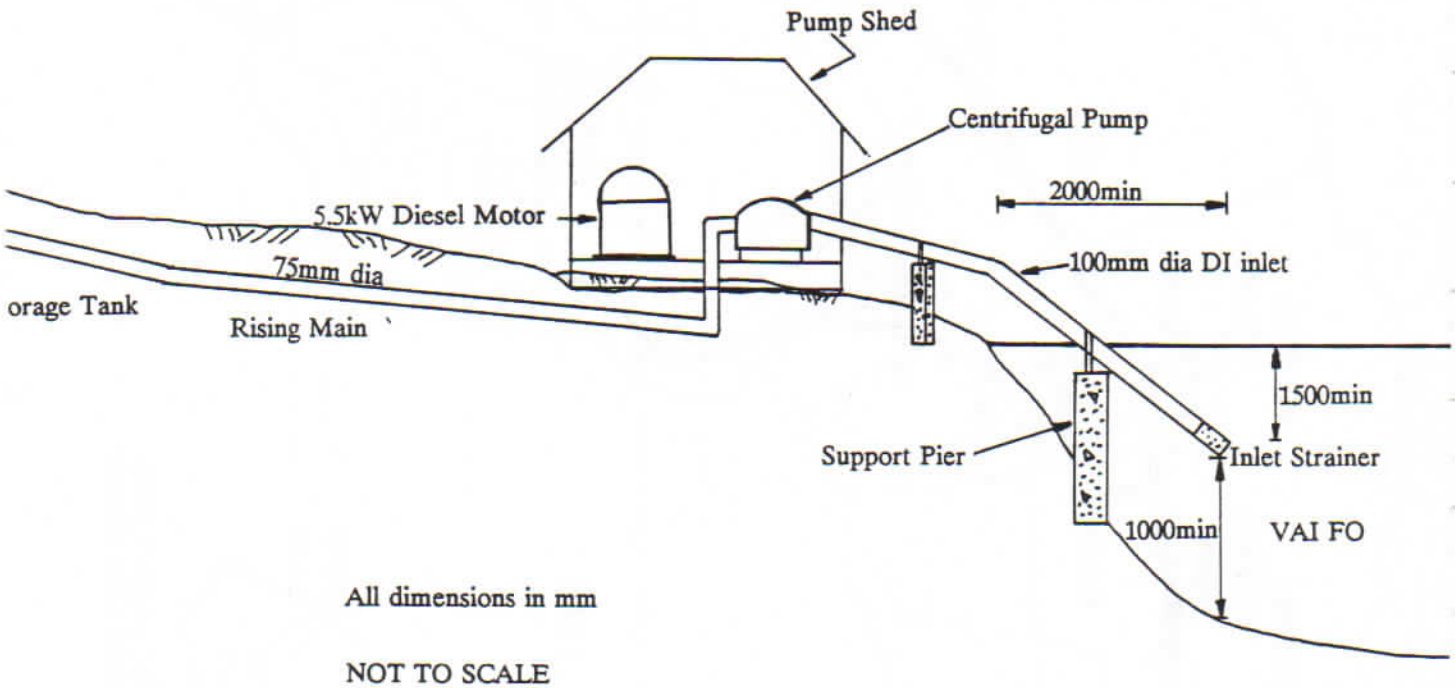
Water will be abstracted from Lake Fo by the pumping station as shown in Figure 8.1. The lake water surface level appears to remain constant hence a fixed intake structure will be used as shown in Figure 8.2. One pump–motor combination will be used with reserve supply being the rainwater supply systems. The pump duty point is approximately 170m head at 2L/S.

Power to the proposed lake pumping station will be by a 5.5kw diesel motor. There are only a limited number of private generators on Niuafo'ou and no reticulated power system.



NIUAFOOU MASTER PLAN UPGRADE

FIGURE 8.1



All dimensions in mm

NOT TO SCALE

LAKE PUMPING STATION
SCHEMATIC ARRANGEMENT
FIGURE 8.2

8.3 Water Quality and Treatment

8.3.1 Chlorination

As the source of potable water will remain rainwater for all Niuafo'ou consumers a chlorination facility is not recommended.

8.3.2 Water Quality Monitoring

In general terms the quality of the rainwater should be good if adequate construction and maintenance procedures are undertaken. Routine bacteriological, chemical or physical analysis should not be required unless specific concerns arise.

8.3.3 Public Health & Education

It is important that parallel to the physical changes of the implementation of the Master Plan that there are changes in public awareness.

In particular continuing public education programmes focusing on water use and maintenance of rainwater supplies needs to be established and maintained by the MOH, VWC and if possible the TWB. Media campaigns could be especially helpful here given the existence of such similar programmes already in use by the MOH.

8.4 Distribution System

8.4.1 Overview

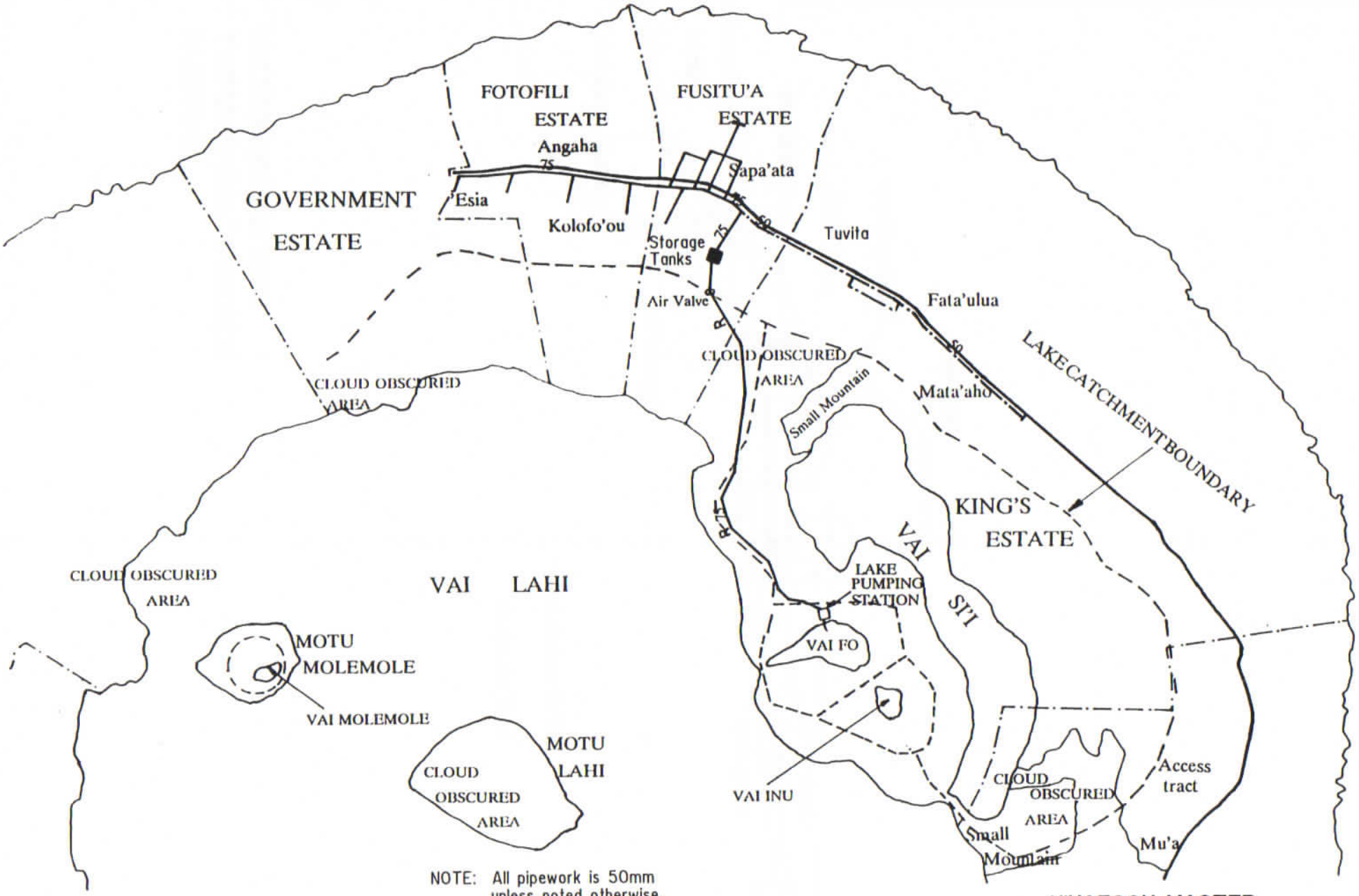
A summary of the total pipework required is given in Table 8.2 and the pipework layout is shown in Figure 8.1.

PIPEWORK REQUIREMENT

Pipe Function	Diameter (mm)	Length (m)
Rising Main	75	1150
Distribution	75	1400
Distribution	50	3200

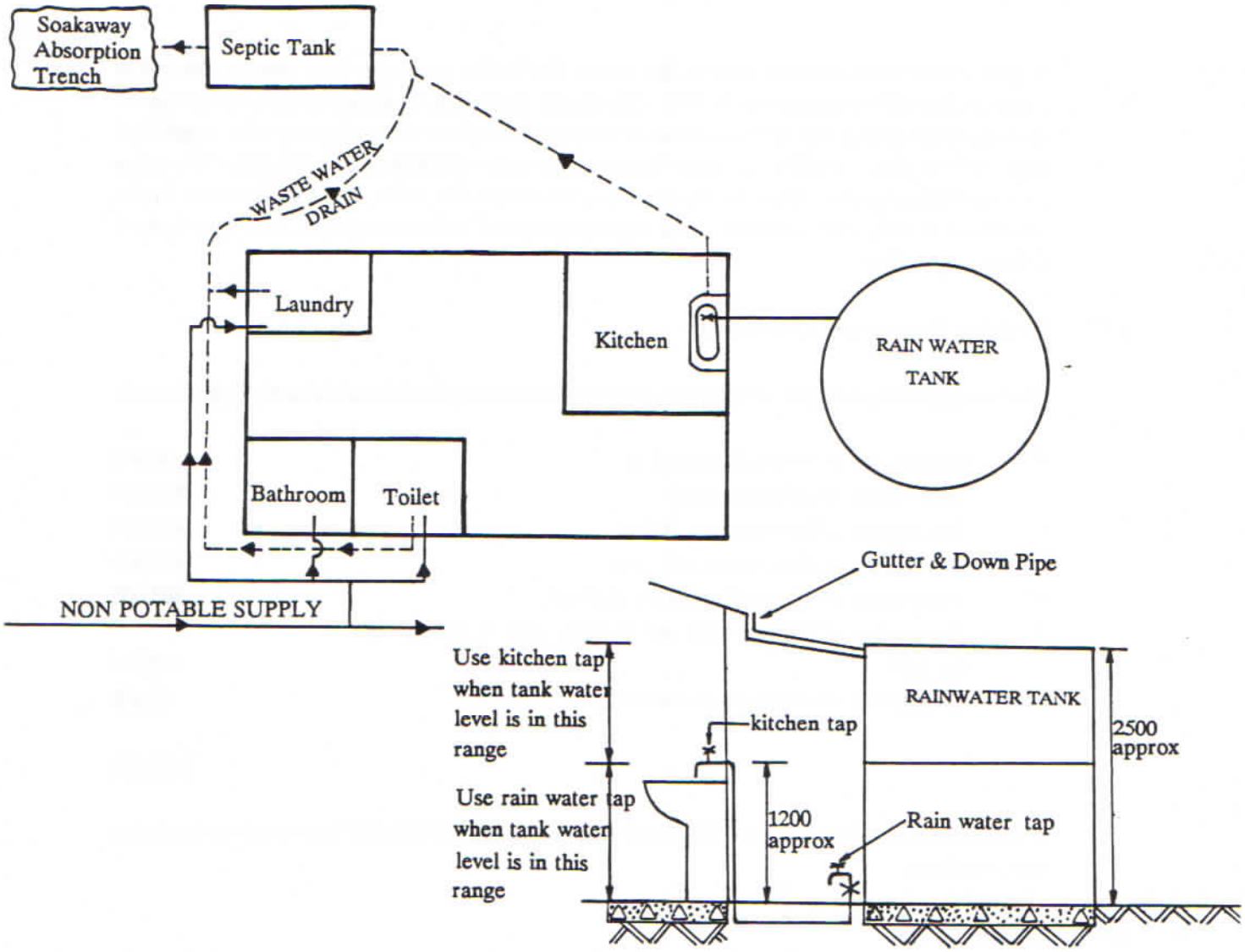
Table 8.2

The concept adopted in the Master Plan for the design of the non-potable water distribution system is that all areas will be supplied directly from the reservoir so that the minimum pressure at the most disadvantaged service connection is not less than 10m at times of peak demand and the maximum static pressure is not greater than 50m.

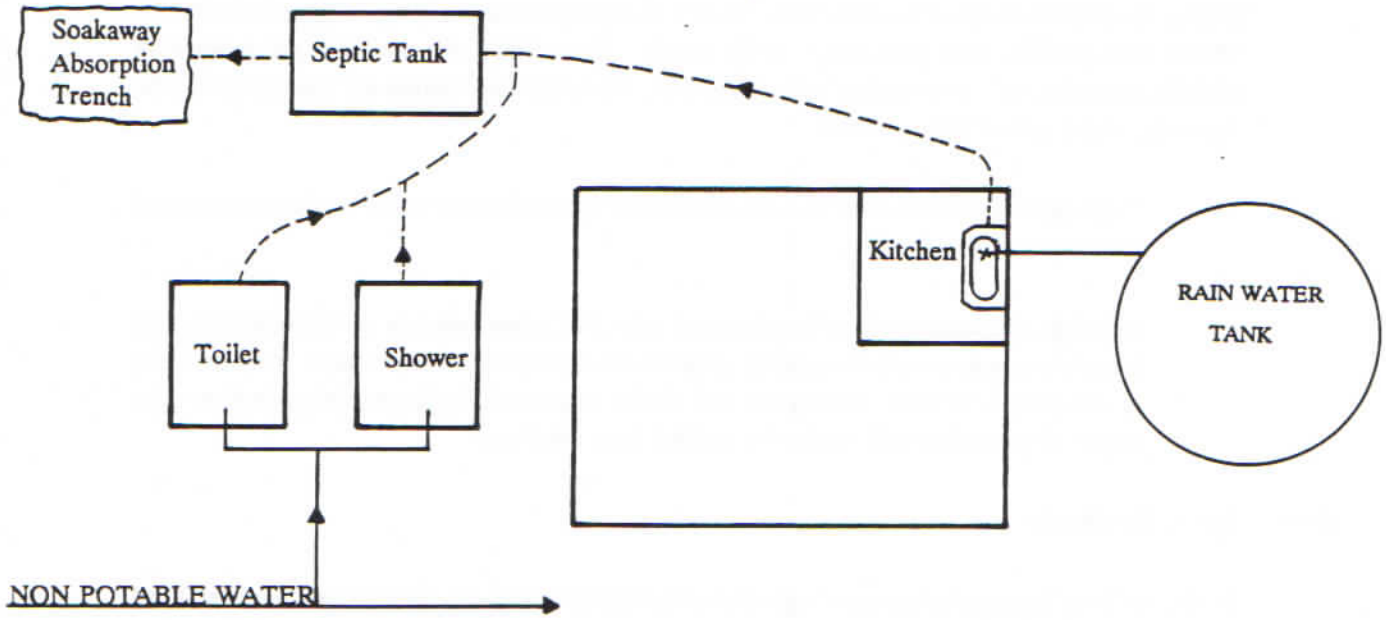


NIUAFOOU MASTER PLAN UPGRADE

FIGURE 8.1



FULL INTERNAL PLUMBING



PARTIAL INTERNAL PLUMBING

POTABLE AND NON POTABLE WATER DISTRIBUTION

Staging of the works includes construction of the distribution system in three phases. The 75mm diameter pipe will be constructed in 1992 – 93. The 50 distribution pipework to serve the villages to the west of the storage tank will be constructed from 1993 to 1995. The last phase, to be constructed from 1997 to 1999, includes the 50mm diameter pipework to Fata'ulua and Mata'aho. The house services will be staged to follow the construction of the distribution mains. The 3 storage tanks will be constructed in 1993, 1997 and 2006. These stages are to spread and costs and could be brought forward if funds are available.

8.7.2 Immediate Improvement Programme

The Immediate Improvement Programme includes the following works and estimated capital costs:

*	Construction of No 22 kL reserviors	$9,000
*	Construction of office/workshop	$10,000
*	Construction of lake pumping station	$25,000
*	Construction of rising mains (75 mm)	$91,000
*	Construction of 75 mm distribution pipework	$68,000
*	Construction of 1375 m of 50 mm diameter main to the west of the tank	$45,000
*	Construction of 110 domestic corrections	$2,500
		$250,500

It is assumed that the newly formed VWC with assistance from the MOH will be responsible for project implementation.

8.7.3 Detailed Design

During the detailed design of recommended works it is important that the designer appreciate that the Master Plan provides only preliminary design details. In particular the diameter and location of pipelines recommended need not be rigidly adhered to. When detailed designs are being prepared the following points should be considered.

* Connections are drawn schematically to illustrate system function rather than represent actual pipeline and valve details.

* Although pipe materials have been assumed to be PVC other materials would be suitable, and subject to proper consideration being given to standardisation, final decisions could be based on competitive tenders. Metal pipes will require both internal and external protection. The degree of protection will need to be decided from field tests.

8.7.4 Master Plan Review

During the Long Term period the actual growth within the Study Area should be closely monitored and compared with projections in this report. Variations from the projected growth could occur with respect to time or location.

The confidence with which projections can be made of growth reduces in the long term. It is envisaged that a review of the Master Plan would be made before 2001 probably about 1995 to confirm the appropriateness and scheduling of recommendations in the Long Term programmes in the light of actual growth.

8.8 Land Requirements

Land acquisition will only be necessary for the new reservoirs. The implementation of projects in Tonga can be delayed through problems in the acquisition of land. Many of these problems can be overcome by advanced planning and early initiation of action to acquire the necessary land.

The future, MOH the VWC and Niuafo'ou village members will be responsible for immediate and longer term land requirements.

8.9 Environmental and Sanitation Aspects

8.9.1 Environment

General

The Impact of the Niuafo'ou Master Plan will have a positive effect on the population by providing a reliable water supply. However, as with any change, there will be some minor and mostly insignificant impacts on the human environment.

Works proposed in the Master Plan will have a very minor adverse impact on the environment. The most noticeable aspect will be the temporary inconvenience caused by pipeline construction and minor disruption to supply during upgrading works. However, with proper planning and co-ordination with other authorities any inconvenience and construction noise and dust can be minimised.

Socio-Cultural

The villages of Niuafo'ou have never had to pay for water and consequently it will be necessary for community consultation to occur before any works are started. A VWC will need to be formed. This is currently underway by the MOH.

The environmental aspects of the wellfield development will have no additional adverse impact on the environment.

Impact On the Natural Environment

Impact on the natural environment will be minimal. The urban natural environment of Niuafo'ou will remain unchanged except for minor disturbances during construction.

8.9.2 Water and Sanitation

Present Situation

All wastewater treatment and disposal in the Niuafo'ou service area is by on site methods. Regulations for on site disposal are included the Health Act.

In Niuafo'ou it is estimated that around 10% of the community's households use septic tank – soil absorption/soakaway systems for sewage disposal. Of the remaining households, about 80% use pit latrines and 10% use pour flush latrines.

The only major report on wastewater treatment and disposal in Tonga was undertaken by Belz (1985) as partof the WHO Urban Sewerage and Drainage Project. This project commenced in 1980 and involves the GOT, WHO and the United Nations Development Programme. This report considers Nuku'alofa but some findings apply to conditions on Niuafo'ou. Belz identified inadequacies with the septic tanks, and more severe problems with the associated soil absorption systems. Many septic tanks discharged into a soil absorption system that was too small to dispose of all the effluent or discharged onto the ground surface around the septic tank. He also identified inadequacies in pour flush latrines and pit latrines.

A reticulated sewerage system is not recommended in Niuafo'ou because of:–

- low population density and ribbon like urban development making the system expensive to construct
- the need for a new operating authority (or group) and the shortage of skilled personnel
- disaster vulnerability

Although highly unlikely a piped sewage collection system if be feasible and desirable at some stage in the future beyond the Master Plan design period the population density and the per capita water consumption in Niuafo'ou increases substantially.

Onsite sanitation systems are considered to offer adequate convenience while achieving sanitation objectives. Use of septic tank–soil absorption systems are recommended and, for residents that cannot afford septic tank systems, pour flush latrines. This recommendation applies also to Niuafo'ou. The basis for the recommendation is that:–

- the soil is sufficiently permeable for onsite disposal of septic tank effluent;
- the plot sizes are large enough for septic tanks and soakaways;
- septic tanks with soakaways are cheaper than conventional sewerage;
- septic tanks are generally affordable.

Remedial measures for those existing septic systems that are inadequate are also recommended including:

- Upgrade of domestic septic absorption systems to include properly designed and constructed lined and unlined seepage pits.
- connection of kitchen, bathroom and other household wastewater to septic tanks.
- removal of existing vents on septic tanks and sealing access holes to the tanks.

Remedial works to existing septic tank systems in Niuafo'ou are yet to be undertaken due to the funding restraints of the National Sanitation Programme. It is likely that replacement of existing pit latrines, and to a lesser extent pour flush latrines, would be of higher priority than remedial works to existing septic tank – soil absorption/soakaway systems.

Impact of Increased Wastewater

The proposed Master Plan improvement will increase the amount of wastewater produced in the service area over the duration of the Master Plan as a result of the increased quantity of water supplied. The majority of wastewater will be domestic although some commercial discharge will also occur.

Older sanitation systems which have not been upgraded in line with Belz's guidelines may become unsatisfactory with an increase in household water consumption. Systems based on the guidelines will be adequate.

Recommendations

It is recommended that the current policy of providing sanitation in Niuafo'ou through properly designed and maintained on site disposal systems is continued.

Sanitation facilities designed according to the guidelines developed by Belz will adequately handle the increased wastewater production generated from water supply improvements. It is recommended that these guidelines as adopted by MOH, remain unchanged.

It is recommended that the implementation of the water supply improvements be coordinated with the National Sanitation Programme. Through this programme vulnerable households are assisted to install proper facilities, public awareness is raised and community participation encouraged. The National Sanitation Programme should be extended, as funding becomes available, to include remedial works, where necessary, and to include replacement of existing pit latrines and pour flush latrines.

9 PROJECT COSTS, ECONOMIC AND FINANCIAL ANALYSIS

9.1 Economic and Financial Objectives

The Niuafo'ou Master Plan has as its broad objective to provide, by a series of staged improvements, a safe and reliable water supply system. The Master Plan is designed to ensure that stages are flexible and can be implemented as population growth and developments proceed. Within this broad objective the Master Plan needs to satisfy economic and financial objectives as well. These objectives are;

* In financial terms that each stage can be as far as is possible financially supported by the water consumers through an appropriate tariff or household charge structure in such a manner as to recoup the funds outlayed at construction time (regardless of the source of those funds). The structure to achieve this must of consequence also be within the ability to pay of the water consumers.

* In economic terms, that the use of the funds for construction benefits the overall goals and objectives of the community and the Government's development program in terms of the National economy. This will occur if direct and flow-on benefits from the project facilitate an improvement in the Balance of Trade.

9.2 Costs

9.2.1 Cost Bases

Cost estimates have been based on prices prevailing in early 1991. An escalation rate of 6% p.a. has been adopted to adjust both local and foreign costs to early 1991 and to calculate price contingencies to allow for inflation in capital expenditure.

All costs are in Tongan Pa'anga. The rates of exchange used to convert foreign currencies to Tongan Pa'anga have been taken as the rates applicable on 1st January, 1991.

* 1 Tonga Pa'anga
  - 0.980= Australian dollars
  - 1.270= New Zealand dollars
  - 0.764= USA dollars
  - 0.381= Pounds Sterling

9.2.2 Unit Cost Rates

Unit cost rates used in the preparation of project estimates are tabulated in Appendix E. Rates have been developed from information obtained from many sources, including

* Manufacturers in Tonga, Australia and New Zealand
* Local contractors and materials suppliers
* Recent Government contracts
* Cost records and estimating data from TWB and MOW.

Rates for imported materials and equipment include the cost of shipping, insurance, customs clearance and handling.

Materials costs for pipelines include the cost of fittings and valves.

Pipeline construction rates include allowances for traffic control, handling of other services and pavement restoration. All rates include materials handling, bedding, pipelaying, concrete anchors, testing and backfilling.

Unit costs for service reservoirs and pumping stations include the cost of siteworks and ancillary pipework, fitting, valves, flowmeters and controls.

The estimates for pumping units and other mechanical equipment includes all associated starters, switchgear, controls and instrumentation.

Physical contingency allowances for unpredictable conditions or uncertain quantities have been incorporated into the unit cost rates where appropriate.

9.2.3 Project Costs

Cost estimates and expenditure schedules for the Immediate Improvements Programme and for Long Term Programmes are presented in Figure 9.1
Pipes and fittings have been considered as foreign costs. All mechanical and electrical equipment costs have been considered as foreign.

Excavation for pipelines has been assumed to have significant labour input in line with current Government policy. In the Long Term Programme all excavation is assumed to be by machine.

Estimates for service reservoirs and pumping stations exclude the cost of land.

Engineering costs for survey, design and supervision have been estimated to amount to 12% of total construction costs (5% Supervision and 7% Design) and have been included in the capital cost estimates. It has been assumed that all the engineering costs will be for overseas personnel.

The Capital Costs of recommended works at 1991 price levels and including engineering are summarised as follows:

Niuafo'ou	Total
Immediate Improvement (1991–1995)	$300,720
Long Term Programme (1996–2011)	$76,250
Totals	$376,970

A more detailed summary of the funds required for the Immediate Improvements Programme is presented in Table 9.4.

NIUAFO'OU WATER SUPPLY MASTER PLAN

nfooulv1.wq1

ITEM	LEVEL 1 COST	(COSTS IN $000) 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1 LAKE PUMPING STATION																						
Pump Station	$25,000		25000																			
Rising Main	$91,000		35000	40000	16000																	
2 RETICULATION																						
75ND reticulation main	$68,000		38000	30000																		
50ND reticulation main to west of tank	$45,000			15000	15000	15000																
50ND reticulation main to east of tanks	$65,000							20000	20000	25000												
New House services	$5,500			1500	500	500	500	500	500	500					500				500			
3 RESERVOIRS																						
3 No 22kL reservoirs	$27,000			9000				9000								9000						
				18000																		
4 VWC Facilities	$10,080			10000								80										
TOTAL CONSTRUCTION COST	$336,580	$0	$98,000	$123,500	$31,500	$15,500	$500	$29,500	$20,500	$25,500	$0	$80	$0	$0	$500	$9,000	$0	$0	$500	$0		
ENGINEERING (12%)	$40,390	$0	$11,760	$14,820	$3,780	$1,860	$60	$3,540	$2,460	$3,060	$0	$10	$0	$0	$60	$1,080	$0	$0	$60	$0		
TOTAL CAPITAL COST	$376,970	$0	$109,760	$138,320	$35,280	$17,360	$560	$33,040	$22,960	$28,560	$0	$90	$0	$0	$560	$10,080	$0	$0	$560	$0		
PRICE CONTINGENCY (25%)	$94,242	$0	$27,440	$34,580	$8,820	$4,340	$140	$8,260	$5,740	$7,140	$0	$22	$0	$0	$140	$2,520	$0	$0	$140	$0		
TOTAL PROJECT EXPENDITURE	$496,412	$0	$137,200	$172,900	$44,100	$21,700	$700	$41,300	$28,700	$35,700	$0	$112	$0	$0	$700	$12,600	$0	$0	$700	$0		
		Immediate Improvement Programme					Long Term Programme															

FIGURE 9.1

Table 9.4
IMMEDIATE IMPROVEMENTS EXPENDITURE SUMMARY
$T at 1991 prices

Year	Component			
	Materials/Equipment	Engineering	Totals	with 25% Contingency
1991	$0	$0	$0	$0
1992	$98,000	$11,760	$109,760	$137,200
1993	$123,500	$14,820	$138,320	$172,900
1994	$31,500	$3,780	$35,280	$44,100
1995	$15,500	$1,860	$17,360	$21,700
Totals	$268,500	$32,220	$300,720	$375,900

9.3 Benefits

9.3.1 Beneficiaries

The primary beneficiaries of the implementation of the Water Supply Master Plan are the water consumers of Niuafo'ou Island villages.

9.4 Financial Analysis

Prices/Charges

In this Draft Master Plan initial financial calculations use a derived average tariff per kL. This can be converted to a per household charge if required by multiplying by the average household monthly consumption.

Revenue Projection

Revenue will vary depending upon the actual water use and how the water is charged. Revenue at the average tariff level can be seen on the Finanical Analysis Spreadsheets in Appendix E.

9.4.1 Cash Flows/IRR's and Tariff

Cashflows for the project situation are shown in Appendix E. The Figure 9.5A indicates the Internal Rate of Return for variation in an "average" tariff and variations from predicted water demands. The desired IRR can be selected from the Figure. It has been assumed that an IRR of 4% will be selected for this project.

The spreadsheet figures were manipulated by varying the average tariff until the project option showed an FIRR of 4.00% or better.

Niuafoou

AVERAGE TAR	2.32	
	PROJECT	
NPV	($120,971)	
NPV RATE	8.00%	
IRR	4.00%	
Percent GRANT Funded	0.00%	
DEMAND VARI	1	

Average Income Percentage	
w/o project	with
0.00%	3.64%

Per Household Charge
$15.62

THE TABLE BELOW SHOWS THE PROJECT INTERNAL RATE OF RETURN FOR DIFFERENT TARIFFS

Tarif	Variation in Demand from Predicted							
$/kL	0.40	0.50	0.70	0.75	0.80	0.85	0.95	1.00
1.00	-2.78%	-2.77%	-2.75%	-2.75%	-2.74%	-2.74%	-2.73%	-2.73%
1.05	-2.53%	-2.52%	-2.49%	-2.49%	-2.48%	-2.48%	-2.46%	-2.46%
1.10	-2.28%	-2.26%	-2.24%	-2.23%	-2.22%	-2.21%	-2.20%	-2.19%
1.15	-2.03%	-2.01%	-1.98%	-1.97%	-1.96%	-1.95%	-1.94%	-1.93%
1.20	-1.78%	-1.76%	-1.72%	-1.71%	-1.70%	-1.69%	-1.67%	-1.66%
1.25	-1.53%	-1.51%	-1.46%	-1.45%	-1.44%	-1.43%	-1.41%	-1.40%
1.30	-1.28%	-1.26%	-1.21%	-1.20%	-1.19%	-1.17%	-1.15%	-1.14%
1.35	-1.04%	-1.01%	-0.96%	-0.94%	-0.93%	-0.92%	-0.89%	-0.88%
1.40	-0.79%	-0.76%	-0.70%	-0.69%	-0.68%	-0.66%	-0.63%	-0.62%
1.45	-0.54%	-0.51%	-0.45%	-0.44%	-0.42%	-0.41%	-0.38%	-0.36%
1.50	-0.30%	-0.27%	-0.20%	-0.19%	-0.17%	-0.15%	-0.12%	-0.11%
1.55	-0.06%	-0.02%	0.05%	0.06%	0.08%	0.10%	0.13%	0.15%
1.60	0.18%	0.22%	0.29%	0.31%	0.33%	0.35%	0.39%	0.41%
1.65	0.42%	0.46%	0.54%	0.56%	0.58%	0.60%	0.64%	0.66%
1.70	0.66%	0.71%	0.79%	0.81%	0.83%	0.85%	0.89%	0.91%
1.75	0.90%	0.95%	1.03%	1.06%	1.08%	1.10%	1.14%	1.16%
1.80	1.14%	1.19%	1.28%	1.30%	1.32%	1.35%	1.39%	1.42%
1.85	1.38%	1.43%	1.52%	1.55%	1.57%	1.59%	1.64%	1.67%
1.90	1.62%	1.67%	1.77%	1.79%	1.82%	1.84%	1.89%	1.91%
1.95	1.85%	1.90%	2.01%	2.03%	2.06%	2.09%	2.14%	2.16%
2.00	2.09%	2.14%	2.25%	2.28%	2.30%	2.33%	2.38%	2.41%
2.05	2.32%	2.38%	2.49%	2.52%	2.55%	2.57%	2.63%	2.66%
2.10	2.55%	2.61%	2.73%	2.76%	2.79%	2.82%	2.88%	2.90%
2.15	2.79%	2.85%	2.97%	3.00%	3.03%	3.06%	3.12%	3.15%
2.20	3.02%	3.08%	3.21%	3.24%	3.27%	3.30%	3.36%	3.39%
2.25	3.25%	3.32%	3.45%	3.48%	3.51%	3.54%	3.61%	3.64%
2.30	3.48%	3.55%	3.68%	3.72%	3.75%	3.78%	3.85%	3.88%
2.35	3.71%	3.78%	3.92%	3.95%	3.99%	4.02%	4.09%	4.13%
2.40	3.94%	4.02%	4.16%	4.19%	4.23%	4.26%	4.33%	4.37%
2.45	4.17%	4.25%	4.39%	4.43%	4.46%	4.50%	4.57%	4.61%
2.50	4.40%	4.48%	4.63%	4.66%	4.70%	4.74%	4.81%	4.85%
2.55	4.63%	4.71%	4.86%	4.90%	4.94%	4.98%	5.05%	5.09%
2.60	4.86%	4.94%	5.10%	5.14%	5.18%	5.21%	5.29%	5.33%
2.65	5.09%	5.17%	5.33%	5.37%	5.41%	5.45%	5.53%	5.57%
2.70	5.32%	5.40%	5.56%	5.61%	5.65%	5.69%	5.77%	5.81%
2.75	5.54%	5.63%	5.80%	5.84%	5.88%	5.92%	6.01%	6.05%
2.80	5.77%	5.86%	6.03%	6.07%	6.12%	6.16%	6.25%	6.29%
2.85	5.99%	6.08%	6.26%	6.31%	6.35%	6.40%	6.48%	6.53%

FIGURE 9.5A

From the analysis it can be seen that a unit tariff of $2.32/kL will produce the required 4.00% rate of return. This represents a per household charge of $15.62 per month. This amount is 3.64% of Household Incomes and is above the cut-off criteria of 3.00%. By way of comparison if the system was 100% grant funded and the New VWCs were only to recover recurrent costs then a tariff of $1.60 per kL or $10.74 per household per month applies. This is 2.51% of Household Incomes and within the cut-off criteria.

The actual tariff to charge will be dependent on the final financing option chosen.

9.4.2 Sensitivity & Risk Analysis

To determine the sensitivity of the projects the spreadsheet was created to allow variations in the following parameters to show changes in the Internal Rate of Return.

(i) Variation of water use from that predicted in this Master Plan (reflected from population, demand, or No of connections)

(iii) Changes in construction costs and timings

(iv) Comparison of tariff as a percentage of household incomes (using a cut-off criteria of between 2% to 3% of Household Incomes)

(v) Trial tariff charge rates

9.5 Economic Analysis

A formal detailed economic analysis has not been performed.

9.5.1 Risks

It is important that the risks involved in the implementation of the various stages of the Niuafo'ou Master Plan are understood. In most circumstances the level of risk is minimised by the flexibility inherently built into the Master Plan

Identifiable risks are;

1. If development and population growth do not proceed at the rate or occur in different areas than predicted. This risk is minimal as the staging allows implementation at appropriate times with the flexibility to modify as needed.

2. Incomes predicted may not be realised if there is consumer resistance to paying for water where they haven't in the past. This risk is high but can be minimised through a careful community consultation program.

9.6 Staging and Funding

9.6.1 Staging

Staging of the works would be as follows;

* The Immediate Improvement Program in place and operational by 1996

* The Long Term Program by 2011.

The staging of the works will depend on actual population growth and availability of funds. It should be reviewed at five (5) yearly intervals by the Village Water Committee, Ministry of Health, Water Resources Committee and the Central Planning Department.

9.6.2 Funding

Funding of the project has not been determined at this time. The high capital costs and the burden that full recovery would place on consumers would indicate that some form of grant funding will be required.

9.7 Management

Management proposals are shown in Section 10.1.1. The cost of paid staff are shown below:–

Superintendent (50% part time)	$3532 pa
Pump Operator/Mechanic/Plumber (full time)	$4984 pa
Bookkeeper (50% part time)	$2397 pa

10 OPERATION AND CONTROL

10.1 General

This chapter presents guidelines for distribution of water under normal conditions, outlines the monitoring system and controls needed for efficient operation, and describes distribution methods under emergency conditions.

10.1.1 Management

Alternative management proposals and required structure for the management of the water supply system are detailed in the Tonga Water Supply Master Plan, Institutional Strengthening and Community Development Report.

There a several options considered:

1. Form a village water committee with all voluntary staff.

2. Form a Village Water Committee on a voluntary basis with paid staff.

3. To hand over control entirely to the TWB.

Option 2 would not provide the expertise required to efficiently operate and maintain the upgraded system in the long term but is certainly the preferable option initially. If a desire by the community to be managed by the TWB should ever occur the system under the Master Plan would be in a position to be easily handed over to the TWB since by that time a correctly maintained and financially viable entity would exist.

Suggested staff for Option 2 are shown in the spreadsheets along with likely wages and summarised below:

Superintendent (50% part time)	$3532 pa
Pump Operator/Mechanic/Plumber (full time)	$4984 pa
Bookkeeper (50% part time)	$2397 pa

10.2 Operating Procedures

10.2.1 Lake Pumping Station

The lake pumping station will be operated manually as discussed in Section 10.4. The pump will be run as required to maintain supply in the storage tanks.

The pump will be shut off when the storage tanks are full which is influenced by the rate of non-potable water consumption. If consumers use more rainwater, rather than non-potable water, than is forecast in Table 5.3 it will be necessary to stop and start the pump at least once per day.

10.2.2 Service Reservoirs

Storage reservoirs should be periodically drained and cleaned.

10.3 Emergency Operation

Emergency operation is necessary in the event of damage to key water supply facilities in particular major pipelines. The construction of bypass pipelines and repairs to restore water supply can usually be effected in a number of days during which rainwater supplies can be used. Damage following a serious earthquake would take longer to repair but such events are rare in Tonga.

10.4 Water Leakage Detection And Control

Reduction of leakage can produce potentially large cost savings from deferral of capital works and from reduced operating costs. There will be a need to control leakage within the Niuafo'ou system in the future.

Leakage Detection and Control

The recommended leakage detection and control programme would be carried out by the VWC possibly with technical advice from the TWB when the programme is first established. VWC control of the programme is essential as they know will the location and condition of the reticulation system. This also promotes a sense of responsibility for the supply facilities and allows the owners of the system to decide to what extent they will reduce operational costs incurred by leakage. The design of a leakage programme will occur during the detailed design of the Master Plan works.

Specific components of the recommended leakage detection and control plan include:

LEAKAGE ASSESSMENT

1. The method used is known as a step test and includes measurement of water used from the elevated reservoir during a low demand period of from, say, 1am to 5am. The VWC contacts all village consumers and requests all water consuming facilities to be shut off during the reservoir drop test.

2. All nominated groups of section valves on the distribution mains are closed at specified times to ensure consumers are sequentially isolated from the water supply.

3. Each district, say groups of around 30 houses, is isolated from the tanks by progressively closing the section valves at an interval of approximately 45 minutes. Following the closure of the last section valve all valves are then opened to re-establish supply.

4. The flow of water into each district is calculated by measuring the loss of water in the elevated tank. The level of water usage in each district is recorded on a suitable form.

5. Any district which exhibits a disproportionately high water use has a relatively high water leakage rate. It will only be practical to reduce the leakage to a moderate level rather than to stop the leakage altogether.

6. The cost of operating the water supply to produce this leakage is compared with the estimated cost of locating and repairing the leaks. If it is cheaper to reduce the leakage then leakage detection and repair work is undertaken.

LOCATING AND REPAIRING LEAKS

1. Locating and repairing leaks firstly involves inspecting the ground surface above the pipes in the district that showed an unacceptably high leakage level. Wet areas or unusually dense vegetation above sections of the pipeline would evidence leakage.

2. If there are no above ground signs of the leaks then excavation of the pipeline will be necessary. This involves progressively exposing the pipeline until the leak is located.
3. The leaking pipe is repaired and details of the location of the works and cost and extent of repairs are recorded.

10.5 System Control And Monitoring

To effectively control and operate the water supply system monitoring of system parameters including lake pumping, water flow at key points, pumping hours and reservoir levels is required.

Provision should be made for a possible increase in the degree of automation when justified by increasing labour costs and the availability of skilled local technicians capable of maintaining such equipment. This automation includes the stopping and starting the lake pump subject to water level in the storage tanks. However control and monitoring of the system will remain predominantly manual for some considerable time.

10.5.1 Lake Pumping Station

The primary control parameter will be the flowrate from the lake . It is necessary for the pump to be equipped with an operational flowmeter that should be read on a daily basis.

The pumping unit will have diesel motor protection and hours run indicators.

10.5.2 Reservoir Control

Both reservoirs will be fitted with a water level indicator and a simple mechanical device which would indicate the occurrence of reservoir overflow.

10.6 Watermain Records

The proposed layout for the Niuafo'ou water distribution system is shown as Figure 8.1. This plan should be transfered to a 1:2000 scale or a similar scale compatible with MLSNR base maps and ammended following construction of the works. The as built drawings when completed should show the size, type, location and year of installation of all pipes as well as valvess and fittings. In particular the smaller diameter pipes should be shown. The VWC may be able to seek assistance from the MSLNR or MOW to help prepare the drawings.