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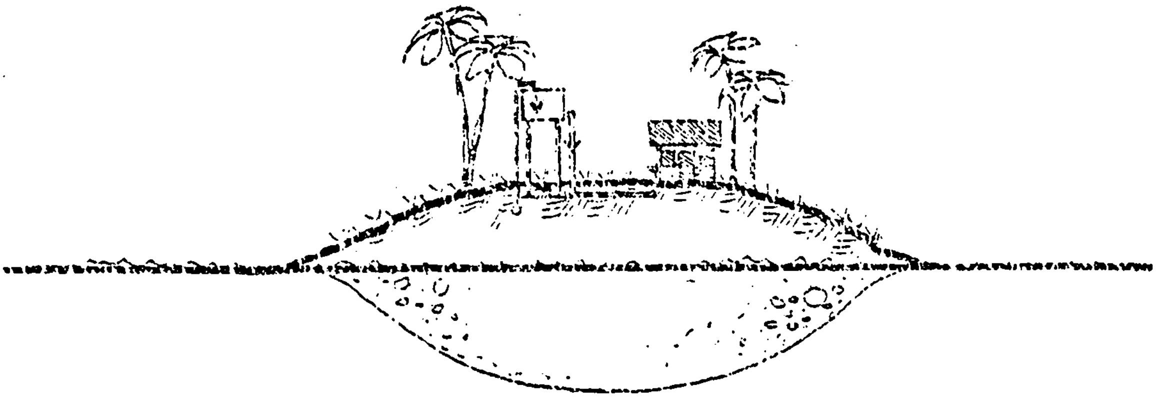
REVIEW OF TARAWA WATER SUPPLY PROJECT



COASTAL AND ENVIRONMENTAL ENGINEERING BRANCH

Report Nº OS 236

MAY 1986

DRAFT

Department of Housing and Construction

Review of
Tarawa Water Supply Project

May 1986

Prepared by: Coastal and Environmental Engineering Branch, Central Office

for : Projects Division, ACT Region

REVIEW OF TARAWA WATER SUPPLY PROJECT [illegible]

Preface

This report was prepared during May 198[illegible] by Mr S. Leppert and Mr D. Henley of Central Office. No visit to Tarawa was possible in the period specified for the review. The observations and comments contained within the report are derived mainly from existing reports and discussions with people who have been involved on site in various aspects of the project.

Special thanks are made for the valuable contributions by Messrs W. Bencke, A. Falkland and P. Mylrea of the Department of Territories whose input to this report was made possible by the kind permission of Mr R. Wardrobe also of the Department of Territories.

DRAFT

SYNOPSIS

This report presents a summary of the history, investigations and progress on the Tarawa Water Supply Project. A brief chronological history of the development of water supply on Tarawa is presented as well as a more detailed summary of the reports and investigations relating to the current project.

A brief description of freshwater lenses is presented as well as a summary of the investigations into the Tarawa lenses. Monitoring requirements are also covered.

The findings of the Pre-design Study on population and demand predictions are presented. These findings are discussed and updated where applicable. A number of issues including deletion of public standpipes and the benefits of the household rainwater tank program are discussed.

A review of the design of the system is presented in Chapter 4. Some minor problems are discussed as well as recommendations on the future strategy for augmentation of the system.

Training issues are discussed in Chapter 5. Recommendations on the areas and requirements for training are discussed.

Summary of Recommendation

Chapter 2

2.1 Current salinity monitoring of Bonriki and Teaoraereke lenses should continue on a monthly basis.

2.2 Repair or redrilling (if necessary) of the Buota boreholes be carried out in conjunction with drilling for Abatoa and Tabiteuea.

2.3 Existing salinity information should be collected in one database and processed. The processing should be designed to correlate predictions of lens behaviour and the measured behaviour.

2.4 The work by Volker et al on modelling of transition zone behaviour should be considered for inclusion in any design of lens modelling computer programs.

2.5 Future monitoring of lenses is essential. The monitoring program must be designed as an integral part of the operation of the lenses. Frequency of monitoring should be established before handover to the PUB.

2.6 Some specialist Australian involvement in interpretation of monitoring results is essential during the first five years of operation of the new scheme. It should be possible to transfer the essential knowledge of safe operation of the lenses to the PUB during this time. Some continuing but decreasing involvement may be necessary after five years.

Chapter 3

3.1 Future population figures for South Tarawa should be collected and related to existing census data in an attempt to improve population predictions. Currently, population growth appears to be slowing down. The extent of this reduction in growth and the reasons for it need to be known for future water supply planning.

3.2 Consumption figures from existing metered houses and future metered connections should be collected to establish actual rates of water consumption. This data should be collected for the full range of domestic, business and industrial users. This information is vital for planning of water supply alterations and augmentation.

3.3 Loss rates for stage one of the system should be measured. Full metering of the bulk supply system and all consumers should provide ample information to establish the percentage of lost or unaccounted for water. Action should be taken to trace the source of losses if the figure exceeds 10-20% of total water produced.

3.4 A leak detection survey of the completed scheme should be considered before final handover to the PUB. This survey should concentrate on existing bulk supply mains and include all reticulation pipework. Tanks and reservoirs should also be surveyed.

3.5 The issue of deletion of public standpipes and the means of ensuring access to water for 100% of the population needs to be addressed. The costs for connection and water usage need to be in line with the aim of ensuring complete coverage of the population.

3.6 The whole issue of financial management of the water supply system needs to be reviewed to ensure the long-term success of the scheme.

3.7 The subsidised household rainwater program should be limited initially to ensure the viability of the lens water program.

3.8 The interest-free charge for tanks should be reviewed (see 3.6 above).

3.9 Charges for owners of household rainwater tanks who 'waste' water need to be established. Some penalty should be incorporated into charges for lens water supplied in these circumstances (except in a drought).

3.10 Owners of houses with household rainwater tanks need to be served by the lens water system during droughts worse than the one in ten year drought. The supply mechanism and the charges for such water need to be established. An official declaration of drought may be required to differentiate between householders who have 'wasted' water and those who genuinely run out due to drought.

Chapter 4

4.1 Reticulation pipework laid in conjunction with the sewerage project in the villages of Bikenibeu and Bairiki should be fully inspected, pressure tested and disinfected prior to incorporation into the new scheme.

4.2 The scheme as currently being constructed should be completed without any significant alterations. Reviews of the system performance after completion should be carried out annually by Australia to establish the need for augmentation and/or alterations. These reviews could be carried out in conjunction with lens monitoring reviews.

4.3 The positive displacement type pumps proposed for Buota and Bonriki galleries should be installed due to their advantage in preventing overpumping of the lenses. If future analyses show more economical pumping arrangements are possible the pumps should be replaced. Any new gallery pumps should be designed to ensure overpumping cannot occur.

4.4 The valve type, size and configuration for throttling of reservoirs should be studied in more detail.

4.5 Overhead tanks at [illegible] [illegible] [illegible] and [illegible] are unable to be directly [illegible] from the [illegible] main during certain conditions of flow in this main. This problem needs further investigation.

4.6 A review of the location and size of all storage tanks (including overhead tanks) should be made to ensure current and future population is adequately served.

4.7 The Teaoraereke lens is currently 'disturbed' due to existing overpumping. The new galleries and pumps could be deferred to allow the lens to recover. The need for the lens to be exploited could be reviewed if and when required. If the galleries and pumps are installed as part of the current program they should not be used until monitoring of the lens indicates sufficient recovery of the lens. This recovery period could extend over a number of years.

4.8 Water hammer in the system should be thoroughly investigated.

4.9 An investigation into the apparent hydrogen sulphide (H_2S) problem should be carried out. High H_2S levels increase chlorine requirements and hence costs as well as being potentially offensive to consumers.

4.10 The Kiribati government should pursue the acquisition of water reserves on Abatao and Tabiteuea which are the next two islands identified for future expansion of the water supply scheme.

Chapter 5

5.1 Training in various trade skills be undertaken during the remainder of the construction period.

5.2 Training of the Water Supply Superintendent and three others in various aspects of system operation be undertaken for a three month period commencing a month before initial start up. A local engineer should be included if possible.

5.3 This training be undertaken by an appropriate person separate from site construction staff.

5.4 Continuing support to operators be provided for up to five years, involving regular visits to Tarawa by the trainer.

5.5 One follow-up visit be timed to coincide with commissioning of the second series of galleries, if this is appropriate.

5.6 The Water Superintendent and one other attend a short training course in Australia on chlorination.

5.7 Australia accept some ongoing professional level responsibility for system operation by reviewing the system performance, including the freshwater lens, initially on an annual basis.

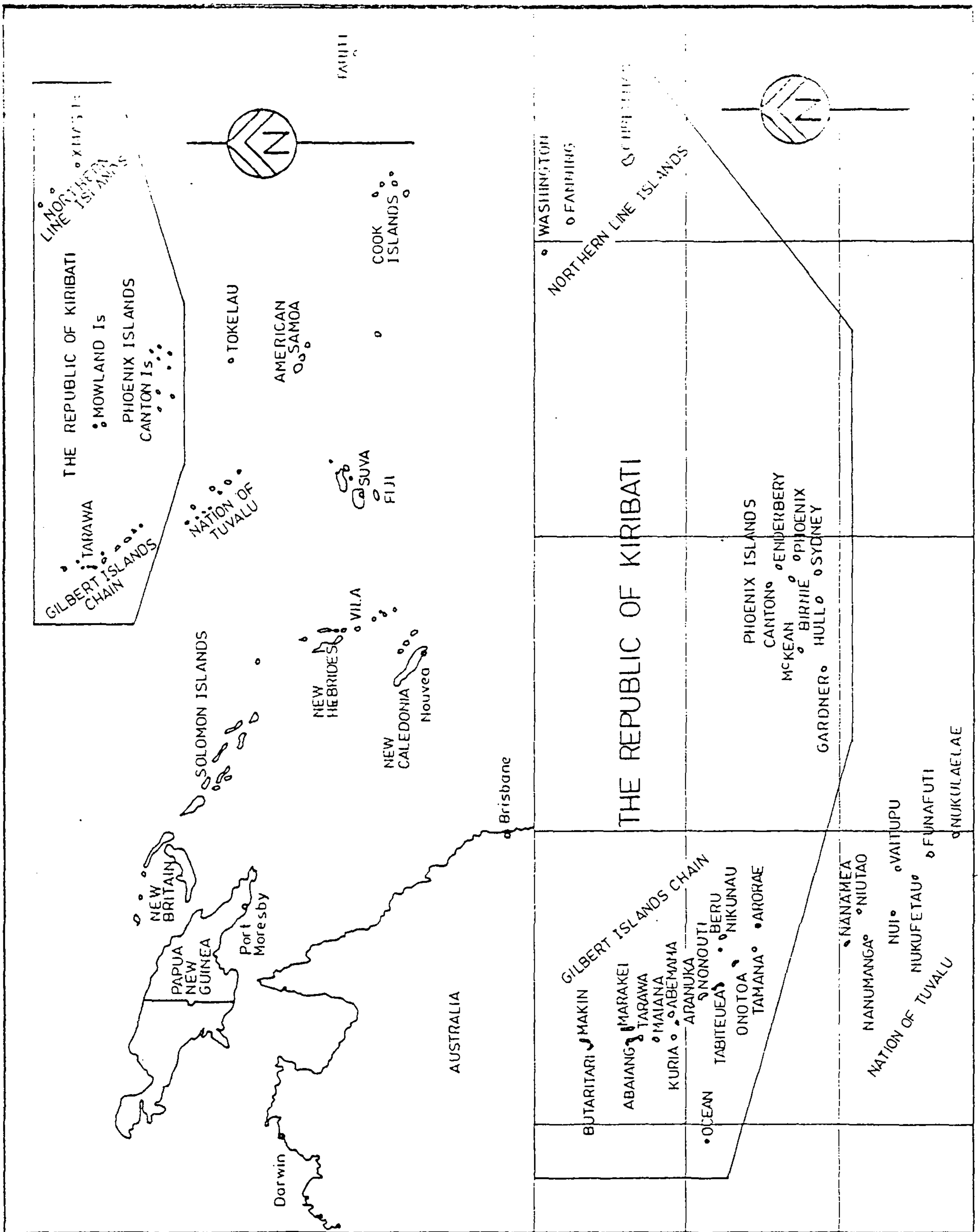
5.8 Operation and Maintenance manuals for specific pieces of electrical and mechanical equipment be prepared in Australia prior to preparation of the system operation and maintenance manual.

5.9 A draft system operation and maintenance manual be finalised in Tarawa during the two months prior to initial starting.

5.10 The draft operation and maintenance manual be updated after twelve months of operation.

5.11 A program of community education about the water supply system including preparation of a film be undertaken.

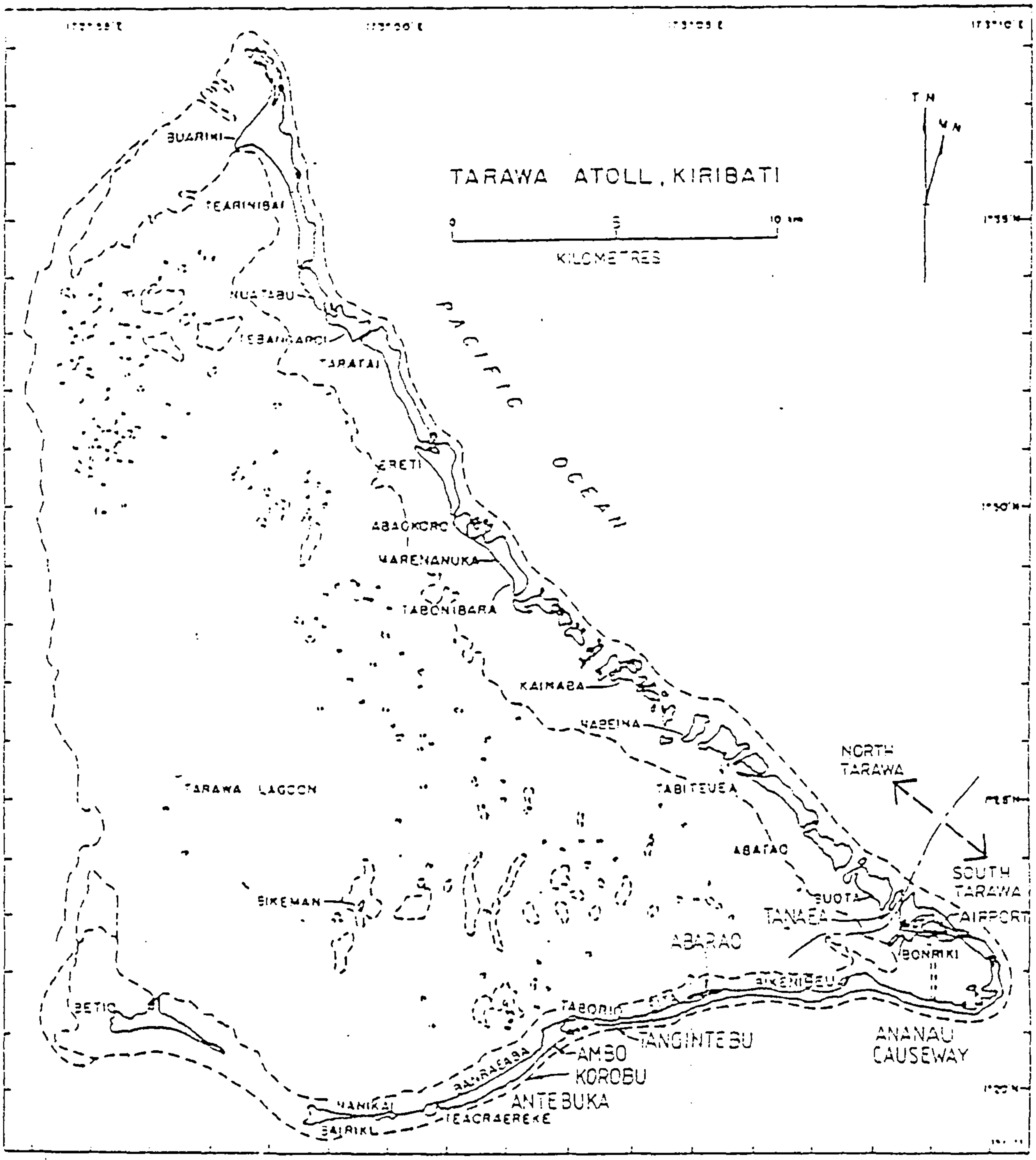
5.12 Confirmation be sought that the PUB is giving adequate attention to financial management of the system.



REPUBLIC OF KIRIBATI

LOCALITY MAP

Figure 1·1A



TARAWA ATOLL	Figure 1·1B

[illegible]

In December [illegible], responsibility for the Tarawa Water Supply Project transferred to Projects Division of the ACT Regional Office from the former Water Supply and Sewerage Division (now part of the Department of Territories). This report was prepared by the Coastal and Environmental Engineering Branch of Central Office of the Department of Housing and Construction (DHC) following a request from the ACT Regional Office of DHC for a review of certain aspects of the project. The report covers:

(i) the historical background of Australia's involvement in water supply aid to Tarawa (including the current project);

(ii) the behaviour of the freshwater lenses which are central to the viability of the water supply scheme;

(iii) a review of projected water demands;

(iv) a review of the design of the water supply scheme; and

(v) training, handover and future support requirements for the project.

1.1 Background

Tarawa is an ocean atoll located at approximately 1°30' North and 173°00' East. The atoll consists of an island fringed lagoon extending about 30 km from east to west and about 38 km from north to south. (Fig 1.1). The islands along the southern edge of the lagoon (from Betio to Tanaea) are known as South Tarawa and those along the north-eastern edge (from Tanaea to Buariki) as North Tarawa. Tarawa is one of the many atolls and islands of the Gilbert Islands which together with the Line and Phoenix Islands form the Republic of Kiribati. Tarawa is the centre of government of the Republic of Kiribati.

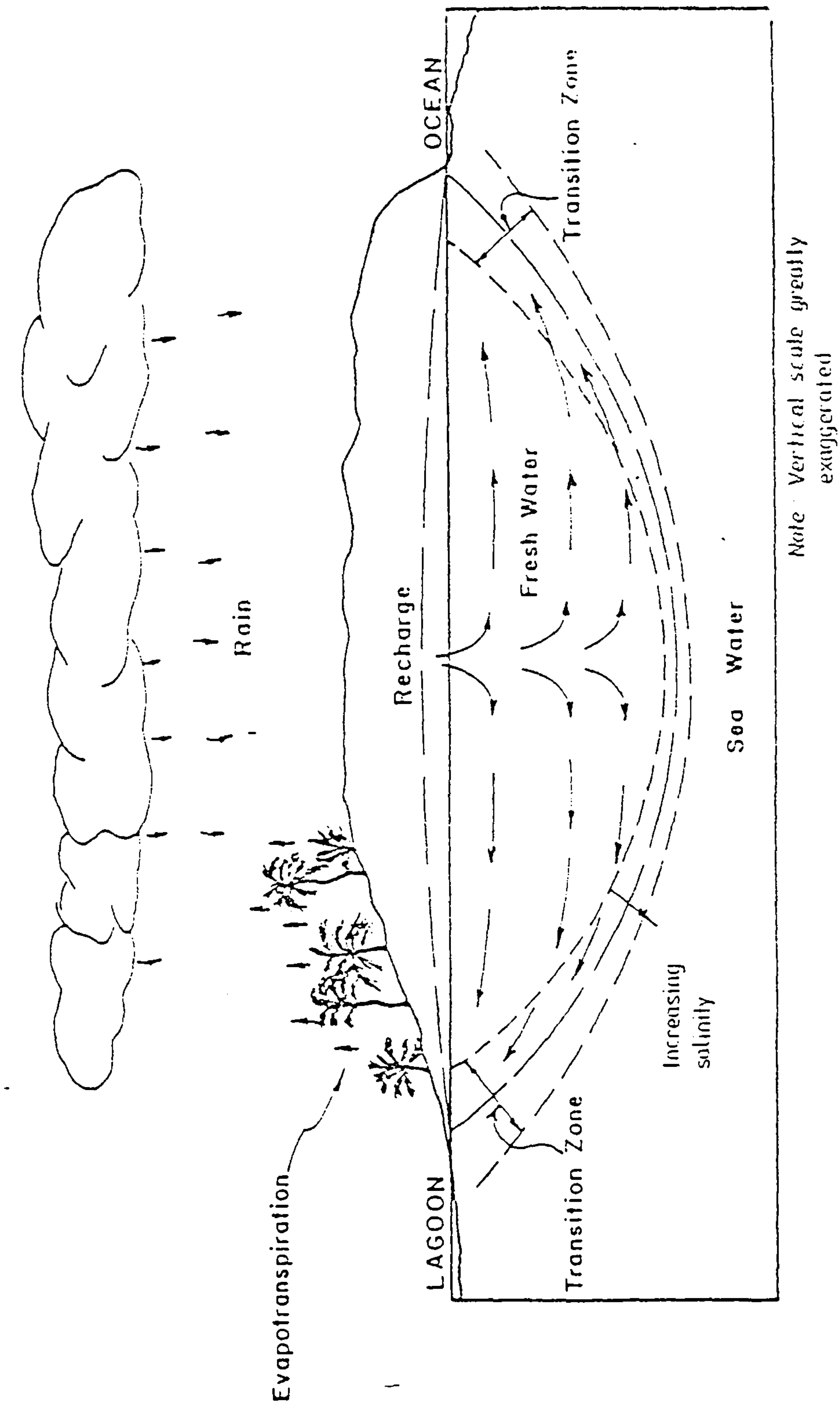
In the latest census of May, 1985. South Tarawa had a population of 21,393. South Tarawa is the urbanised part of Tarawa and has been experiencing high population growth over recent years due mainly to high internal migration.

1.2 Historical Background

On Tarawa, potable water has traditionally been derived from two sources; rainwater collection schemes and groundwater sources. Rainwater collection has always been of limited extent and the majority of the population derived its potable water from groundwater sources.

1.2.1 Groundwater

All of the islands of the Tarawa atoll are underlain to some degree by reserves of relatively fresh groundwater of varying salinity and purity. The occurrence of freshwater storage in this situation is known as a 'lens'. (See Fig 1.2).



TYPICAL LENS

FIGURE No. 1·2

The [illegible] and traditional means of extraction of groundwater [illegible] dig down to the water table (usually only 1-2 m below ground level) and extract water from the resulting well. More recently, lens water has also been extracted using pumps.

Two major problems with the traditional groundwater sources on Tarawa have been:

(i) contamination from human wastes due principally to the lack of a suitable sewerage scheme; and

(ii) where pumped extraction has been introduced, some localized over-pumping. This has caused major disruption to lenses in these areas resulting in increased salinity levels.

The rapidly increasing population over the past two decades placed increasing strain on the existing groundwater sources and led to requests for overseas aid to improve the sewerage and water supply systems.

1.2.2 Australian Involvement

Australia's involvement in water supply aid to Kiribati began in the early 1970's. A feasibility study of potable water supply sources for the island of Betio (the major population centre of South Tarawa) was carried out in 1972 by the then Department of Works (now DHC) (Reference 1).

The water supply scheme proposed in that report was then implemented. A dual reticulation system was proposed with one system carrying potable water for drinking and washing and the other seawater for flushing a waterborne sewerage scheme. The potable water system was constructed in the 1970's and consisted of major lens water extraction galleries and pumps at Buota and Bonriki and minor galleries at Teaoraereke-Antebuka and Betio. A rising main of six inch (155 mm) PVC pipe was constructed linking Buota and Teaoraereke. Prior to the Australian scheme, a New Zealand government sponsored scheme was built comprising galleries at Teaoraereke-Antebuka, a four inch (100 mm) PVC rising main linking the galleries with Betio and a half-million gallon (2.27Ml) concrete reservoir on Betio. The Australian scheme provided a reticulation system on Betio for potable water.

The problem of lack of adequate sewerage facilities was relieved by an Australian aid project which provided a seawater flushed sewerage scheme for South Tarawa. This scheme was constructed between 1978 and mid-1983.

Increasing population on South Tarawa including Betio during the 1970's and a cholera outbreak in 1977 led the Kiribati government to seek assistance to further develop the water resources of Tarawa. The British consulting engineering firm, Richards and Dumbleton International (RDI) (Reference 2) was commissioned by the Kiribati authorities in 1978 to execute a study of the water resources of Tarawa. The Australian government was then requested by the Kiribati Government to implement the RDI proposals. Following a review of the RDI report in Australia it was proposed that further investigatory work be carried out to more accurately determine the potential of the known freshwater lenses on South and North Tarawa and other lesser water supply resources such as household rainwater collection and centralised rainwater collection from larger public buildings.

The [illegible] phase of this investigation [illegible] team from the Water Supply and Sewerage [illegible] of DHC supported by Central Investigation and Research Laboratory of DHC and the Bureau of Mineral Resources, Geology and Geophysics (Reference 3).

This field investigation work was the basis of the "Tarawa Water Resources Pre-Design Study" (Reference 4) prepared by DHC and released in late 1981. This major report summarised existing water resources on Tarawa and proposed a scheme to safely utilize these resources. This scheme provided for safe water supply to all inhabitants of South Tarawa principally from lens water. An increased household rainwater collection scheme was also proposed as a minor additional source of water. The overall cost of the scheme was estimated to be $2.8 million in June 1981.

The scheme (Fig 1.3) proposed for South Tarawa consisted of:

* new infiltration galleries and pumping installations at Buota, Bonriki and Teaoraereke;

* upgraded main connecting Betio and Teaoraereke;

* village reservoirs and overhead tanks; and

* reticulation, house connections and standpipes to make water easily accessible to all inhabitants of South Tarawa.

The Government of Kiribati formally requested Australian assistance with construction of the Tarawa water supply project (TWSP), in December 1982. It also requested that work on the TWSP begin prior to the completion of the Tarawa Sewerage Project (TSP) due to concern over large-scale retrenchments of the labour force engaged on the TSP.

Australian Government ministerial approval was granted in March 1983 for expenditure of $3.21 million on the TWSP over three years. $3.21 million was the updated estimated for the project in March 1983 values.

An Australian Development Assistance Bureau (ADAB) program planning mission of July 1983 recommended that a review team be sent to Tarawa with the objectives being

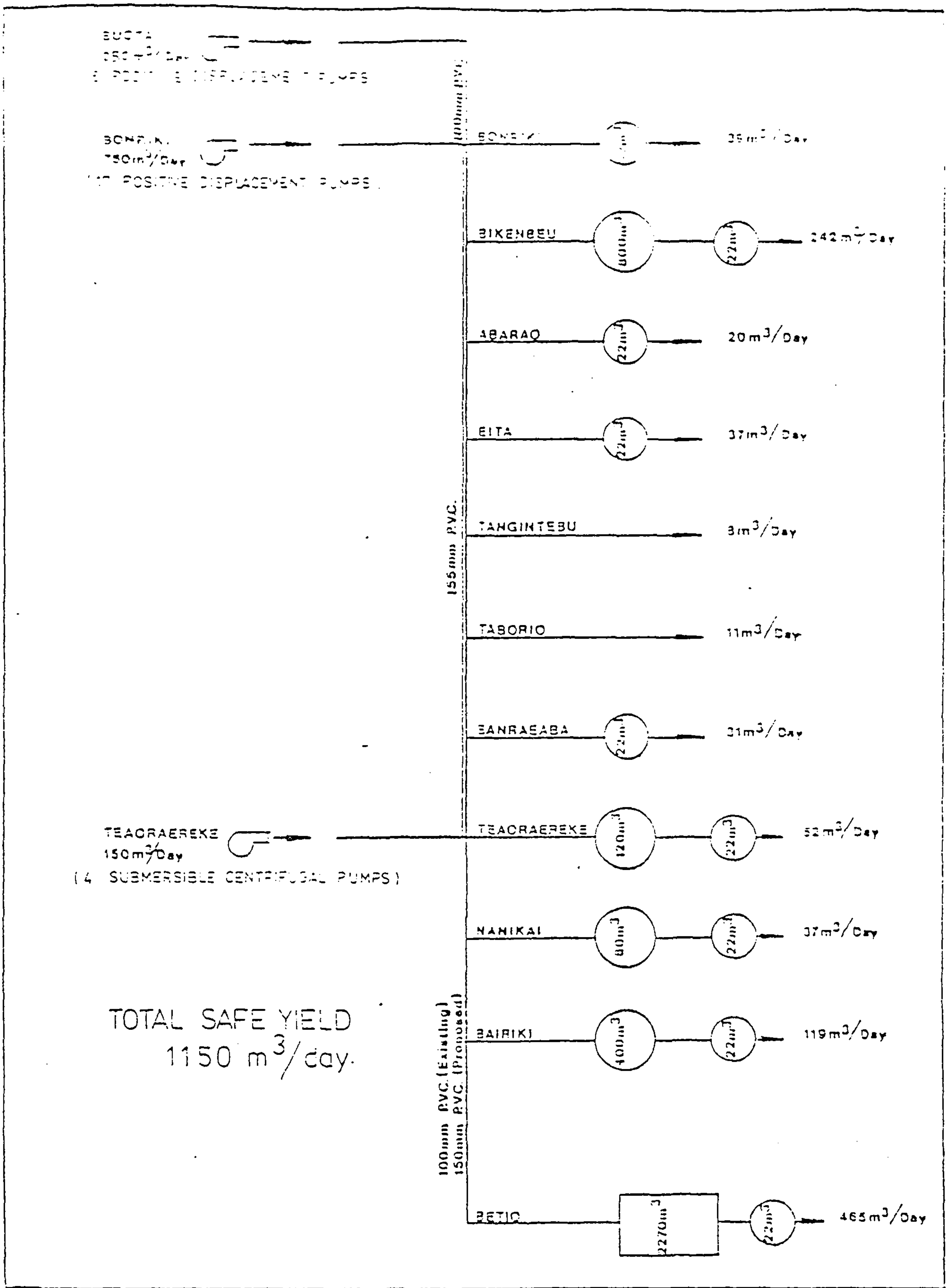
* evaluation of the completed Tarawa Sewerage Project;

* appraisal of the Tarawa Water Supply Project; and

* review of the management of the Tarawa Public Utilities Board (PUB).

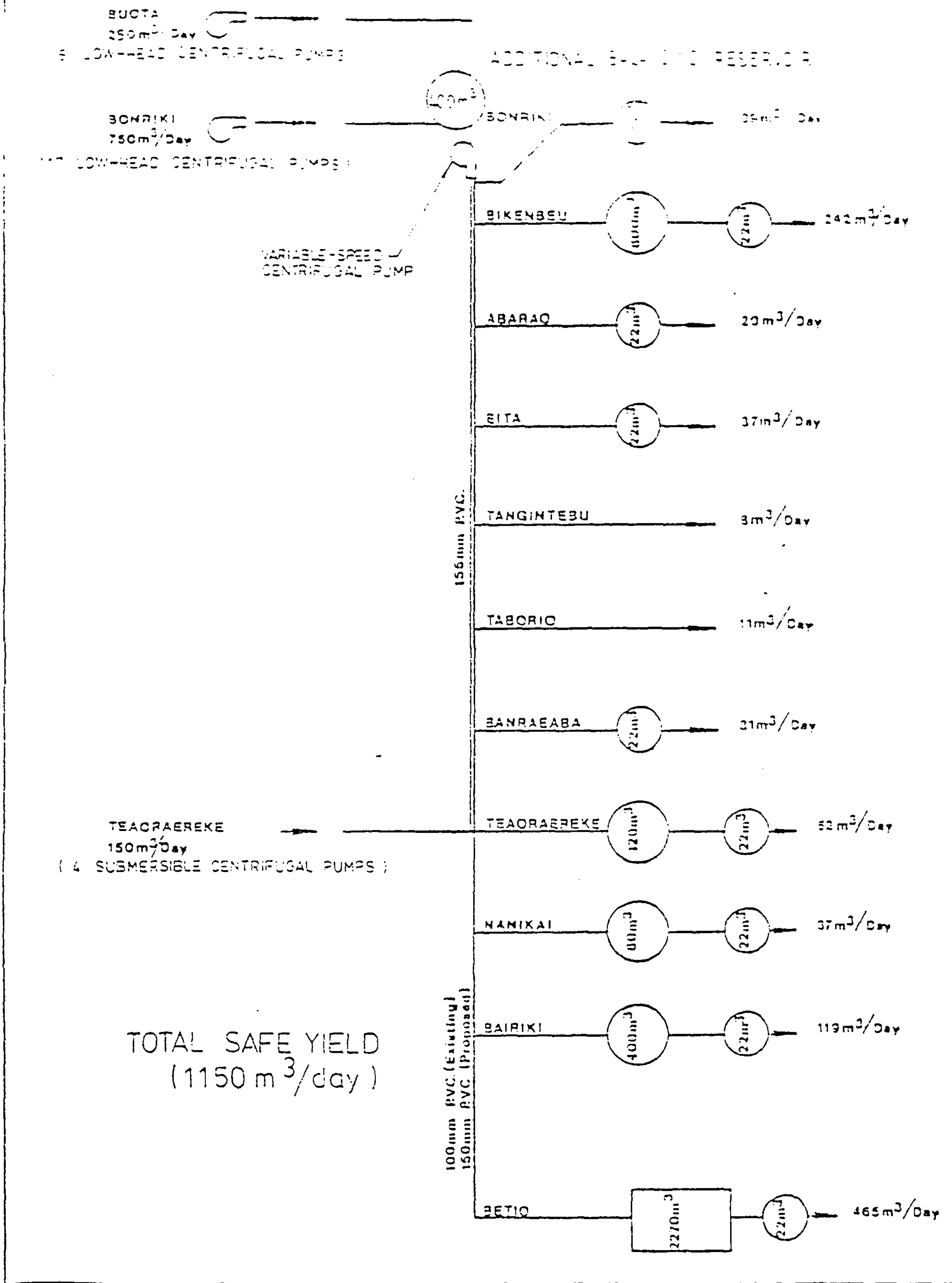
Following this planning mission the budget for the TWSP was increased to $4 million and the construction period increased to four years.

The ADAB review team visited Tarawa in late 1983 and completed a draft report in February 1984 (Reference 5). The report made a number of recommendations and delays in the decisions on which recommendations were to be followed led to significant delays in construction progress on site. Final decisions on which recommendations were to be followed were transmitted to the site towards the end of 1984.



Pre-design Study Proposed Scheme [Year 2000 Projection B Domestic Demands shown]

FIGURE No. 1·3



Scheme Two ('From Comparison of Alternative Pumping Arrangements') [Year 2000 Projection B Domestic Demands shown]

FIGURE No. 1·4

One of the major concerns expressed by the ADAB review team was the high operational cost of the proposed scheme. Several alternative pumping and reservoir arrangements were proposed in the report. The ADAB review team recommended that an urgent review of pumping arrangements be undertaken.

This review was undertaken in 1984 by DHC (Water Supply and Sewerage Division, ACT Region) and the findings summarised in the report "Kiribati-Tarawa Water Supply, Comparison of Alternative Pumping Arrangements" (Reference 6).

This report concluded that no capital cost savings could be achieved by changing the original pre-design study proposal. If a reduction in recurrent costs was desired, however, then the adoption of a modified scheme could achieve this at an increased capital cost.

The modified scheme (known as Scheme 2) involved construction of a low-level reservoir and variable speed pump station at Bonriki, and the use of low-head centrifugal pumps on the galleries at Buota and Bonriki (see Fig 1.4). Water would be pumped from the Buota and Bonriki galleries to the reservoir on Bonriki and from there by the variable speed pump to the remainder of South Tarawa.

The report further recommended, however, that due to critical water shortages on Tarawa the original scheme be immediately implemented. The Scheme 2 modifications could then be implemented towards the end of the project subject to a review at that time carried out in consultation with the PUB.

Currently (May 1986) the project is about 40% complete. Construction of the 225 mm PVC rising main and the galleries on Bonriki are well advanced. Significant progress has been made on the Buota galleries, overhead tank stands and tank installation and on the rainwater tank program.

The project is scheduled for completion by December 1987.

2. BEHAVIOUR OF FRESHWATER LENS

2.1 Introduction

The islands of the Tarawa atoll are all underlain by freshwater lenses of varying size, salinity and purity. Where favourable geological conditions occur, these lenses exist in a delicate state of dynamic equilibrium in which some of the freshwater is continuously being lost to the ocean and the lens is recharged by rainfall percolating into the lens from above.

When water is pumped from a lens, the depth of the lens reduces and the width of the transition zone between freshwater and seawater generally increases.

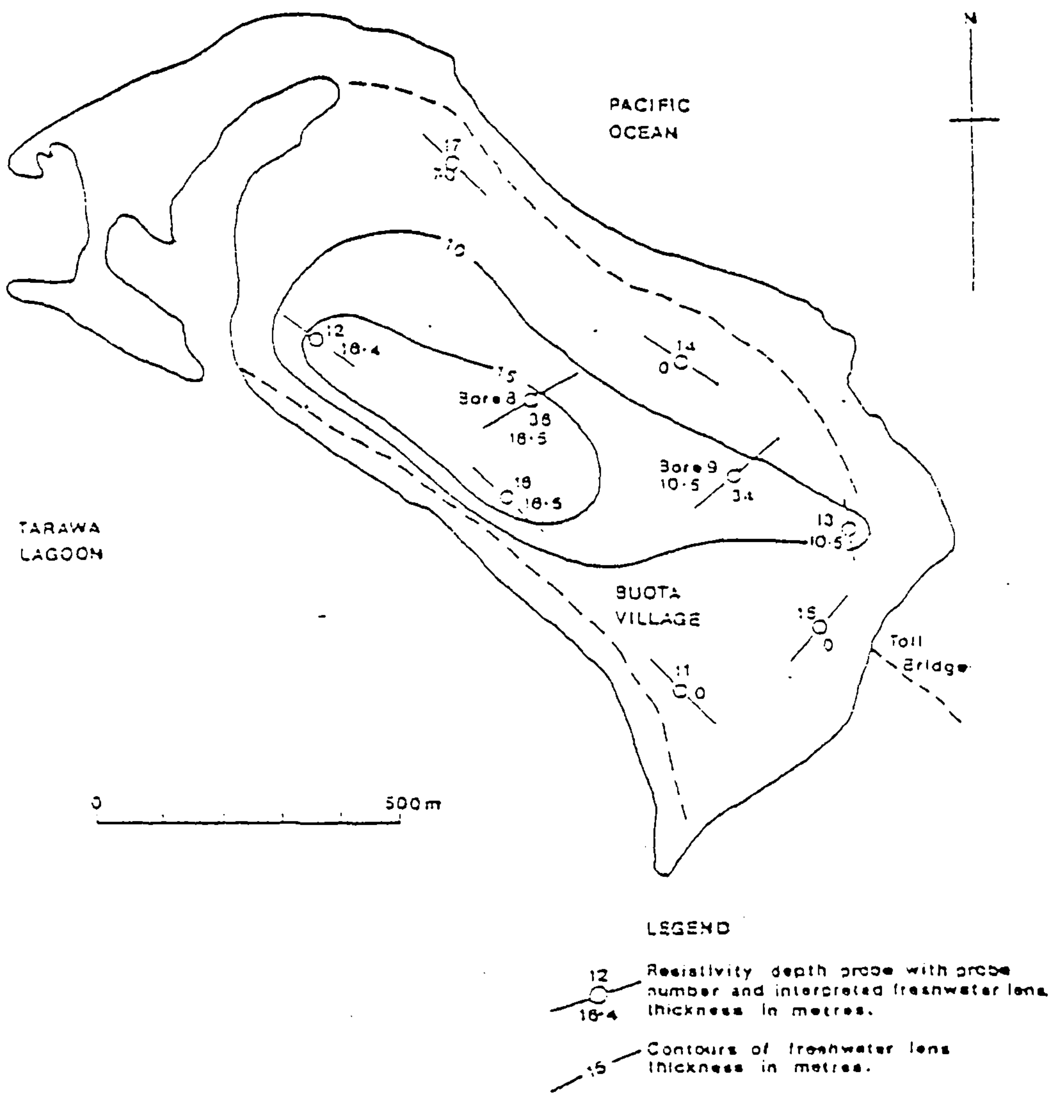
Long-term exploitation of lens water is fraught with difficulties and requires a good understanding of the behaviour of groundwater lenses, a regular and well-designed monitoring program and strict control of all pumping activities.

2.2 Investigations of Tarawa Lenses

Investigations for the current Tarawa water supply project were carried out as part of the Pre-design Study. DHC requested the Bureau of Mineral Resources, Geology and Geophysics (BMRGG) (Ref 3) to carry out some studies in late 1980. The Central Investigation and Research Laboratory (CIRL) of DHC was also involved in the on-site investigations at the same time. BMRGG was principally involved in carrying out surface resistivity testing to define the configuration of various lenses whilst CIRL was involved in a drilling and testing program to gain additional data on the lenses. Some of these boreholes and various additional boreholes drilled in subsequent drilling programs form the basis of the conductivity monitoring network which is used to monitor the important lenses on Bonriki, Buota and Teaoraereke. The results of the BMRGG resistivity investigations of the lenses on Bonriki and Buota are presented in figures 2.1 and 2.2.

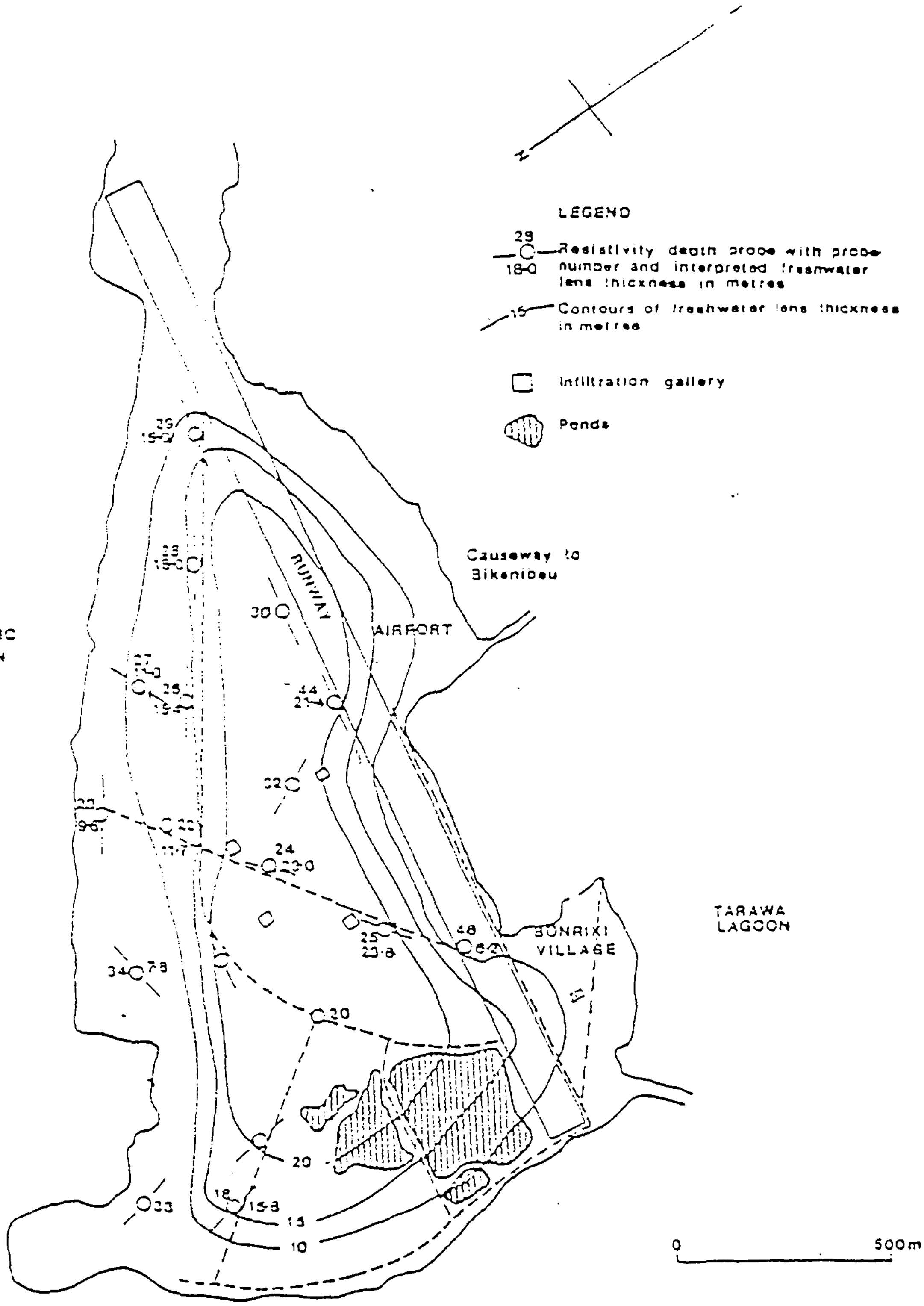
A study was carried out as part of the Pre-design Study to predict the safe yields of various island lenses. A model was developed to determine lens recharge as a function of rainfall and evapo-transpiration. This study was carried out using rainfall data from the Betio meteorological station for the period 1947 to 1980. The 34 year average for rainfall was 1976 mm/year and the calculated average lens recharge was 664 mm/year (33.6% of rainfall).

Following detailed analysis and modelling of lens behaviour the figure for safe yield was selected as 30% of recharge. This value is about the same as safe yield values used by Chidley and Lloyd (25-30% of recharge) for Grand Cayman Island in the Caribbean Sea. Subsequent studies by Falkland (Reference 7) of the water resources of Christmas Island (also in the Republic of Kiribati) confirmed that the safe yield value selected for Tarawa was quite reasonable.



BUOTA - RESISTIVITY DEPTH CONTOURS
(FROM PRE-DESIGN STUDY)

FIGURE No. 2·1



BONRIKI - RESISTIVITY DEPTH CONTOURS
(FROM-PRE DESIGN STUDY)

FIGURE No. 2·2

The calculated safe yields for the various island lenses are:

Bonriki	750 m^3/day	8.7 l/sec
Buota	250 m^3/day	2.9 l/sec
Teaoraereke	150 m^3/day	1.7 l/sec
Abatao	200 m^3/day	2.3 l/sec
Tabiteuea	150 m^3/day	1.7 l/sec
TOTAL	1500 m^3/day	17.4 l/sec

Note: Only Bonriki, Buota and Teaoraereke are included in the first stage of the project. Abatao and Tabiteuea have been identified for later stages.

The modelling of lens behaviour was carried out using a numerical model and assumed a sharp interface between the fresh and salt water at the bottom of the lens. This model suggested that the proposed extraction rates could be easily managed. A finite element model which included the transition zone between fresh and saltwater was attempted but could not produce reliable results within the time constraints of the Pre-Design Study.

It was noted in the Pre-design Study that a continuing lens monitoring program is essential before and especially after the extraction of water began.

2.3 Current Monitoring of Lens Behaviour

Monitoring of the main lenses located on Bonriki, Buota and Teaoraereke has been carried out since the Pre-design Study. The most important lens located on Bonriki currently has 15 operational monitoring boreholes, Teaoraereke has nine operational boreholes and Buota had its two boreholes vandalised during 1985. Repair or redrilling of the Buota boreholes as well as further borehole drilling is proposed. Conductivity data from these boreholes has been collected monthly since about September 1985 and before that on a more sporadic basis with intervals of between three and twelve months between data collection.

At present, no processing of the collected data has been carried out. It is suggested that this processing be carried out prior to the new scheme being brought into operation. This would enable the effects of pumping in the new scheme to be evaluated immediately by comparison with the data collected prior to the scheme.

Recent work by Volker et al (Ref 8) on modelling of the transition zone between fresh and seawater has improved the capability to evaluate the behaviour of lenses. This should be considered in any processing or predictive work.

2.4 Future Monitoring

Future monitoring of lenses from which water is extracted is an essential aspect of the operation of the new scheme. Monitoring will allow rapid detection and rectification of any problems caused by overpumping or intermittent pumping. The monitoring program over the longer term will enable evaluation of the long-term safe yield of the lenses.

It is considered important that there be some continuing specialist Australian involvement in interpretation of monitoring results during at least the first five years of operation of the scheme.

3. REVIEW OF WATER DEMANDS

3.1 Pre-Design Study Report Predictions

As part of the Pre-design Study, predictions of water demands were made up to the Year 2000. The Pre-design Study concluded that domestic uses would account for about 90% of all metered demands. Total demand predictions were thus very dependent on population predictions which in turn were very dependent on changes in internal migration. In 1980, Tarawa was experiencing high growth due mainly to internal migration.

3.1.1 Pre-Design Study Population Predictions

Population projections were based on predictions made by Dr Graham Harrison for South Tarawa as part of his socio-economic study conducted in early 1980. These figures were based on census data up to and including the 1978 census.

As quoted in the Pre-design Study, Harrison made predictions for years 1988 and 1998 for four different combinations of changing fertility and mortality and two different scenarios for internal migration. These scenarios were

(i) no growth on outer islands (continuing high internal migration); and

(ii) proportionate growth (internal migration halted).

The pre-design study used predictions for the declining fertility and mortality combination and the two internal migration scenarios as upper and lower bounds for population predictions. A third scenario of change in internal migration (an approximate arithmetic average of the upper and lower bound cases) was also considered. The population predictions were made for years 1990 and 2000. These population predictions are presented in Figure 3.1. The 1985 census value is also plotted.

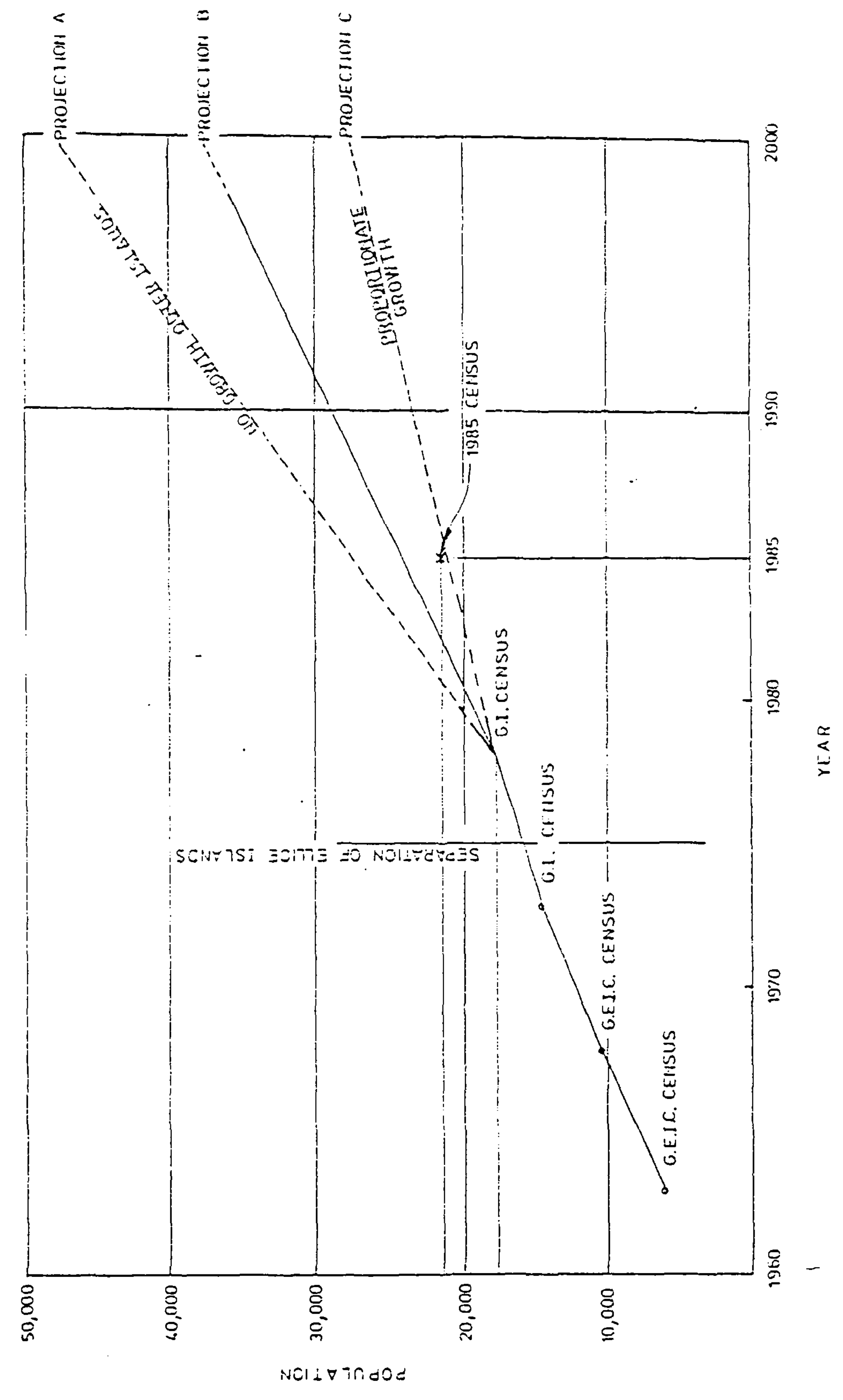
3.1.2 Pre-Design Study Demand Predictions

3.1.2.1 Domestic demands

Domestic demands were estimated on the basis of 'various surveys' carried out in the major population centres of Betio, Bairiki and Bikenibeu. From these surveys consumers were divided into three broad categories of housing. Category I (comprising 10% of total population) appear to be the 'better' grade of housing with western style roofs; Category II (65% of total population) encompasses most of the housing between Category I and Category III. Category III (25% of total population) is described as 'local' housing. This category presumably encompasses all semi-permanent and makeshift housing.

In order to predict total domestic demand for 1990 and 2000 a number of assumptions had to be made. These were:

* The proportions of housing in each category determined for the major centres of Betio, Bairiki and Bikenibeu were applicable to all of South Tarawa. This appears to be a reasonable assumption and would have little overall effect on demand predictions.



POPULATION PROJECTIONS TO YEAR 2000 (FROM PRE-DESIGN STUDY, 1980)	Figure 3·1

* 90% of Category I housing becomes self sufficient for 90% of the time after rainwater systems for these houses are restored or installed. The remaining 10% of the time (during draughts of 1 in 10 year or worse) these consumers would become reliant on lens water. The remaining 10% get house connections and consume water at 40 litres/capita/day. A high marginal water charge rate was the mechanism assumed to be capable of limiting consumption to this figure. Thess assumptions are discussed in 3.3.2.

* 80% of Category II housing gets house connections and consume water at 40 l/c/d. This high rate of connections was assumed possible due to a high level of subsidy for the initial cost of the installation.

* The remaining 20% of Category II and all Category III housing consume water at 20 litres/capita/day through access to water via standpipes or communal tanks. This assumption is discussed in 3.3.3.

* Distribution of population with respect to housing category remains about the same as at the time of the surveys.

* Population growth rates occur at an equal rate for each centre. This was felt to lead to an over-estimate of demand for Betio.

* Consumption rates per capita for the various categories outlined above would remain constant. This assumption is discussed in 3.3.2.

On the basis of the above assumptions the average consumption/capita over the long term could be calculated viz.

Housing Category	Average water consumption rate (litres/capita/day)
I	(1 - 0.9 * 0.9) * 40 = 7.6
II	0.8 * 40 + 0.2 * 20 = 36
III	20

The overall average domestic demand is thus

0.1 * 7.6 + 0.65 * 36 + 0.25 * 20 = 29.16 litres/capita/day

3.1.2.2 Industrial, Commercial and Social Demands

Demands for these categories were assessed on the basis of current usage and likely future developments. Predictions were made for likely 1990 and 2000 demands

	Year 1990 demand (m^3/day)	Year 2000 demand (m^3/day)
Industrial	30	50
Commercial	15	30
Social	15	30
TOTAL	60	110

3.1.1.3 "Unaccounted for" Water

This category of water consumption includes all water which does not pass through a metered connection. It would include all losses due to leaks, burst mains, reservoir overflows and routine operation activities such as reservoir cleaning, main flushing, swabbing etc. Illegal connections would also fall into this category. A figure of 10% of total water use was adopted in the Pre-design study. Losses are discussed in 3.3.5.

3.2 Updated Population Predictions

3.2.1 1985 Census Data

A census of the Republic of Kiribati was carried out in May 1985. The figures for South Tarawa are given in Table 3.1. The figures for the island of Buota (part of North Tarawa) are included as the new scheme will now include this island. The 1978 census figures are also given.

A comparison of the Pre-design Study population predictions which were based on the 1978 census and the 1985 census data (see Figure 3.1) shows that population growth has almost followed the Projection C line. This is probably attributable to significantly reduced internal migration and possibly decreasing fertility.

Population redistribution is a little more difficult to quantify accurately (see Table 3.1). The strip between Abarao and Teaoraereke and the Ananau causeway area (east of Bikenibeu) have experienced above average growth over the seven years between the censuses. This is undoubtedly due to population pressures in other areas forcing redistribution to these less densely populated areas.

The potential for significant population redistribution is considered to be limited due to most of South Tarawa being already heavily built-up. Some redistribution away from Betio is likely especially following completion of the Betio-Bairiki causeway. Likely areas for growth are around Banraeaba and the Ananau causeway area. These redistributions need to be considered to ensure that adequate levels of service will be provided in these growth areas. The overall effect of redistribution away from Betio and closer to the main sources of water (at Bonriki and Buota) is favourable to reducing pumping costs.

Table 3.1 1978 and 1985 Population Data for South Tarawa

Island/Village	1978 census[1]	1985 census	% change
Tanaea	-	77	-
Bonriki	635	848	+34%
Ananau Causeway	-	404	-
Bikenibeu	3971	4293	+8%
Abarao	322	405	+26%
Eita	612	1088	+78%
Tangintebu	128	106	-17%
Taborio	187	297	+59%
Banraeaba	501	931	+86%
Antebuka	-	612	-
Teaoraereke	848	1331	+57%
Nanikai	604	528	-13%
Bairiki	1956	2086	+7%
Betio	7626	8387	+10%
Remainder[2]	531	-	
S/TOTAL	17921	21393	+19%
Buota	-	364	
TOTAL (incl. Buota)	-	21757	

Notes:-

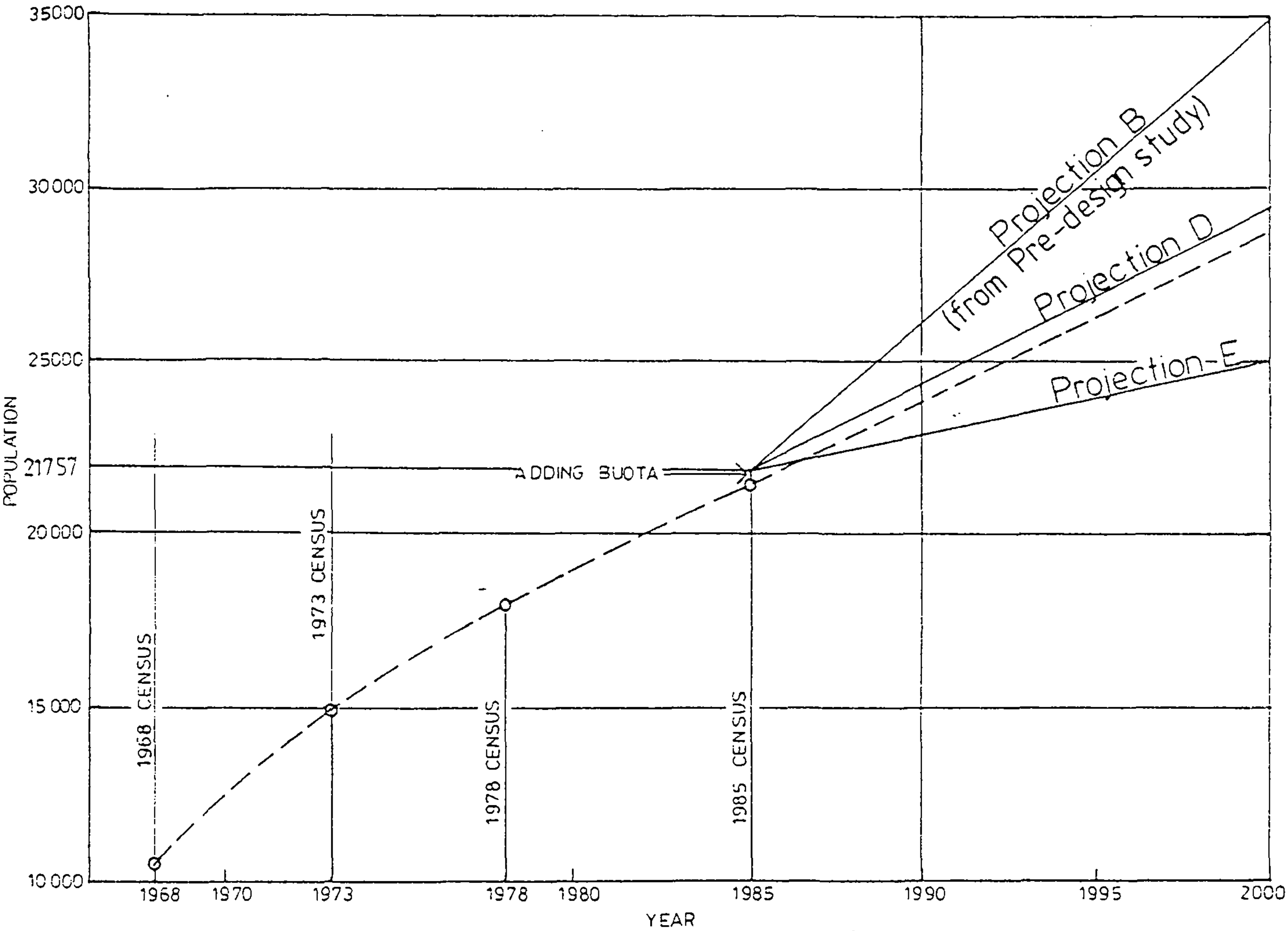
1) 1978 census data as quoted in Pre-design Study

2) The villages included in the category 'remainder' in the 1978 census are unknown.

These population movements have been taken into account on site and have resulted in overhead tanks being proposed for the villages of Ambo and Korobu (located either side of Banraeaba). Further changes to the scheme are discussed in 4.4.

3.2.2 Future Population Predictions

Overall, it would appear reasonable to assume that population growth to the year 2000 is unlikely to again approach the levels experienced in 1978. In the absence of any detailed studies of likely population growth, three new scenarios for population growth are presented in Figure 3.2. The upper bound assumes the same rate of growth as the Projection B figures from the Pre-design Study; the middle line is a straight line extrapolation through the 1978 and 1985 population totals and the lower bound assumes a further reduction in the rate of growth below that experienced between 1978 and 1985.



	YEAR 1990	YEAR 2000
PROJECTION B (high growth)	26,300	35,000
PROJECTION D (steady growth)	24,500	30,000
PROJECTION E (reduced growth)	22,800	25,000

POPULATION PROJECTIONS TO YEAR 2000 | Figure 3·2

3.3 Demand Predictions

3.3.1 Introduction

As was pointed out in the Pre-design Study report, demand predictions are very dependent on population predictions. Population movements since the Pre-design Study have shown a significant decrease in rate of growth. This was discussed in 3.2.2. Some assumptions made in the Pre-design Study with regard to water consumption rates are discussed in more detail in 3.3.2.

Also recently the Kiribati government has requested that the proposed public standpipes be deleted from the scheme. The ramifications of this proposal are discussed in 3.3.3.

Developments in the implementation of the household rainwater tank scheme are discussed in 3.3.4.

3.3.2 Domestic Consumption Rates

The Pre-design Study scheme made a number of assumptions on domestic demands based on various surveys carried out in Tarawa. Basically, there were two consumption rates assumed. People living in houses with a house connection (and also those with a household rainwater tank) were assumed to consume water at 40 litres/capita/day. People whose only access to water was from a public standpipe were assumed to consume water at 20 litres/capita/day. The breakdown of population assumed in the Pre-design Study (see also 3.1.2.1) is as follows:

Housing category	Source of water and usage by % of population		
	Lens water (from house connections) (use 40 l/c/d)	Lens water (from public standpipes) (use 20 l/c/d)	Rainwater (from household tank) (use 40 l/c/d)
I	1.0%		9.0%
II	52.0%	13.0%	
III		25.0%	
TOTAL	53%	38%	9%

It was assumed that consumption could be limited to 40 l/c/d for houses with metered connections by "having a rapidly increasing marginal water charge rate" after the base household allowance was exceeded. This assumption has the major disadvantage of relying on a very efficient tariff system (which will be run by the PUB). A second difficulty is the problem of accounting for different numbers of people living in a house (with one connection and one meter) when trying to restrict water on a per capita basis.

The figure of 20 litres/capita/day for consumers using public standpipes is understandably less than that for consumers with house connections. It was not proposed to charge for water drawn from public standpipes because of the difficulty and cost of devising a satisfactory method of payment.

With stage one of the scheme fully operational, an apparently abundant supply of water will become available, certainly a much greater supply than that presently available. This may lead to increasing wastage of water due to taps being left running unattended and less conservation of water. An increasing disregard for conservation of fresh water has apparently been observed in recent times on Tarawa. Commissioning of the water supply scheme therefore needs to be accompanied by an education program on the need for water conservation. A successful education program accompanied commissioning of the sewerage scheme (see 5.4)

Experience in Indonesia and elsewhere has shown that once a water supply scheme is installed, demand typically rises rapidly to reach the level of supply. It has been observed that average demands of 100 litres/capita/day are not uncommon. Thus, following completion of stage one of the scheme on Tarawa it is quite possible that demands will rise well above the levels assumed in the Pre-design Study. Appendix B shows plots for 50% and 100% increases in consumptions on the Pre-design Study estimates.

An alternative method of limiting supply to prescribed limits is by incorporating hydraulic restrictions and/or limiting pipe size to equitably supply water to all consumers. This method has not been incorporated into the scheme except for "throttling" butterfly valves on the intakes to reservoirs. These valves will be used to adjust flows into reservoirs from the rising main and thus attempt to ensure adequate supply to all reservoirs along the length of the rising main. This matter is discussed further in 4.4. Supply will be limited to some degree in the reticulation due to the use of only 6m high overhead tanks.

3.3.3 Proposed Deletion of Communal Standpipes

Recently, information has been received that the Kiribati government wishes to have communal standpipes deleted from the scheme. The intention is apparently to allow access to water only through individual house connections in line with a general Kiribati government policy of 'user pays'. Compliance with this request may have a number of ramifications for the success of the scheme as a whole and on future demand levels.

The original intention of providing communal standpipes was to ensure that all people on South Tarawa not having a house connection would have access to water from a standpipe located no further than 100 metres (and preferably less than 50 metres) from any house. About 38% of the population were assumed to gain access to water from communal standpipes in the Pre-design Study. 53% were assumed to have house connections installed and this was expected to be achieved due to heavily subsidized initial connection fees.

Recent information from Tarawa indicates that the PUB has control of house connection applications and that the charge is quite high by Tarawa standards ($20 or $30). In addition, the charge for water consumed is high (about $1.00/kilolitre). Significant numbers of people will be unable to afford these charges.

If communal standpipes are deleted and the high connection and usage charges remain, the potential success of the whole project could be severely jeopardised. The principal aim of the project is to provide all inhabitants of South Tarawa with access to a reliable supply of potable water which together with the recently constructed sewerage scheme should gradually and significantly improve the public health of the South Tarawa population.

If significant numbers of people have no access to water from the scheme, either from their own connection or through an arrangement to use water from someone else's connection then they will have no alternative but to return to more unsafe sources of supply e.g wells. The practice of more than one household using a single connection is undesirable as it would increase the need for storage of water and hence the risk of contamination of water in those households without their own connection.

If the Kiribati government wishes to proceed with its request to delete standpipes then both the connection charges and water rates must be low enough to attract consumers to the system (by subsidy from Australia if necessary.) This is necessary to ensure that everyone on South Tarawa has access to water from their own connection.

It is important to have as many paying customers of the scheme in order to reduce the potential operating deficit of the scheme. It is considered likely that the scheme will not cover operating costs in the early years although this should be a long-term aim.

The matter of overall financial management of tne scheme is crucial to its success but apart from the general comments made above and elsewhere it is considered to be outside the scope of this report.

If communal standpipes are deleted from the scheme and assuming that a way is found to ensure that virtually every household has its own connection, another problem may arise. The problem is that overall demand on the system would rise as the 38% of people assumed in the Pre-design Study to take water from communal standpipes would now have an individual house connection.

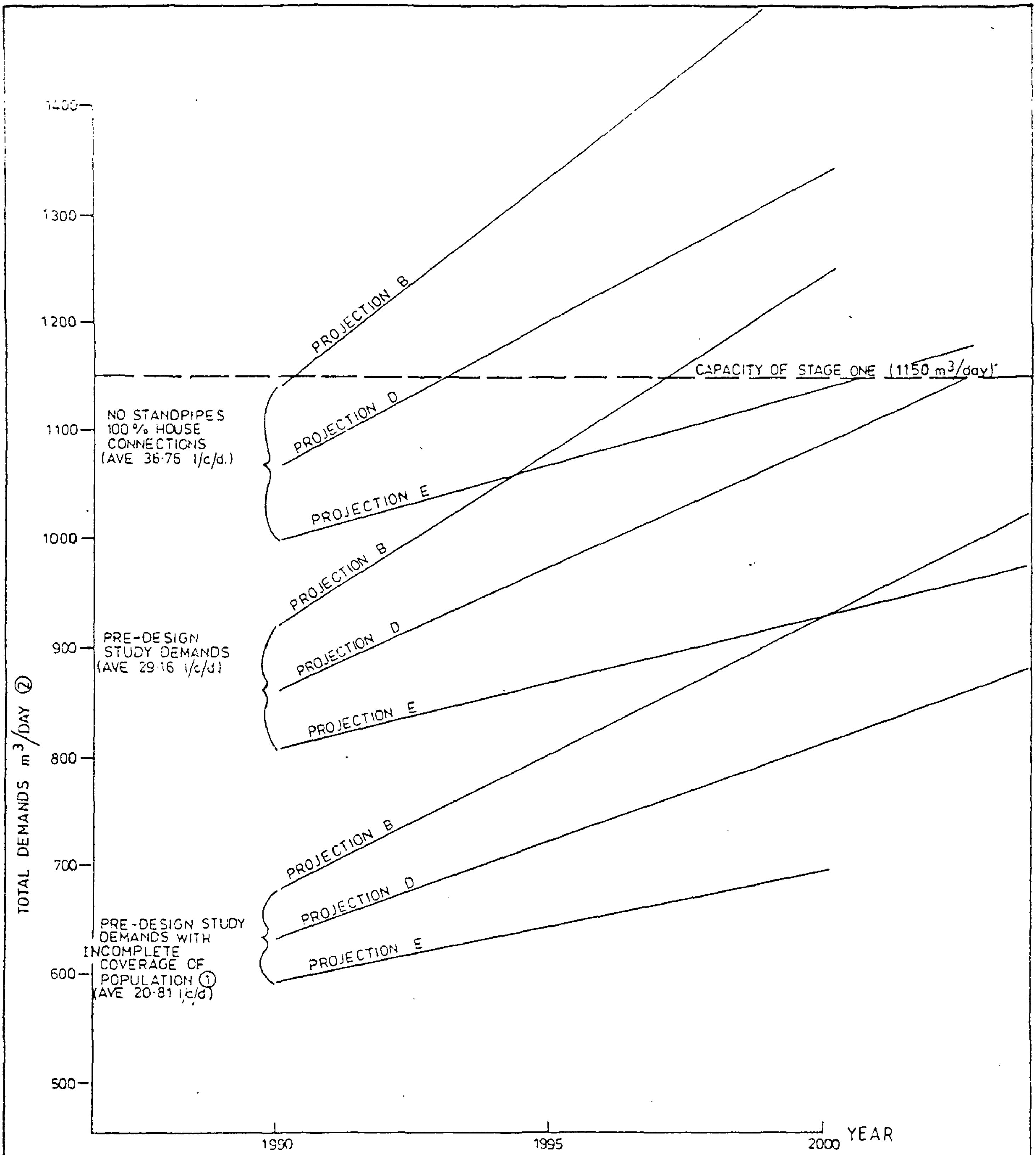
The case of 100% house connections is likely to be an upper bound but must be considered. The average consumption figure assuming 40 l/c/d for houses without rainwater tanks rises to

Category	
I	(1 - 0.9*0.9) * 40x0.1= 0.76
II,III	40 * (0.65+0.25)= 36
TOTAL	36.76 l/c/d

This compares with 29.16 l/c/d/ in the Pre-design Study scheme. This is an increase of 26% for average per capita consumption. The affect of this change is plotted in Fig 3.3.

A possible solution to this problem would be to provide a metered standpipe to serve groups of houses where no connections are made. The standpipe (or tap) would be located to allow easy access for all people in the group. Payment for water usage under this arrangement would need to be resolved by the PUB and Kiribati government.

Consumptions per capita under this arrangment are likely to be less than for houses with individual connections. If the percentage of houses served by this arrangement is the same as that assumed for public standpipes in the Pre-design Study (38%) and the same consumption rates apply (20 l/c/d) then the overall average consumption would be 29.16 l/c/d (the same as in the Pre-design Study).



NOTES

① THIS CASE ASSUMES THAT NOT ALL OF THE POPULATION IS CONNECTED TO THE LENS WATER SYSTEM.
ASSUMED THAT 100% OF CATEGORY I HOUSING SERVED (9% FROM HOUSEHOLD TANKS, 1% HOUSE CONNECTIONS); 75% OF CATEGORY II SERVED AND; 50% OF CATEGORY III SERVED.
(TOTAL POPULATION SERVED (10 x 1·0 + 65 x 0·75 + 25 x 0·25) = 71·25%)

② TOTAL DEMANDS INCLUDING DOMESTIC, INDUSTRIAL AND COMMERCIAL AND ASSUMING 10% LOSSES.

Total Demand Projections to Year 2000 — Figure 3·3

If the percentage of houses served by metered standpipe is less than 38% or the consumption for this group exceeds 20 l/c/d/ then overall consumption would exceed 29.16 l/c/d and may approach 36.76 l/c/d. Actual total water demand will therefore depend on the proportions of types of connections and on how well water conservation is practices. It will not become clear until the system has been operational for some time.

The comments made in the previous section (3.3.2) on the possible increase of demands in excess of 40 l/c/d are equally valid for this situation.

3.3.4 Household Rainwater Tank Program

According to the Basis of Design report, rainwater tanks would be provided to A, B and C grade Government houses and private houses with in excess of 130m^2 of roof area. About 340 houses were to be included in the current scheme.

It was estimated in the Pre-design Study that this would reduce the demand on the lens water scheme by 80m^3. Each house on the scheme is designed to be self sufficient against a drought of up to 1 in 10 years provided that the scheme is adequately maintained.

During a severe drought (1 in 10 years and worse) houses whose tanks run dry would be served from the lens water scheme. The mechanism of supply and the tariff arrangements under these circumstances would need to be resolved by the Kiribati Government and the PUB.

It was estimated in the Pre-design Study that about 9% of the overall population would have rainwater tank schemes. If this figure increases it should be noted that the rainwater scheme is more expensive than the lens water scheme (both on a per cubic metre of water basis or per house connection). The recovery of costs for installation of the rainwater tank(s) and pump and repairs to guttering and facia is by a monthly charge, currently $9.00/month. This is an interest free charge to recoup the costs of installation.

Maintenance of tanks, pumps, guttering and pipes would be the individual householder's responsibility for private houses and the responsibility of the Government Housing Corporation (GHC) for government houses. The capacity of the GHC to adequately maintain the 200-300 household schemes is questionable.

It is recommended that

1) The household rainwater tank program should be strictly limited because it is relatively uneconomic due to higher initial and maintenance costs. In the longer term, when the lens water scheme is operating near capacity, an increase in the number of household rainwater tanks can be re-evaluated.

2) The charge for tanks should be reviewed compared to the costs of the lens water in order to make the lens water more attractive.

3) Householders who either inadequately maintain their tank systems or use 'excess' water need to be charged a high rate for any lens water requirements in order to deter these practices.

During a drought worse than a "one in ten year" drought, all consumers normally served from household rainwater tanks would also need to be served from the lens water system. This is not considered to be a critical design case even though it would make the remaining 9% of the population dependent on the lens water system. During a drought of this severity, it is considered that public awareness reinforced by government broadcasts and other measures would lead to the necessary conservation of water and all inhibitants would still have access to safe water. The characteristics of a drought are quite important to the operation of the system. An official drought declaration may need to be made to allow people served by rainwater tanks to purchase water from the lens water scheme without being penalized for using excess water (see recommendation 3 above).

3.3.5 Losses

The loss figures adopted in the Pre-design study are considered to be quite low. Australian water supply schemes commonly average 20-30% losses and Indonesian schemes commonly experience unaccounted water between 20% and up to 65%.

No information on present losses experienced in Tarawa is available but it is not unreasonable to expect that losses of around 20% of total demands are being experienced.

It is recommended that a leak detection survey and any rectifications be considered for the water supply system before the scheme is handed over to the PUB.

This survey should include all mains, reticulation pipework and tanks in the system. The parts of the scheme already maintained by the PUB would need to be surveyed with PUB's approval. The 18km of existing 155 mm PVC between Bonriki and Teaoraereke and the 1.6km section of 100 mm PVC connecting Buota and Bonriki need particular attention.

4. REVIEW OF SYSTEM DESIGN

4.1 Introduction

The new water supply scheme currently being constructed on South Tarawa principally involves the utilisation of lens water from gallery collection systems. The gallery systems for stage 1 (the current stage) are located at Buota, Bonriki and Teaoraereke. Lenses identified for future expansion of the scheme are at Abatao and Tabiteuea.

Extraction rates determined in the Pre-Design Study are as indicated.

	Island	Proposed No. of galleries	Total pumping capacity (m^3/d)	Maximum extraction rate based on safe yield (m^3/d)
Stage 1	Bonriki	17	850	750
	Buota	6	300	250
	Teaoraereke	4	200	150
	Sub Total (Stage 1)		1350	1150
Stage 2	Abatao	5	250	200
Stage 3	Tabiteuea	4	200	150
	Total		1850	1500

TABLE 4.1

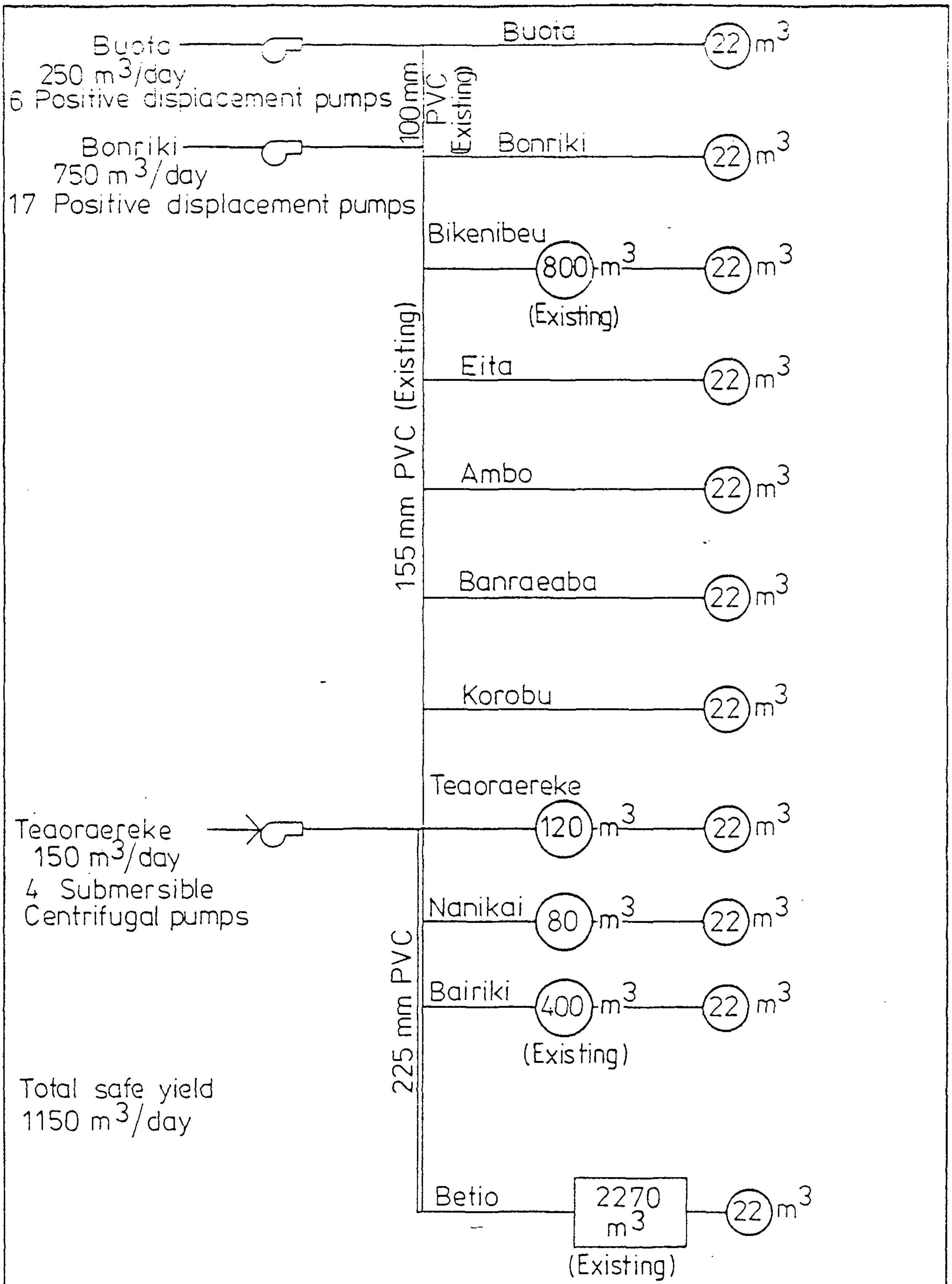
A household rainwater collection program is also being implemented. The safe yield available from this source, however, at $80m^3$/day is small compared to the freshwater lens sources.

The lens water scheme basically involves extraction of the majority of water from galleries located at Buota and Bonriki on the eastern end of Tarawa and distribution of this water along South Tarawa. The remained of the water is extracted at Teaoraereke, about 10km from Betio The major population centre and hence demand is located at Betio on the western end of the atoll which is about 30km from Buota. The principal water storage is located at Betio. A schematic layout of Stage 1 of the scheme is shown in Fig 4.1.

4.2 Principal Components of the System

The water supply system has been designed to incorporate, where practicable existing pipelines and reservoirs. The major components of the system are:

- Rising main (from Buota to Betio)
- Gallery systems
- Reservoirs and tanks of offtake points
- Reticulation, house connections and standpipes
- Household rainwater tanks



Note: All components new except those marked existing. Existing components will be refurbished and modified as necessary.

Schematic Diagram of Water Supply System – MAY 1986

Figure 4·1

4.2.1 Rising Main

The existing 155mm PVC main (six inch imperial size) from Bonriki to Teaoraereke (approx 18.2km) and existing 100mm PVC main from Buota to Bonriki (approx 1.6km) will be incorporated into the new system.

The existing 100mm PVC main connecting Teaoraereke and Betio will be replaced with a 225 PVC main (this new main was proposed as 150mm PVC in the Pre-design Study). Construction of the section of main across the reef between Bairiki and Betio has been delayed at the request of the Kiribati Government authorities awaiting the construction of the causeway as a Japanese funded aid project. It is hoped that the main will be laid in the causeway as this will be cheaper initially and for future maintenance. Chlorination of water from the Buota and Bonriki galleries will be carried out at a single location just downstream from the Bonriki galleries. The chlorination system has changed from the Pre-Design Study and will now use gaseous chlorine.

Minor chlorination and re-chlorination systems will be located at Buota, Teaoraereke, Betio, Nanikai and Bairiki.

4.2.2 Galleries

As part of Stage 1, galleries will be constructed at Buota, Bonriki and Teaoraereke, as shown in Table 4.1. The number of galleries on Buota has been reduced from seven to six as a result of salinity monitoring carried out after the Pre-design Study was completed.

The gallery arrangement has also been altered from the original pre-design study 'H' configuration to a straight line 300m long as shown in figure 4.2.

The design yield of each gallery is 50m^3/day over a 24 hour continuous pumping period. The galleries will be fitted with helical rotor type positive displacement pumps each driven by a 1.1kW electric motor.

4.2.3 Reservoirs and Tanks

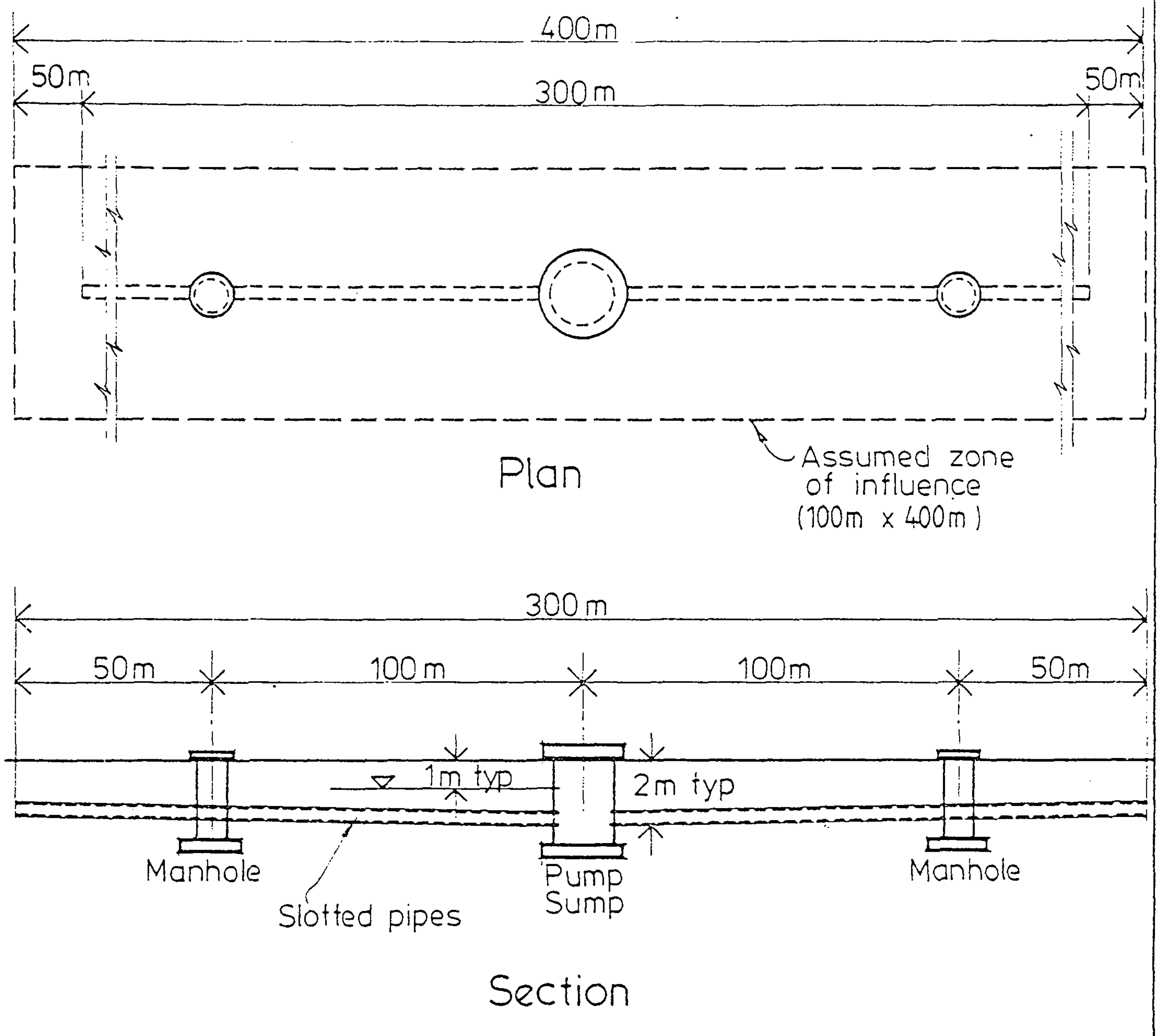
(a) Low Level Storages

Low level storages are sized to provide for diurnal fluctuations and emergency storage. Low level storages to be constructed or refurbishment are

Bikenibeu	800m^3
Teaoraereke	120m^3
Bairiki	400m^3
Nanikai	80m^3

The existing 2270m^3 reservoir at Betio will be incorporated into the new system as it is in good condition. The pumps at Betio will be replaced and pipework modified to enable the head tank to be bypassed to feed water directly into the reticulation and to allow water to be pumped back down the rising main to Bairiki, as required.

Existing low level storages at Bikenibeu and Bairiki are to be refurbished to give the required storage volumes. At Teaoraereke and Nanikai, multiples of 22m^3 ferro-cement tanks will be constructed.



Typical Gallery (Not to scale) | Figure 4·2

(b) High Level Tanks

High level storage (an elevated tank 6m above ground level) is provided at most villages and towns connected to the system simply to provide operational pressures to reticulation. These tanks are the standard $22m^3$ ferro-cement tank. Extra high level tanks, have been proposed for Ambo and Korobu (located either side of Banraeaba) since the Pre-design Study. This is to serve rapidly increasing population in these areas. Buota and Tanaea will also be connected to the lens water system, probably served from an existing high level tank on Tanaea. Where no ground level storage is provided, the high level tanks are of sufficient capacity to provide for diurnal and limited emergency storage for the populations being served.

4.2.4 Reticulation and Connections

(a) Reticulation

Reticulation pipework is generally served from the high level tanks and consists of 50mm pipework in a simple branched or sometimes looped layout. In those villages where demand is so small that construction of a high-level tank cannot be justified, reticulation is connected directly to the rising main. Some 100 mm water supply reticulation at Bikenibeu and Bairiki was installed concurrently with the sewerage scheme. This reticulation needs to be inspected, tested and disinfected before connection to the system.

Performance of the reticulation on Betio was analysed in the pre-design study under a demand of $470m^3$/day (Year 2000, projection B, average day demand). The maximum head loss was about 2m and hence this pipework will be included without modification.

(b) Connections

In general, connections will be off reticulation mains. All connections will be metered.

The Kiribati government has recently requested that community standpipes (as proposed in the pre-design study and basis of design reports) be deleted in favour of 100% house connections. This request has a number of significant ramifications which were examined in section 3.3.3.

4.2.5 Household Rainwater Tanks

All suitable houses will receive two $13.5m^3$ ferro-cement rainwater tanks, pressure pump and necessary roof plumbing modifications. About 340 houses were planned to be included in this scheme as part of the project (making 680 tanks in all.) It is estimated that demand on the lens system can be reduced by $80m^3$/day by full implementation of the household rainwater tank scheme.

4.3 Implementation of the Project

4.3.1 Background

The system as proposed in the Pre-design Study and described in the Basis of Design report has been adopted virtually intact. It involves direct pumping from galleries into a common rising main. Storages along the rising main are fed directly and all 'surplus' water flows to the Betio reservoir. Betio reservoir acts as a balancing storage for the system.

Due to the undesirability of frequent stop-start pumping from groundwater lenses, the gallery pumps were selected as positive displacement pumps delivering a virtually constant flow rate of $50m^3$/day over 24hr/day continuous pumping. Due to the characteristics of positive displacement pumps, their nominal flow rate can be maintained almost constant against varying heads.

4.3.2 Pumping Arrangement Considerations

As pointed out in the ADAB review report of 1984 (Volume 3) (Reference 5), the use of positive displacement pumps as the main pumps in the system is perhaps not the most cost-effective system in terms of operating costs. This matter was addressed in the DHC report "Comparison of Alternative Pumping Arrangements" of 1984. (Reference 5)

Four methods of distributing lens water from Buota and Bonriki to consumers on South Tarawa were compared in this report (including the original proposal). The schemes were subjected to an economic comparison of their total capital, construction and operating costs. The four schemes can be summarised as:

1. The original pre-design study scheme which consists of a total of 23 positive displacement pumps, all pumping directly into a common rising main.

2. The use of a low head centrifugal pump on each gallery, all pumping into a $400m^3$ ground level reservoir on Bonriki. A variable speed pump is used to pump water from the Bonriki reservoir to other reservoirs on South Tarawa. (Fig 1.4)

3. This scheme is similar to scheme 2 but uses solar powered centrifugal pumps to pump from the galleries to the Bonriki reservoir.

4. Augmentation of the existing 155 mm main between Bonriki and Teaoraereke involving replacement of the initial 9.1km of 155 PVC with 225 PVC and duplication of the remaining 9.1km of 155 PVC with 150 PVC in parallel. Pumping is by 23 medium-head centrifugal pumps directly from each gallery into the upgraded rising main.

The conclusions and recommendations of this report can be summarised as:

* The presently proposed scheme is the outright cheapest irrespective of the discount rate used (for discount rates of 2%, 5%, and 8% which were considered applicable for overseas aid projects) up until the year 1999 based on projection B demand growth;

* Neither the solar scheme (scheme 3) nor duplication of the rising main (scheme 4) are economically viable over the 20 year period of analysis;

* Scheme 2 has greatly reduced operating costs over scheme 1 after 1997 although it initially has higher energy costs;

* Scheme 2 would require a more complicated operating system to balance both the Betio and Bonriki reservoirs;

* Scheme 2 becomes more favourable if demand growth exceeds pre-design study predictions after stage 1 of the scheme is completed;

- * Scheme 2 provides aeration of lens water in the Bonriki reservoir before it is chlorinated. Recent reports from Tarawa indicate significant hydrogen sulphide levels in the Buota and Bonriki lenses. Aeration of this water would lead to significantly reduced chlorine demand and hence cost savings. It is doubtful whether this factor alone justifies the construction of scheme 2;

- * Scheme 2 offers greater flexibility if monitoring and analysis of the behavior of the Buota and Bonriki lenses leads to an increased safe yield.

The report concluded that overall, Scheme 2 was the best long-term solution. However, due to the chronic shortage of water it recommended that Scheme 1 be implemented as soon as possible until construction of the various facilities for Scheme 2 could be completed. Scheme 2 requires the construction of a 400m^3 reservoir at Bonriki. The additional project construction cost of implementing the scheme in this way was estimated to be $100,000 over Scheme 1 alone.

4.3.3 Present Implementation of Water Supply Scheme

At the time of writing of this report (May 1986) only scheme 1 is being implemented. Apparently the Public Utilities Board (PUB) of Kiribati, who will be responsible for operation and maintenance of the water supply scheme once it is handed over, have expressed reservations at the inclusion of a variable speed pump in the scheme. These reservations are believed to be based on lack of familiarity with variable speed technology and concern over the introduction of another type of pump into the water supply system.

One major advantage of scheme 1 is the use of positive displacement pumps for pumping from lenses ensures an almost continuous rate of pumping despite possibly large changes in heads in the rising main. This will guard against possible overpumping of the lenses, an important consideration especially in the early period of operation of the system.

4.4 Review of Design of the Project

4.4.1 Introduction

The comments made in this section (4.4) of the report refer to stage one of the project which is under construction at the time of writing (May 1986). Stage one of the water supply project involves

(i) construction of the new galleries pumps and chlorination equipment at Buota, Bonriki and Teaoraereke;

(ii) upgrading of the existing main between Teaoraereke and Betio to 225 PVC and abandonment of the existing 100 mm PVC main;

(iii) construction of low-level reservoirs and overhead tanks at various locations;

(iv) installation of reticulation and house connections as required throughout South Tarawa;

(v) installation of about 340 individual household rainwater tank systems; and

(iv) upgrading and modification of various existing facilities which are being incorporated in the new project.

The total sustainable capacity of stage one is 1230 m^3/day with 1150 m^3/day being extracted from groundwater lenses and 80 m^3/day from the household rainwater tank systems.

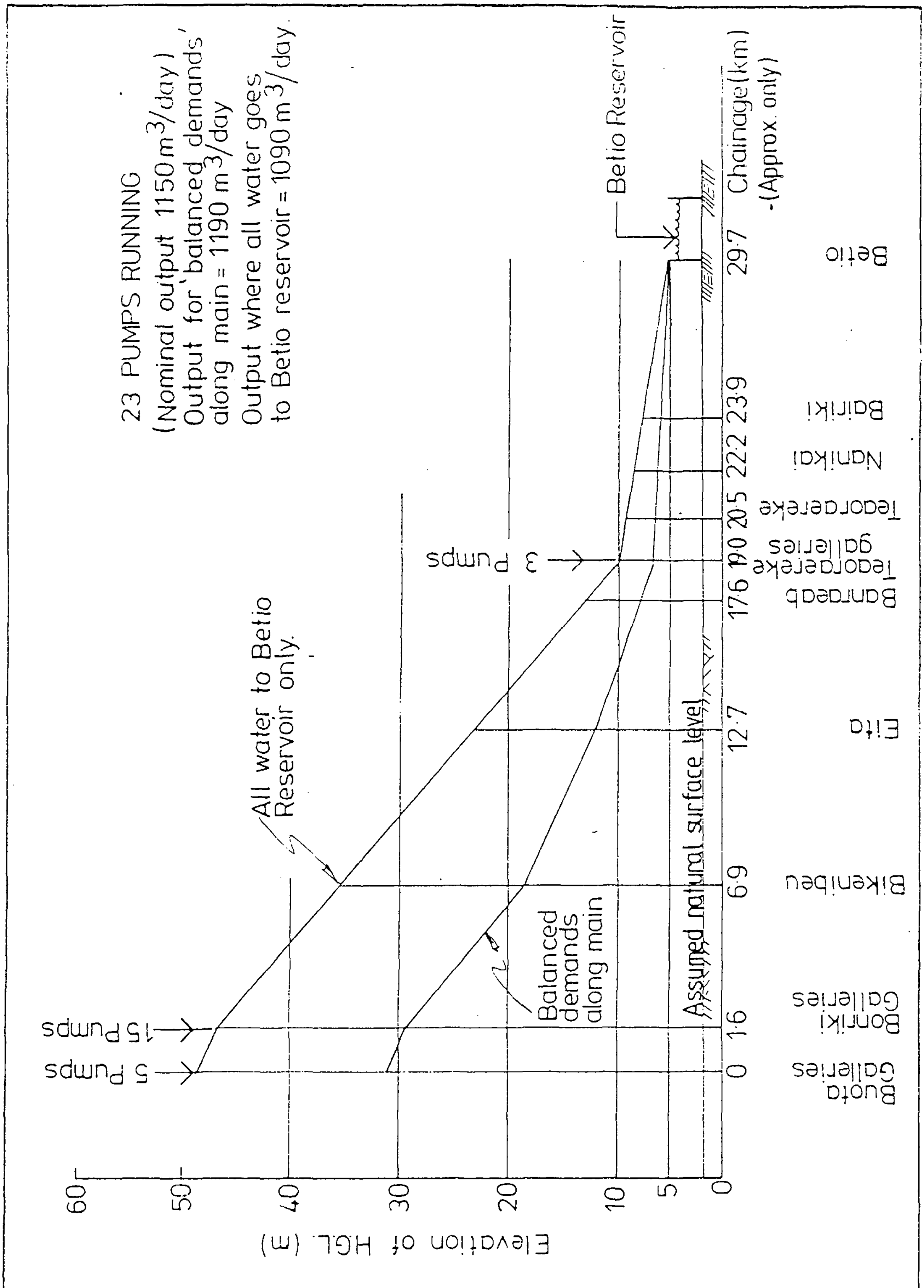
Stages two, three and four of the project have been identified (in the Pre-design Study) and may be implemented in the future, the timing depending principally on future demand levels. Future considerations are discussed in 4.5.

4.4.2 Problem Areas in Stage One

The potential problem areas have been identified mainly from a computer model of the water supply scheme. The data for this model is not extremely accurate as no 'work as executed' or other detailed drawings were available at the time of writing. This model using the program 'WATSYS' is described in Appendix A.

(A) Throttling of Reservoirs

The successful operation of the lens water scheme relies strongly on having the inflow rates to the reservoirs located between the Bonriki galleries and Betio reservoir carefully 'throttled' to maintain a constant inflow rate 24 hours/day. This may be referred to as 'balanced operation'. The correct throttling of the reservoirs located closest to the Bonriki galleries, especially Bikenibeu reservoir (which has a relatively high demand) is important. If the 'early' reservoirs are allowed to take water at too high a rate the pressure in the whole system is reduced and a greatly reduced flow is available to serve the other reservoirs. Under these conditions, the early reservoirs would fill up and shut off more quickly. The pressure in the main would thus fluctuate widely depending on whether these reserviors are taking water or not. These variations lead to higher energy costs for pumping. Increases of about 20% over balanced operation have been estimated (Reference 6) under these conditions. The means of controlling inflow to reservoirs in the system is by butterfly valves located in the inlet line to each reservoir in addition to ball-float valves which perform the altitude function for the reservoirs. The throttling valves are adjusted at each resevoir in an attempt to achieve balanced operation. It appears that the butterfly valves currently proposed will not provide sufficient sensitivity in throttling, and will need to be 80^o or more closed before any significant throttling will occur. Head loss in a valve can be expressed as $K V^2/g$ where V is the nominal velocity through the valve, and K is a constant depending on the degree of opening of the valve. To achieve the required head loss requires very high K values, corresponding to a high degree of valve closure, or high nominal velocity through the valve. This high velocity can be achieved by utilisation of smaller diameter valves. For the situation in Tarawa, valves of 25mm or even 18mm diameter will provide much greater sensitivity of control than the 50mm or 100mm valves currently proposed. It is probably desirable to not reduce the maximum flow capacity into the various tanks, hence it is recommended that small diameter control valves be placed on a 'bypass' around each of the proposed butterfly valves which would normally remain closed. This system offers greater flexibility than systems involving lengths of reduced diameter pipe or the use of restrictions to achieve the required head loss.



HYDRAULIC GRADE LINES AT NOMINAL CAPACITY OF STAGE ONE (1150 m 3/ day.)	Figure 4·4

(D) Teaoraereke Galleries

The Teaoraereke galleries are to be constructed in the existing water reserve replacing the existing galleries. They will feed directly into the new 225 mm section of the rising main and pump through to Betio. The pumps proposed for these galleries are low-head submersible centrifugal pumps with a nominal duty point of 35 l/min at 8.5 m total head. Unlike the positive displacement pumps on the other new galleries, these pumps exhibit significant variations in flows in response to relatively small changes in head. When heads are below 8.5 m in the rising main (which will occur at low total demands or some conditions of 'unbalanced' operation) the pumps will extract water from the lens at a rate in excess of 50 m^3/day. This may be significant during the early years of the scheme when total demands are low. It is understood, however, that due to existing disturbances to the Teaoraereke lens (caused by overpumping) that only the Buota and Bonriki lenses will be used in the early stages of operation of the scheme. Once monitoring of the Teaoraereke lens indicates that adequate recharge and flushing has occurred, the Teaoraereke lens can again be exploited but the pumping rate needs to be controlled to 50 m^3/day.

4.4.3 Design Problems Requiring further Investigation

Some further matters which require investigation are identified below.

(A) Water Hammer

The potential occurrence of water hammer is from two main sources:

(i) power failure causing all pumps running at that time to stop (the reverse case of all pumps starting should be prevented by adequate time delays in the pump controls); or

(ii) rapid closure or opening of valves in the system eg. reservoir 'throttling' valve.

Ball float valves are proposed to perform the altitude valve function for the reservoirs. Water hammer problems are unlikely to be caused by the operation of the ball float valves.

(B) Efficiency of Positive Displacement Gallery Pumps

The efficiency of the positive displacement pumps being installed at the Buota and Bonriki galleries is quite low especially at low heads. This has been recognised in the report "Comparison of Alternative Pumping Arrangements". The efficiency of other pumps, however, at low heads eg. small centrifugal pumps is also quite low. One important feature of the positive displacement pumps is that they maintain an almost constant flow against the range of head conditions possible in the scheme. This will safeguard against overpumping of the lenses.

The matter of pump efficiency should be looked at a later stage when the capacity of the water supply scheme needs to be increased or if running costs of the scheme become a matter for concern. During the initial period of operation of the scheme, it is considered desirable that the positive displacement pumps should be retained because of their safety in preventing overpumping of the lenses.

(C) Hydrogen Sulphide Levels in Lens Water

Hydrogen sulphide (H_2S) levels in the water from the Buota and Bonriki lenses are occasionally quite high. High H_2S levels lead to increased chlorine demands and costs and may also lead to rejection of the lens water due to offensive odour and taste by some consumers or potential consumers. Indications are that H_2S levels in water from the new scheme will be significantly lower than in water from existing galleries. This is because new galleries have been sited to avoid low-lying areas and babai pits - two major sources of H_2S. The new chlorination system should also be more reliable thus reducing the incidence of high H_2S levels. Further investigation is required into ways of reducing H_2S levels and chlorination costs preferably before the scheme becomes operational.

4.4.4 Operational Considerations

(A) Lens Behaviour

A vital aspect of operation of the new project is adequate control of pumping activities and continual monitoring of the behaviour of the freshwater lenses. Good management of the lenses is essential to the long-term success of the scheme. Overpumping of the lenses (which should be difficult with the positive displacement pumps) or intermittent pumping should be avoided. Intermittent pumping is believed to cause significant disruption to lenses when higher pumping rates are used for shorter periods of the day. For example, pumping at 100 m^3/day over a 12 hour period is less desirable than a constant 50 m^3/day over 24 hours. Pumping at increased rates is not possible using the proposed positive displacement pumps. Unnecessary switching in and out of galleries, however, should still be avoided. See also 2.4.

(B) Throttling of Reservoirs

As mentioned in 4.4.2 (A) the degree of throttling on the valves is crucial to the smooth and efficient running of the system. The degree of throttling on all the reservoirs needs to be periodically checked and adjusted if necessary in response to variations in demand and other operational considerations. An 'over-throttled' reservoir will gradually empty and an under-throttled reservoir may lead to lack of flow further along the rising main. The aim will be to slightly under-throttle to ensure each reservior remains near full.

If throttling valves are opened or shut too quickly water hammer will result. The potential for damage from this phenomenon will be investigated further.

(C) Betio Reservoir Operation

The general operating procedure proposed in the Pre-design Study uses the Betio reservoir as a balancing reservoir for the system.

Details of the proposed operating procedure are outlined in the Pre-Design Study in section 9.4.

The system has been designed for simplicity of operation and is considered appropriate for the level of supervision and control likely to exist within the operating authority (the PUB).

4.5 Future Considerations

Implementation of the current scheme (scheme one) alone has a number of advantages over implementation of scheme two straight after scheme one is completed. Some of the advantages are:

* According to the report "Comparison of Alternative Pumping Arrangements", scheme one has cheaper running costs at the lower demands which should be expected during the remainder of the 1980s and into the 1990s.

* The 23 positive displacement pumps installed as part of scheme one will have a useful economic life rather than being replaced after only one or two years.

* The positive displacement pumps should ensure that galleries are not over-pumped during the early stages of operation of the system. This should allow more time to evaluate the safe yield of the lenses and ensure that no damage is done to the lenses.

* Future augmentation of the water supply system can be evaluated closer to the time at which it is needed. This should allow experience gained in operating scheme one and any changes in technology to be incorporated into the design of the augmentation. This should also lead to capital cost savings.

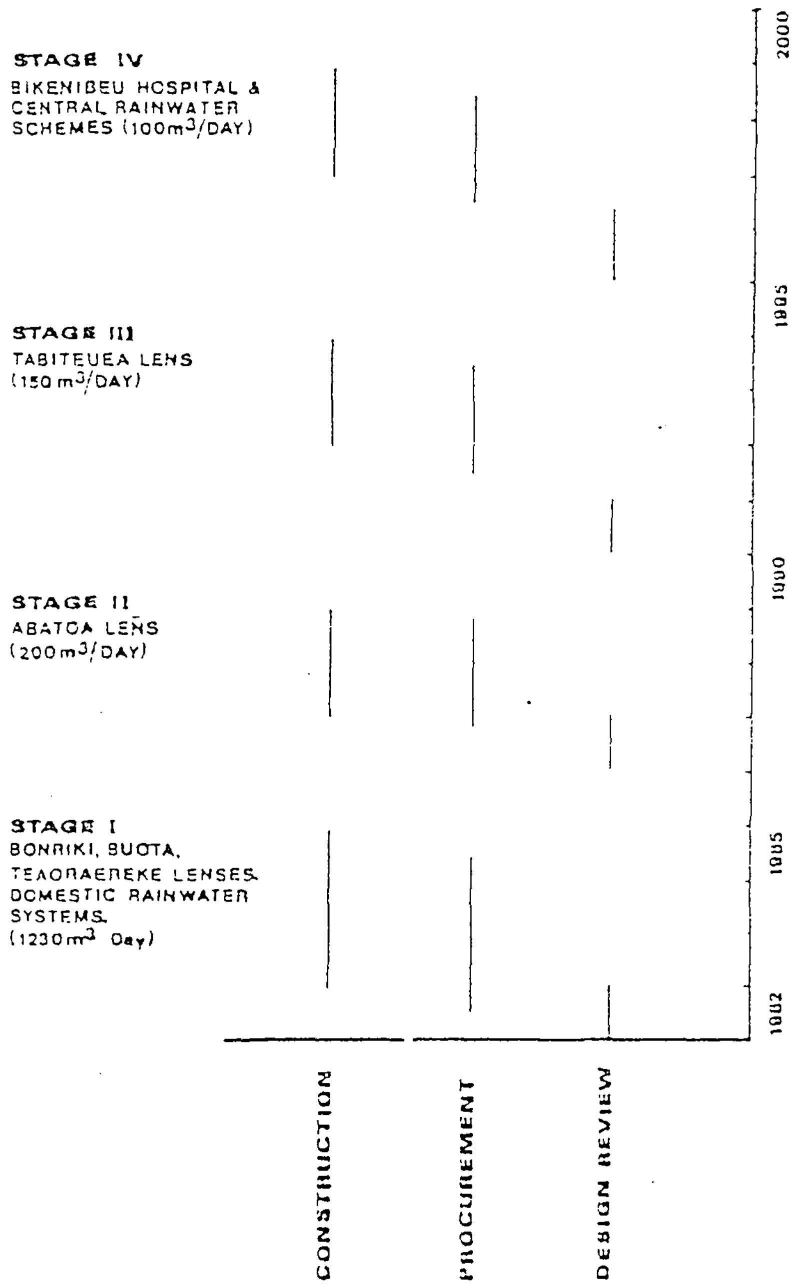
* Scheme one is simpler to operate than scheme two which should allow the PUB to gain experience for operation of necessarily more complicated future augmentations.

Some disadvantages of not implementing scheme two immediately following scheme one are:

* Possible increased chlorination rates and costs due to lack of aeration of the lens water from the Buota and Bonriki galleries. See 4.4.3 (C).

* If demand rises quickly during the early stages of operation of the scheme then scheme two would become more favourable in terms of running costs. A rapid rise in per capita demand is possible if experience with other schemes is any guide.

The pre-design study report included a master plan for augmentation of the scheme in four stages (Fig 4.5), the current scheme being stage one. An examination of costs clearly showed that stages two and three of the scheme should be to 'tap' the lenses on Abatao and Tabiteuea respectively which are the two islands immediately north of Buota. The safe yield of these lenses is estimated at a total of 350 m^3/day which is only a 30% increase on stage one. Significant difficulty may be experienced in acquiring land on these islands for use as a water reserve if the experience on Buota is any guide. This matter should be persued at an early stage by the Kiribati Government.



PRE-DESIGN STUDY

MASTER PLAN TO YEAR 2000

FIGURE No. 4·5

Stage four of the pre-design study master plan was construction of centralised rainwater collection schemes at the towns of Betio, Bairiki and Bikenibeu and a separate scheme at Bikenibeu Hospital. The total quantity of water from these sources was estimated at 95 m^3/day.

Apart from possibly a self contained scheme at Bikenibeu Hospital, these schemes are expensive to construct and even more expensive to operate and maintain. It appears that due to the small quantities of water produced and high costs, this source of water should be considered a 'last resort' when all other sources of water have been exploited.

Other sources of lens water which are all located in North Tarawa are increasingly distant from the major population centres on South Tarawa. Buariki, located at the far north of the Tarawa atoll appears to have the highest potential yield of any of the islands on Tarawa (Ref 3), however its isolation makes it an expensive source of water for supply to South Tarawa. The lenses on the islands of North Tarawa should be a matter for further study after other more economic sources have been exploited.

5. TRAINING

The subject of training has previously been addressed by Mr Kevin Paine of Water Supply and Sewerage Division DHC (now Department of Territories) in December 1985, and his proposals are endorsed. It is considered that training should as far as possible be on-the-job, and should cover both experience during construction/installation of equipment, and operation and maintenance training.

5.1 On-the-job Trade Training

The adviser to PUB, Mr John Wanneck considers that training in basic plumbing skills is not required. This seems to be a reasonable evaluation of the situation. Mr Paine, following discussion, proposed the following for training of PUB personnel:-

TRAINING AREAS	PERSONNEL
GALLERY CONSTRUCTION	Three plumbers, one each from Bikenibeu, Bairiki and and Betio for a minimum one month each.
COLLECTOR MAINS INSTALLATION	Three plumbers, one each from Bikenibeu, Bairiki and Betio for a minimum of one month each.
GALLERY PUMPS INSTALLATION	Two teams each of two persons from maintenance unit for a minimum three weeks during installation.
	Two Electricians for duration of installation.
RISING MAIN CONSTRUCTION	Three plumbers, one each from Bikenibeu, Bairiki and Betio for a minimum of three weeks each.
FERRO CEMENT TANKS	Three concrete hands, one each from Bikenibeu, Bairiki and Betio for a minimum of three weeks each during construction.
RESERVOIR CONSTRUCTION	One concrete hand for a minimum of three weeks for each type of construction, 22m^3 elevated, 22m^3 ground level and refurbishment of existing larger ground level storages.

OTHERS

WATER SUPERINTENDENT	To inspect construction and installation progress and hence become familiar with the new system. Approx. one day per fortnight.
ENGINEER (if available)	Short term secondments (two months) at key stages of the project.
DRAFTSMAN	Long term secondment.

This program, as a minimum, needs to be organised as soon as possible by the site engineer and PUB, to co-ordinate with the relevant parts of construction activities.

5.2 Operation and Maintenance Training

The following list of areas to be covered by operation and maintenance training is adapted from that prepared by Mr Paine.

- how the system is designed to work
- operation of system
- monitoring of system, including freshwater lens
- procedures/routines
- use of detailed O&M manuals for reference
- separate manuals for each class of equipment
- E&M maintenance - pumps/motors
- preventative maintenance schedules
- adequate spares lists and storage; parts identification
- spares ordering procedures
- chlorination - procedures/safety.
- leak detection

The Water Superintendent and up to three of his main assistants should be trained in all of these areas. An engineer if available should also be made familiar with requirements.

The majority of O&M training cannot really commence in earnest until the system is operational and/or manuals available, since it needs to be hands-on, practical training rather than academic training, to be effective.

Hence it is recommended that the main phase of training should commence about a month before startup of the system and continue initially for three months. It is envisaged that training would be undertaken by a senior technical officer or works supervisor, experienced in water supply operations and desirably with experience in training, preferably gained in a developing country.

Following this initial three month period, operators should be left temporarily to accept full responsibility for operation, to develop their own feel for the system and to tackle problems which will not necessarily occur while full technical support is at hand. However the trainer should return for a period of about three weeks each four months during the first year of operation to monitor the performance of the operators and assist with problems that arise. One of these visits should correspond with commissioning of the second or later sets of pumps, as it is probable that each set of galleries will be brought on line at different times. Contact should be maintained and support offered during any intermediate period when assistance is not available in Tarawa.

The amount of support required by the project after startup, as indicated above, should be considered as provisional, since it is impossible to estimate exactly how quickly local officers will be able to develop the required skills.

Beyond the first year, probably as long as five years or more, assistance will be needed. This is a most important aspect of projects such as this which has not often been formally recognised in the past. The recent "Review of Australian Assistance to the Indonesian Water Supply and Sanitation Sector" (Ref 9) found "ample evidence to suggest that more extensive inputs into post-project assistance would be beneficial". There seems no reason why this should not also apply in Tarawa.

This will apply also particularly in those areas covered under 5.3, Professional Level inputs.

The exception to the above on-the-job training would be training in the use of chlorination equipment. This is a specialized area where safety considerations are important now that gaseous chlorination is to be introduced. Short courses are availabe in Australia and it is recommended that the Water Supply Superintendent, desirably with one extra person, be put through this course. Timing could best be before the Superintendent, the key person in the system operation, is fully occupied during the early phases of system operation.

5.3 Professional level input to Operations

There are some aspects of the continuing operation of the system that will be beyond the capacity of the Superintendent, and possibly even beyond the capacity of a local professional engineer if one were available. These include monitoring of freshwater lenses and continuing review of their capacity, the possibilities and economics of modifications to and upgrading of the system, and the continuing need to augment the system to meet increasing demands. It is essential that any water supply system be considered as dynamic and constantly changing and continual review is necessary.

An annual review at this level is considered to be essential, and it will probably be necessary for Australia to accept responsibility for this, at least for the first five years. Evaluation of lens performance is essential over the first five or more years of operation of the system. This evaluation must be carried out by a suitably experienced professional engineer in Australia.

Professional input will also be needed in preparation of operation and maintenance manuals which should be considered as an essential prerequisite to training in system operation. Specific manuals on pieces of electrical and mechanical equipment should be prepared in Australia. Following this, it is recommended that a draft manual for the whole system be finalised in Tarawa during the two months prior to initial start up. It is considered that present site staff are unlikely to have sufficient time to carry out this task, but will have considerable input into it.

This draft should be updated towards the end of the first year of operation, however it should remain in loose leaf format to permit alterations to be made.

5.4 Community Education

The overall success or otherwise of the system will depend to a large extent on community acceptance and use of the system. A similar program to that undertaken for the sewerage system is recommended, involving film or video, and posters. Consideration could also be given to community discussion groups. As the central feature, a film(s) should at least explain the water supply system, the potential benefits from its use, the need for conservation in water use, and the unavoidable fact that water must be paid for.

Preparation of such a film is a highly specialised task, and particular local cultural values must be considered and incorporated. It is considered worthwhile to pay a little extra for creativity in such a film. It should be prepared prior to initial startup for use during the early months of system operation.

5.5 Financial Management

This is considered to be the province of the PUB, however adequate meter reading, fee collection, and overall financial management of the system will be critical in the long term. It should be ensured that this is given adequate consideration.

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APPENDIX A

WATSYS Model of System

A computer model of the Tarawa water supply system was established using the WATSYS program on the DHC mainframe computer.

The model included the gallery pumps at Buota, Bonriki and Teaoraereke, the rising main from Buota to Betio, the village low-level tanks or high-level tanks and associated butterfly throttling valves, altitude valves and reflux valves. No reticulation was included.

Due to insufficient information available at the time of setting up the model a number of assumptions had to be made. Some of these include:

(i) level of the ground surface - assumed to be constant RL=2m

(ii) gallery pipework and configuration not modelled. HGL at suction side of pumps assumed RL=0m

(iii) low-level storage tanks have floor level RL=2m, TWL = 6m

(iv) overhead tanks floor level RL=8m, TWL=10m

(v) Betio reservoir floor level RL=2m, TWL=5m

(vi) locations of reservoirs and direct reticulation off-takes taken from pre-design study. Some locations scaled from drawings

(vii) Consumptions taken from pre-design study with minor changes due to 1985 census data.

None of the above assumptions are expected to significantly affect the results reported in Chapter 4 of the report.

The model can be easily changed as more accurate data becomes available (if this is warranted).

The model was used to confirm or reveal certain aspects of the design and operation of the system. These aspects are detailed in Section 4.4 of the report.

For any further information on the model, contact Stephan Leppert, DHC Central Office.

APPENDIX B

Demand Predictions

A number of patterns for water demand are possible. It is impossible to predict with any degree of certainty what the actual total demand will be when the system initially becomes operational let alone in the year 2000 or beyond. A number of different demand cases are presented here which cover a broad range of possibilities.

As discussed in Section 3.2, domestic consumption accounts for about 80 to 90 per cent of expected water demands. Domestic consumption is in turn dependent on population growth. Three possible curves for population growth to the Year 2000 are presented in Figure 3.2.

As industrial, commercial and social consumption is only a small component of total consumption, the estimates for these categories from the pre-design study will be used unchanged. Total consumption for these categories was estimated as $60m^3$/day for the year 1990 and $110m^3$/day for the year 2000.

Losses were estimated as 10 per cent of total water produced in the pre-design study. As discussed in section 3.3.5 losses of around 20 per cent are not uncommon in many systems in Australia and overseas. Therefore total consumptions are plotted for two cases; 10 per cent losses and 20 per cent losses.

The various consumption patterns tabulated in Table B.1 are as follows:

1. Pre-design study figures
   See section 3.1.2.1
   Total average domestic demand = 29.16 l/c/day.

2. No public standpipes, 100 per cent house connections
   Consumption assumed to be 40 l/c/d.
   9 per cent of population assumed to have rainwater tanks
   Total average domestic demand
   = (1-0.9*0.9)*40x0.10+40x0.9
   = 36.76 l/c/d.

3. Pre-design study figures with 50 per cent increase in consumption rates.
   This equates to 60 l/c/d for houses with individual connections and 30 l/c/d for people using standpipes.
   Total average domestic demand
   = 1.5*29.16
   = 43.74 l/c/d.

4. Pre-design study figures with 100 per cent increase in consumption rates.
   Similar to (3); 80 l/c/d for individual connections and 40 l/c/d for standpipe users.
   Total average domestic demand
   = 2.0*29.16
   = 58.32 l/c/d.

5. No public standpipes, 100 per cent individual house connections and 50 per cent increase in demand rates. From (2)
   Total average domestic demand
   = 1.5*36.76
   + 55.14 l/c/d.

6. No public standpipes, 100 per cent individual house connections and 100 per cent increase in demand rates.
   Total average domestic demand
   = 2.0*36.76
   = 73.52 l/c/d.

7. Incomplete coverage of population case. This case assumes that not all of the population (for one reason or another) is connected to the lens water system or has a rainwater tank. The remainder would necessarily get their water from alternate sources e.g. wells. The pre-design study (PDS) figures are used as a basis and modified as follows:

   Category I housing as in PDS
   (1-0.9*0.9)*40*0.1 = 0.76 l/c/d.

   Category II housing, only 75 per cent served
   0.75 * (0.8*40+0.2*20)*0.65 = 17.55 l/c/d.

   Category III housing, only 50 per cent served
   0.50*20*0.25 = 2.50 l/c/d.

   TOTAL = 20.81 l/c/d.

TABLE B.1: Year 1990 Demand Predictions

		Loss rate (%)	Average domestic consumption litres/ capita/ day	Total Water Demand		
				Projection E_3 (22,800) m^3/day	Projection D_3 (24,500) m^3/day	Projection B_3 (26,300) m^3/day
1. PDS figures	(a)	10	29.16	805	860	919
	(b)	20	29.16	906	968	1034
2. No standpipes	(a)	10	36.76	998	1067	1141
	(b)	20	36.76	1123	1201	1283
3. 50 per cent increase on PDS domestic consumption	(a)	10	43.74	1175	1257	1345
	(b)	20	43.74	1322	1415	1513
4. 100 per cent increase on PDS domestic consumption	(a)	10	58.32	1544	1654	1771
	(b)	20	58.32	1737	1861	1992
5. 50 per cent in domestic consumption (no standpipes)	(a)	10	55.14	1464	1568	1678
	(b)	20	55.14	1646	1764	1888
6. 100 per cent increase in domestic consumption (no standpipes)	(a)	10	73.52	1929	2068	2215
	(b)	20	73.52	2170	2327	2492
7. PDS scheme incomplete service 100 per cent of Cat. I housing; 75 per cent of Cat. II housing, 50 per cent Cat. III	(a)	10	20.81	594	633	675
	(b)	20	20.81	668	712	759

PDS = Pre-design Study.

TABLE B.2: Year 2000 Demand Predictions

		Loss rate (%)	Average domestic consumption litres/capita/day	Total Water Demand		
				Projection E_3 (22,800) m^3/day	Projection D_3 (24,500) m^3/day	Projection B_3 (26,300) m^3/day
1. PDS figures	(a)	10	29.16	932	1094	1256
	(b)	20	29.16	1049	1231	1413
2. No standpipes	(a)	10	36.76	1143	1348	1552
	(b)	20	36.76	1286	1516	1746
3. 50 per cent increase on PDS domestic consumption	(a)	10	43.74	1337	1580	1823
	(b)	20	43.74	1504	1778	2051
4. 100 per cent increase on PDS domestic consumption	(a)	10	58.32	1742	2066	2390
	(b)	20	58.32	1960	2325	2689
5. 50 per cent in domestic consumption (no standpipes)	(a)	10	55.14	1654	1960	2267
	(b)	20	55.14	1861	2205	2550
6. 100 per cent increase in domestic consumption (no standpipes)	(a)	10	73.52	2164	2573	2981
	(b)	20	73.52	2435	2895	3354
7. PDS scheme incomplete service 100 per cent of Cat. I housing; 75 per cent of Cat. II housing, 50 per cent Cat. III	(a)	10	20.81	700	816	932
	(b)	20	20.81	788	918	1048

PDS = Pre-design Study.