

# KIRIWATSAN Water Resources Assessment Nikunau Island, Kiribati



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EUROPEAN UNION



SPC  
Secretariat  
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Community



A UNICEF project in partnership with the European Union and SPC for Kiribati





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# KIRIWATSAN

## Water Resources Assessment

### NIKUNAU ISLAND, KIRIBATI

Secretariat of the Pacific Community, Suva

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## Abbreviations and symbols

ADB	Asian Development Bank
AUD	Australian dollars
CV	Coefficient of Variation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EC	Electrical conductivity
EDF	European Development Fund
EM	electromagnetic
ENSO	El Niño – Southern Oscillation Index
GoK	Government of Kiribati
HYCOS	Hydrological Cycle Observation System
IC	Island Council
JSS	Junior Secondary School
KIRIWATSAN I	Kiribati Water and Sanitation Phase I for outer islands
KAP	Kiribati Adaptation Program (Phases I, II & III)
KMS	Kiribati Meteorological Service
KPC	Kiribati Protestant Church
MDGs	Millennium Development Goals
MELAD	Ministry of Environment, Land, and Agricultural Development
MIA	Ministry of Internal Affairs (formerly known as the Ministry of Internal & Social Affairs)
MPWU	Ministry of Public Works and Utilities
NWRIP	National Water Resources Implementation Plan
NWRP	National Water Resources Policy
NWSCC	National Water and Sanitation Coordination Committee
NZAID	New Zealand International Aid and Development Agency
OI(s)	Outer Island(s)
OICWSP	Outer Island Community Water Supply Project
OIWT	Outer Island Water Technician
PE	polyethylene
PfWG	Programme for Water Governance (EU)
PUB	Public Utilities Board (within MPWU)
RWH	Rainwater harvesting
SAPHE	Sanitation, Public Health and Environment Improvement Project
SOPAC	Pacific Islands Applied Geoscience Commission (now known as the Applied Geoscience & Technical Division (AGTD) of SPC)
SPC	Secretariat of the Pacific Community
UNCDF	United Nations Capital Development Fund
UNDP	United Nations Development Program
UNDTCD	United Nations Department of Technical Cooperation for Development
UNICEF	United Nations Children’s Fund

VWAP	Village Water Action Plan
VWSC	Village Water and Sanitation Committees
WASH	Water, sanitation and hygiene
WEU	Water Engineering Unit (within MPWU)
WHO	World Health Organization
WRA	Water Resources Assessment

### Measurements

EC	Electrical conductivity (measure of salinity)
KL/day	Kilo litres per day
L	Litres
L/sec	Litres per second
L/p/day	Litres per person per day
m <sup>2</sup>	Square metres
m <sup>3</sup>	Cubic metres
ML/day	Mega litres per day
μS/cm	Microsiemens per centimetre (unit for EC and used as an indicator of salinity)
mbgl	Metres below ground level
mS/cm	Millisiemens per centimetre
mg/L	Milligram per litre

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- Kiribati Meteorological Service for the use of its historical rainfall data.
- National Statistics Office for the census data on village population and water supply and sanitation facilities.

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## 1.0 EXECUTIVE SUMMARY

As part of the EDF10 KIRIWATSAN I Project, Nikunau Island was visited from 5<sup>th</sup> to 19<sup>th</sup> August 2013 for water resources assessment. The survey was conducted at Muribenua, Tabutoa, Rungata and Nikumanu, and included the following:

- A survey of existing and potential rainwater harvesting facilities.
- A survey of wells to record their condition, construction, potential sources of contamination, and water quality.
- A geophysical survey to estimate the spatial extent and thickness of the freshwater lenses beneath the villages.

Sixty-one (61) permanently roofed buildings were surveyed for rainwater-harvesting potential and improvements. Of these, twenty-two (22) were communal buildings, namely churches and *maneaba*. These communal buildings are considered suitable for rainwater harvesting improvements, because of their substantial roof catchment and accessibility to community members. Recommendations for improvements include the following:

- Installation of proper guttering to cover the entire roof circumference.
- Installation of downpipes, transmission pipes and inlet screens.
- Installation of additional tanks, with outlet taps.
- Removal of overhanging vegetation to prevent potential roof-catchment contamination from falling leaves and other organic matter, and access by animals.
- Installation of first-flush elements, where suitable, to minimise the contamination from dust.
- Installation of screens on tank inlets to protect freshwater from organic matter, and access by mosquitoes.
- Construction of fencing around the storage and outlet areas to minimise damage.

Two hundred and twenty-five (225) wells were assessed for infrastructural status and groundwater quality. Water table depth and salinity were assessed at an average of 2.61 mbgl and 2.12 mS/cm, respectively. Most wells:

- use bailers for abstraction;
- are inadequately constructed using coral rocks;
- are uncovered without a suitable lid;
- do not have a parapet; and
- are close to contaminant sources, namely toilets, general household rubbish, *bwabwai* pits and piggeries.

Bacteriological sampling and analysis, through the compact dry plate filtration membrane procedure, indicated the presence of E.coli bacteria in more than 90% of the sampled wells and rainwater tanks. Tests for nitrate indicated a low level of contamination. To ensure the protection of wells and improved groundwater quality in the short and medium term, the following are suggested:

- Substitution of coral rocks by locally-made concrete rings as casing/lining material to prevent the ingress of surface runoff and providing an additional length as parapet.
- Providing proper covering to prevent the entry of foreign matter and reduce the growth of algae.

- Use of concrete as apron material to prevent the infiltration of surface water close to the well.
- Construction of fences to protect well infrastructure and minimise access by animals.
- Promote the use of *Tamana* pumps to reduce the potential of contamination from bailers.
- Promote the use of bailer stands to keep the bailers off the ground where bailers are continued to be used.
- Decommissioning and/or relocation of wells too close to potential contaminant sources.
- Backfilling of all abandoned wells up to ground level.
- Boiling of all well water prior to any human consumption.

Real-time monitoring for groundwater level, conductivity and temperature at selected village wells yielded the assessment of tidal lag and tidal efficiency. Results suggest reasonable hydraulic connection between the groundwater system and the adjacent tidal/oceanic environment compared with Bonriki measurements, further suggesting increased permeability and possibly shallower depths to the underlying limestone than found in Bonriki.

Anomalous electrical gains and losses in the EM34 geophysical equipment generated erroneous results when determining the thickness of the freshwater lens underlying the target villages. This prohibited the groundwater resources estimation and its analysis under changes in population and climatic conditions. Further geophysical survey is proposed prior to the implementation phase to ensure that reliable information on freshwater lens potential is available to the target communities to warrant the selection and installation of appropriate water supply options.

Freshwater development options in the target villages will focus on rainwater harvesting improvements for communal buildings, and groundwater development in areas where moderate groundwater potential is detected. Options for groundwater development include household well improvements (cost to be borne by well owner), shared or communal wells, village wells and infiltration galleries.

Dry compost toilet is strongly recommended as the appropriate sanitation option because it uses no water, and has minimal impact on the groundwater resource. Additionally it produces a valuable by-product that can be used safely to improve soil fertility and food production.

Collective and coordinated community involvement, through an effective village action plan, with sanitation marketing will be required to ensure the sustainable operation and management of sanitation systems. A village action plan, addressing operation, management, accessibility, and maintenance aspects of sanitation systems, is suggested as a necessary prerequisite for potential infrastructural assistance.

Monitoring and evaluation of freshwater resources and the systems that are used to access the resource will be an important component of the projected implementation. A monitoring system should be established which engages both villagers and national government alike with defined roles and responsibilities. This will permit the assessment of the changes in freshwater quality and quantity under different climatic regimes. Monitoring and evaluation will encourage community to take ownership, and encourage correct operation and maintenance of systems.

## 2.0 INTRODUCTION

### 2.1 European Union EDF10 – KIRIWATSAN

The European Union in consultation with the Government of Kiribati developed the KIRIWATSAN Project under the 10<sup>th</sup> European Development Fund (EDF10). The KIRIWATSAN Project will focus on improving water and sanitation systems in outer islands in the Gilbert Group and in fostering community engagement in the project and ownership of the installed systems. The project is being undertaken in two phases. Phase I of the project has the following three components:

- (1) Assessment and design – Assessment of freshwater resources in 35 target villages across 8 islands, and design of sustainable groundwater, rainwater, and sanitation facilities.
- (2) Rainwater-harvesting installations for specific buildings in target villages.
- (3) Capacity building and governance which includes adapting WASH guidelines and introducing cost recovery mechanisms and training of community-based water-supply caretakers in the outer islands.

Phase II will include the construction of the water supply and sanitation systems for selected villages.

This report provides the results for the water resources assessment (WRA) carried out in Nikunau Island, under component 1 of the KIRIWATSAN Phase I Project.

Field investigations for Nikunau Island were undertaken from 5<sup>th</sup> to 19<sup>th</sup> August 2013. The assessment was conducted in four (4) target villages: Muribenua, Tabutoa, Rungata and Nikumanu, and included the following:

- A survey of 61 buildings to assess existing and potential rainwater harvesting systems.
- A survey of 225 groundwater wells to determine their condition, construction type, and risk to water safety.
- An electromagnetic (EM34) geophysical survey to estimate the thickness of the freshwater lens beneath the target villages.

The overall objectives of the assessment in target villages were to:

- (1) assess the conditions, construction, potential sources of contamination and water quality for groundwater wells.
- (2) Survey existing and potential rainwater harvesting facilities.
- (3) Estimate the thickness of the freshwater lens beneath the island.
- (4) Determine the feasibility of developing freshwater resources and their vulnerability to population growth and climate change.
- (5) Design suitable water-supply options for the target communities.

This report summarises the assessment's methods, major findings and recommendations for the above target villages on Nikunau Island.

## 2.2 Survey team and schedule

The survey team for Nikunau consisted of Aminisitai Loco from the GeoScience Division of the Secretariat of the Pacific Community (SPC), Martin Mataio and Mwaketa Iotebwa from the Water Engineering Unit (WEU) of the Ministry of Public Works and Utilities (MPWU), and the Nikunau Island Water Technician, Nintabeti Tekitea. Eight casual day labourers assisted with the surveys, and were selected from each of the respective target villages for the day of survey. Summary of the survey schedule is appended as Annex 1.

## 3.0 BACKGROUND

### 3.1 Location and Geography

Nikunau Island, located between longitudes 176°24'E and 176°30'E and latitudes 1°19'S and 1°26'S, is one of the southern islands of the Gilbert Islands Group (Figure 1). The island has an area of 17.63 km<sup>2</sup> and is approximately 14 km long. The NW-trending island, 2.6 km wide at its widest point and 0.26 km at its narrowest, is split into two parts connected by a narrow strip of land in the middle. The northern part accommodates the main services infrastructure such as the Council offices, airstrip, seaport and the villages Muribenua, Tabutoa, Rungata and Manriki. The southern part accommodates Nikumanu and Tabomatang villages (Office of te Beretitenti, 2012).

Most villages are scattered in a linear pattern along the lagoon shoreline. Vegetation on the island includes coastal strand, mangroves, coastal marsh vegetation and inland atoll forests. Like the other Gilbert Group islands, coconut palms, pandanus and breadfruit, along with the marine resources play important roles in food supply and agricultural activities mainly because copra and fishery remain the major income earners in the villages. Most households cultivate swamp taro (*bwabwai*) on family land away from the main villages because of its significance as a traditional food, whilst pawpaw and banana are rare on the island because of the predominant dry climate and the intensive care needed in drought periods for their cultivation (Office of te Beretitenti, 2012). The summary of the locations and additional descriptions of the four (4) target villages are presented in Table 1. The target villages are: Muribenua, Tabutoa, Rungata and Nikumanu.

There are 6 villages on Nikunau Island. Figure 2 is a map showing the locations of the target villages.



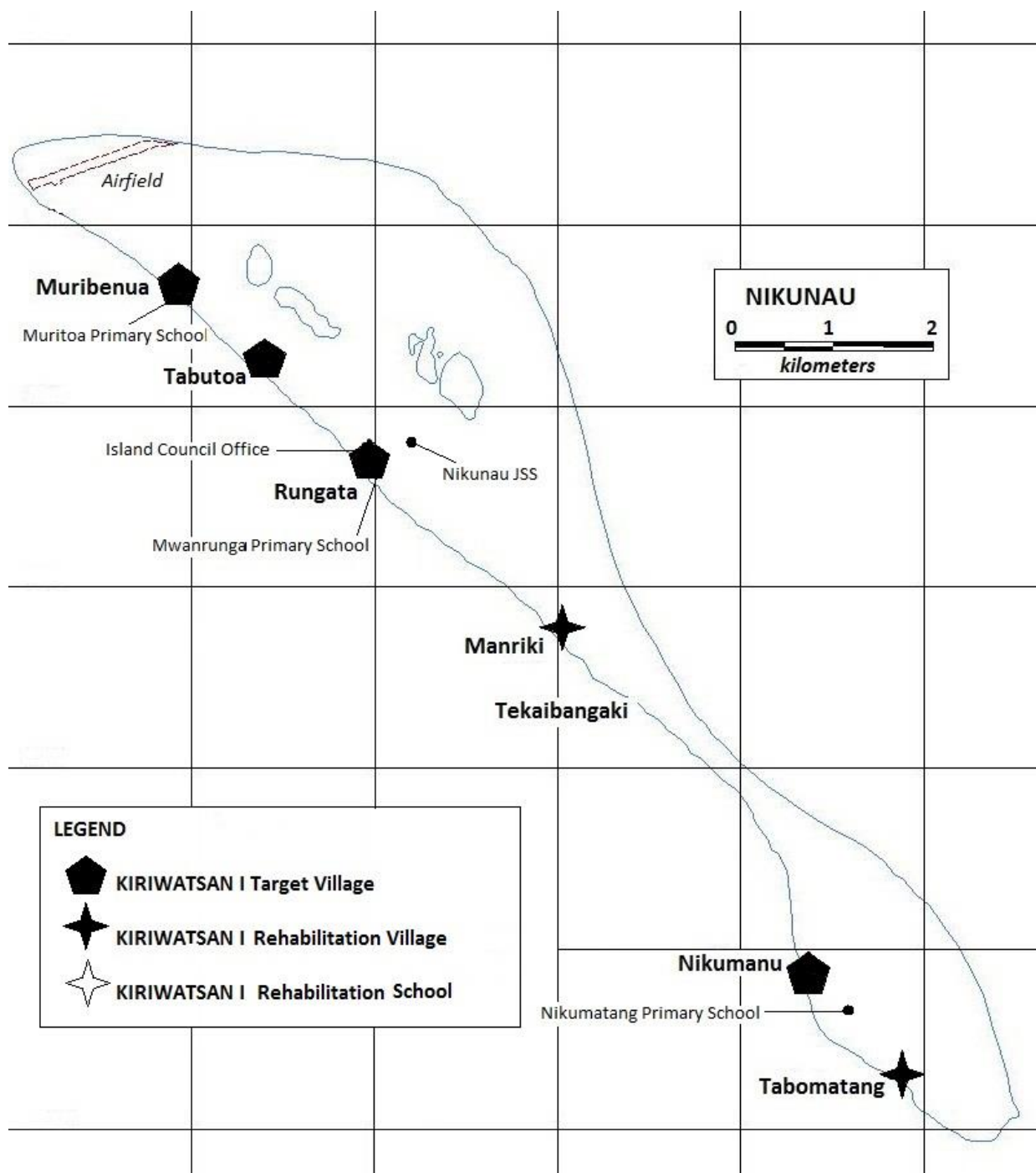


Figure 2. Location of KIRIWATSAN 1 WRA target villages (Map Source: Nikunau Island profile, UNICEF 2012 profiling report).

## 3.2 Population

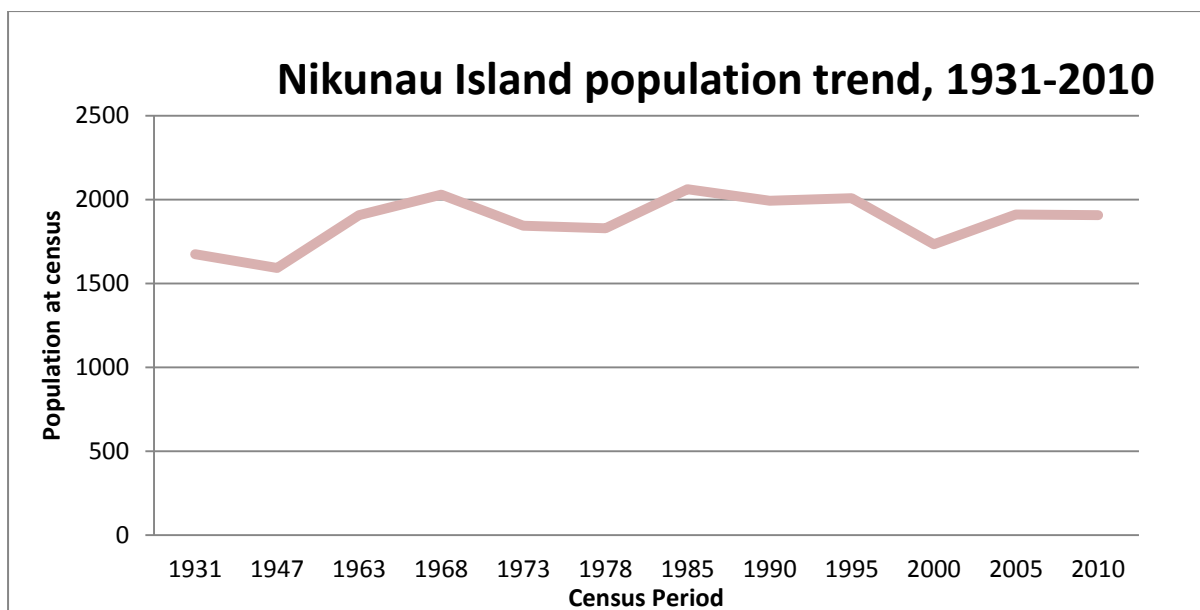
Population on the island over the last two decades has, according to census data, stabilised with minor fluctuations recorded between villages and over time. Minor population increase was recorded from 1990 to 1995 and from 2000 to 2005, with 1.5% and 2.1% growth rates, respectively. Minor declines were registered from 1995 to 2000 and from 2005 to 2010, with a 3.8% and 0.1% negative growth rates, respectively. Table 2 shows the annual growth rates between censuses and the average annual growth rates for all villages. It should be noted that there is significant variation in growth rate between censuses suggesting that the data should be treated with caution for planning purposes.

**Table 2. Population data for Nikunau from census periods during 1990-2010. Target villages in bold. (Source: National Statistics Office)**

Village	Census Data					Annual Growth Rate					Estimated Population
	1990	1995	2000	2005	2010	1990-1995	1995-2000	2000-2005	2005-2010	1990-2010	
<b>Muribenua</b>	294	426	228	240	240	9.0%	-9.3%	1.1%	0.0%	0.2%	249
<b>Tabutoa</b>	211	228	157	139	154	1.6%	-6.2%	-2.3%	2.2%	-1.2%	117
<b>Rungata</b>	748	834	813	933	976	2.3%	-0.5%	3.0%	0.9%	1.4%	1253
Manriki	217	200	186	197	184	-1.6%	-1.4%	1.2%	-1.3%	-0.8%	155
<b>Nikumanu</b>	369	332	281	316	265	-2.0%	-3.1%	2.5%	-3.2%	-1.5%	188
Tabomatang	155	125	68	87	88	-3.9%	-9.1%	5.6%	0.2%	-1.8%	56
<b>Total</b>	<b>1994</b>	<b>2145</b>	<b>1733</b>	<b>1912</b>	<b>1907</b>	<b>1.5%</b>	<b>-3.8%</b>	<b>2.1%</b>	<b>-0.1%</b>	<b>-0.1%</b>	<b>1877</b>

Note that the projected 2030 population is estimated through the mean of all the annual growth rates calculated between each pair of census periods from 1990 to 2010.

The population trend from 1931 to 2010 indicates moderate fluctuations recorded between 1947 and 2000 before stabilising in the last 10 years (Figure 3).



**Figure 3. Population growth on Nikunau Island 1931 - 2010 (Source: National Statistics Office).**

The different growth rates in the target villages will affect land use and the exploitation of the underlying freshwater resources. Additional water demands will accompany any increase in population, plus increased wastewater disposal. Should sanitation practices remain poor, increased contamination potential of the groundwater will result. The community will need to consider the impacts of population pressure on water resources, in addition to climate variability influences.

### 3.3 Rainfall Analysis

Monthly rainfall data for Nikunau are available from 1955 to 2011 with gaps. The bulk of the complete rainfall data is within the periods from 1955 to 1972, and from 1981 to 1987, accounting for a total of 24 years. Some records are available from 1973 until 1980 (8 years), with rainfall records mostly unavailable from 1989 to 2010 (21 years). Recent records were collected from 2011, after the installation of a manual rainfall station in Rungata under the joint support of the EU-funded Hydrological Observing Systems (HYCOS Project, 2006-2010) and the Kiribati Adaptation Program (KAP); although gaps are consistently noticed.

The daily rainfall is currently recorded manually by the island water technicians into a purpose-designed rainfall recording book with carbon copies sent to the Water Engineering Unit within the Ministry of Public Works and Utilities, and the Kiribati Meteorological Service (KMS) in Tarawa, with a copy kept on the island.

Climate stations are maintained by the Kiribati Meteorological Service for selected islands and in these locations, datasets with longer rainfall records are available along with parameters other than just rainfall. The climate stations for the Gilbert Islands are:

- Betio, South Tarawa
- Butaritari
- Beru

The available monthly rainfall data for Nikunau are compiled with data from the Kiribati Meteorological Service with some gaps filled by Taylor (1973), 'An Atlas of Pacific Islands Rainfall', and non-KMS rainfall stations. The climate data are summarised in Table 3 and the monthly records as Annex 2. The maximum monthly rainfall during this period occurred in December 1974, reading 765 mm; zero monthly rainfall has sometimes been recorded for all months except for June, July and August. Nikunau, as with other islands within the Gilbert Group, have on average a 5-month 'wetter' December to April period, and higher mean rainfall, followed by a 7-month 'drier' May to November period, with lower mean rainfall. Comparison between the mean and the median values shows that the rainfall distribution is positively skewed towards higher rainfall. The variability of monthly rainfall is moderate between wet and dry seasons. It is noted that rainfall in July is on average slightly higher than surrounding dry months possibly due to some high-rainfall events in 1964, 1974, 1976, 1982, and 1987 (Annex 2).

**Table 3. Statistics of monthly rainfall in Nikunau for the period 1955-2011 (with gaps).**

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
<b>Mean (mm)</b>	157	110	107	116	83	91	151	101	66	74	74	131	<b>1242</b>
<b>Standard deviation (mm)</b>	181	156	133	144	86	125	137	95	87	94	104	159	<b>782</b>
<b>CV*</b>	1.2	1.4	1.2	1.2	1.0	1.4	0.9	0.9	1.3	1.3	1.4	1.2	<b>0.6</b>
<b>Maximum (mm)</b>	695	618	490	656	329	695	499	356	384	362	417	765	<b>3332</b>
<b>Minimum (mm)</b>	0	0	0	0	0	1	2	1	0	0	0	0	<b>309</b>
<b>No. Years</b>	33	32	32	32	31	31	32	32	33	32	30	31	<b>26</b>

\*CV: Coefficient of variation = standard deviation/mean

A comparison between mean annual rainfall and latitude for Gilbert Islands was undertaken. There is a discernible trend indicating that the further from the equator the island is, the more rainfall can be expected; and the further an island is situated north of the equator the more likely it is to have increased annual rainfall than islands of similar latitude south of the equator. A notable outlier is Butaritari, which has a significant increase in rainfall for its latitude, and is within a 'rainbelt', whilst Aranuka, Marakei and Tamana indicate a 'rain shadow' with less mean annual rainfall than suggested by the trend line (Figure 4).

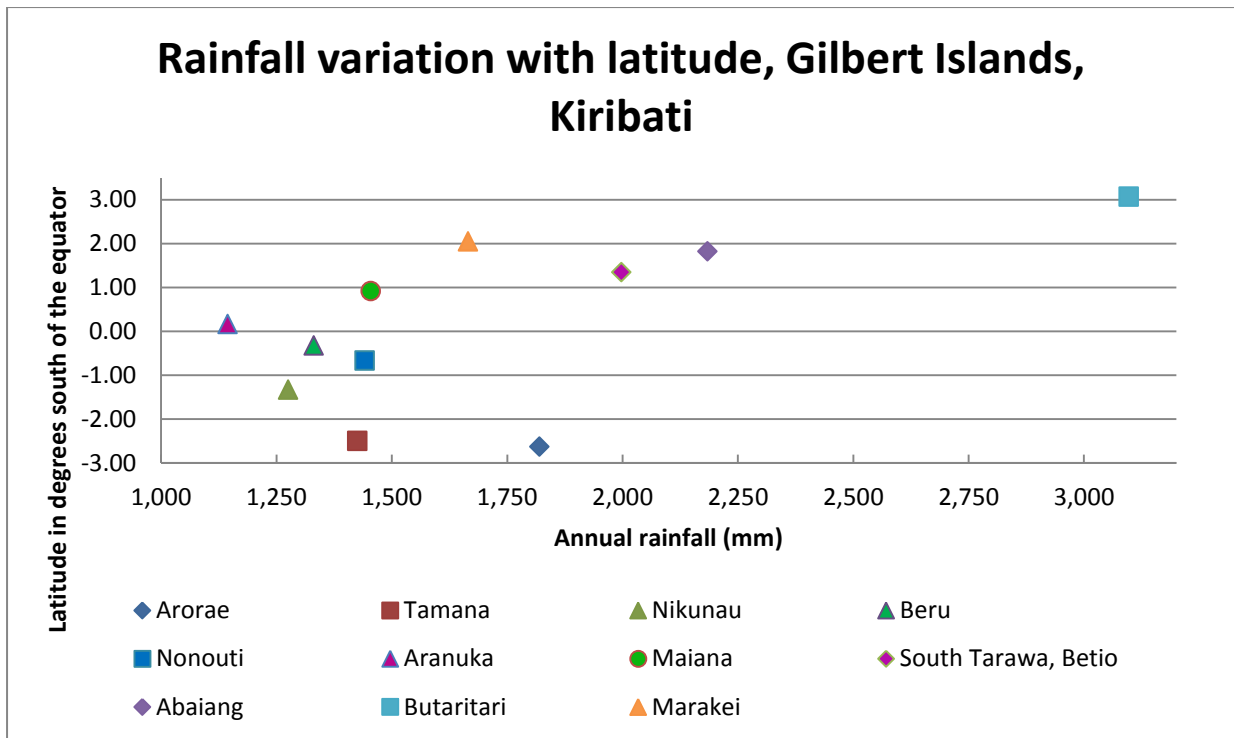


Figure 4. Mean annual rainfall (1950- 2014) variation with latitude for the Gilbert Islands Group.

A comparison of islands with regards to their monthly variation indicates some common seasonal variation for rainfall between islands, with the seven months May to November being the ‘drier’ season (Figure 5). Seasonal rainfall statistics, specifically for Nikunau, is contained in Table 4.

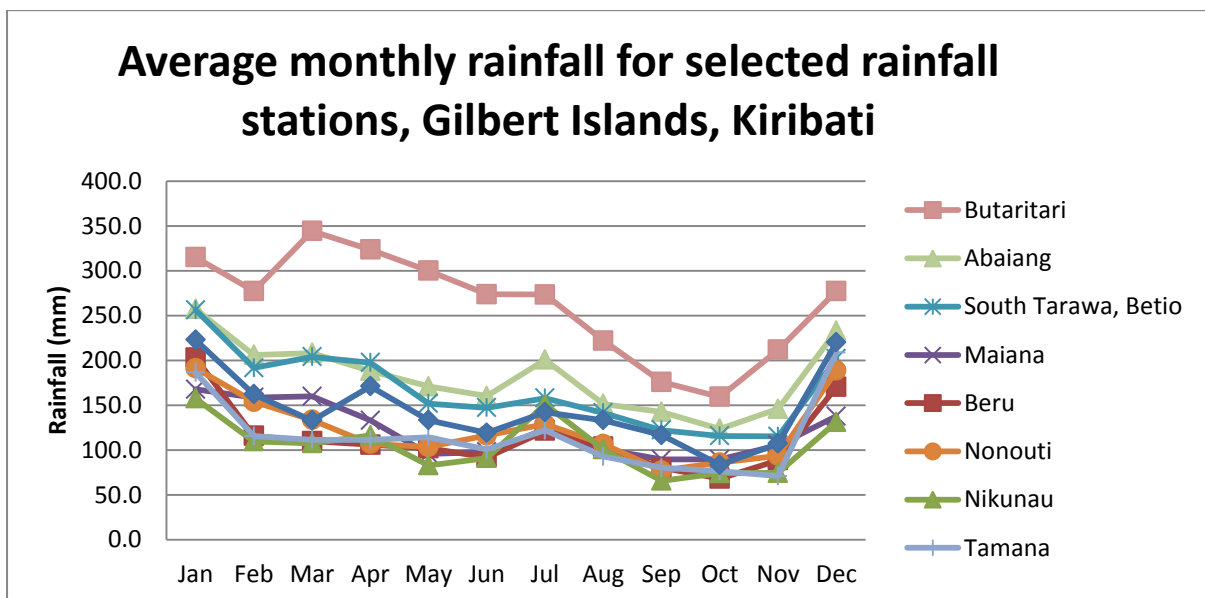


Figure 5. Variation in monthly rainfall for selected islands, 1945-2014 (available records). Generally, the months from May to November are considered the driest months whilst the months from December to April, the wetter months, for Gilbert Islands.

**Table 4. Annual rainfall (mm) ‘drier’ May to November (7 months) and ‘wetter’ December to April (5 months) seasonal rainfall statistics for Nikunau 1955 to 2011.**

Statistic	Annual	May-Nov	Dec-Apr
Mean	1242	595	648
Std Dev	782	500	569
CV	0.63	0.84	0.88
Max	3332	2191	2193
Min	309	25	53
Median	1123	386	532
No. Years	26	26	26

It is noted that the ‘drier’ 7 months from May to November for Nikunau received less rainfall than the ‘wetter’ 5 months from December to April for the period 1955-2011.

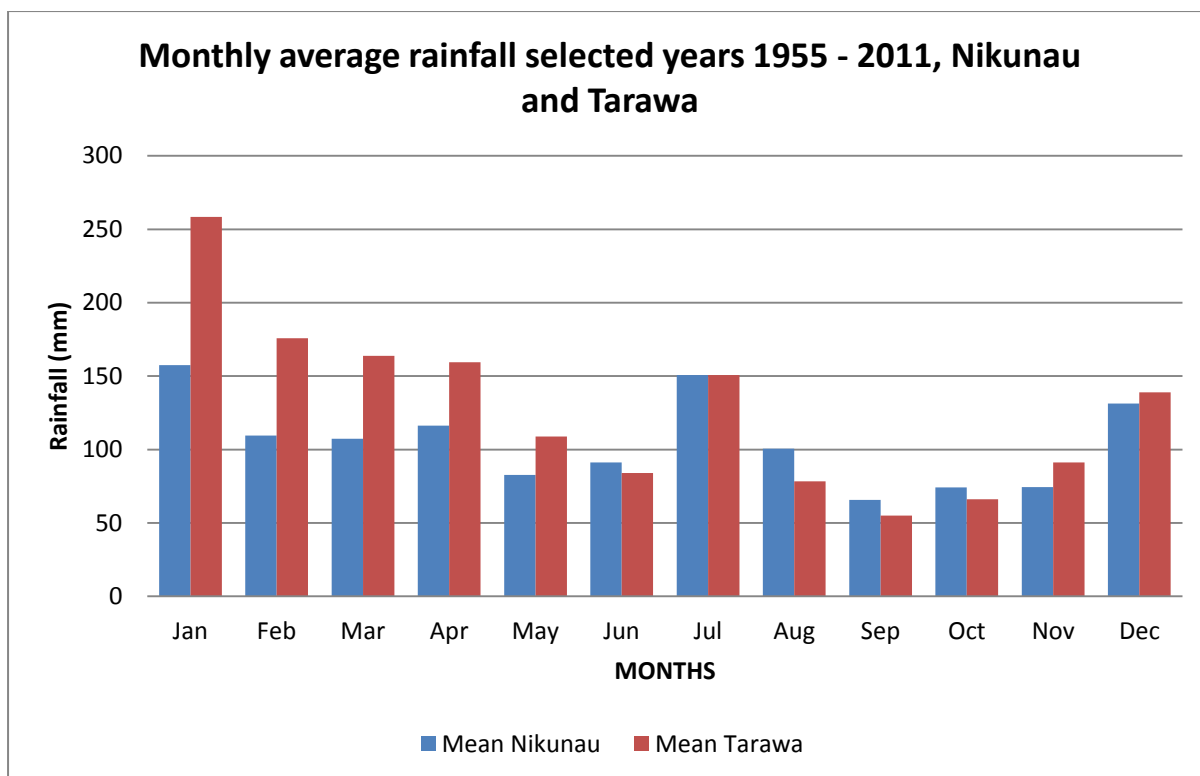
The Coefficient of Variation (CV) = the standard deviation/mean and is a measure used to indicate the variance of rainfall away from the long-term average. The higher the CV the greater the range of variability in rainfall and the greater the departure from the long-term annual average rainfall that can be expected. A lower CV indicates a lesser range of variability in rainfall and greater confidence in receiving a rainfall for any given year close to the long-term annual average. The CV of rainfall can be considered as an index of risk, the higher the CV, the higher the risk that rainfall will be less reliable. Because CV considers deviations from averages, it can be used for comparisons of variability within and between regions.

The CV for Nikunau is 0.63 indicating that rainfall in any one year, for about 68% of the time, can be expected to vary  $\pm 63\%$  from the long-term annual average rainfall, 1242 mm.

The Nikunau CV, 0.63, indicates a high temporal variability of rainfall. It is also noted that the seasonality of the rainfall suggests a greater variability of rainfall away from the long-term seasonal average, indicating that rainfall is even less reliable with consideration to any particular season. This is an important consideration in the assessment of water security especially with regard to reliance on rainwater harvesting.

The relatively large gaps in the Nikunau rainfall dataset precludes further analysis of the rainfall data. The Tarawa rainfall station has good quality long-term data and a comparison between the two datasets indicates that monthly rainfall on Nikunau is on average 37% lower than on Tarawa, although there is great variability within any one year and between months for the two islands (Figure 6). Caution is required when attempting to transpose the rainfall from Tarawa for Nikunau.

It is recommended that the daily rainfall recordings for each island continue to be supported by the Government of Kiribati as it provides critical datasets for water resource management by providing an indication of climate variability both temporally and spatially.



**Figure 6. Average monthly rainfall for common years at Nikunau and Tarawa for the period 1955-2011.**

ENSO has a dominant effect on the rainfall distribution on Gilbert Islands and the Pacific. An El Niño event will generally result in increased rainfall for the Gilbert Islands, whilst a La Niña event will result in reduced rainfall.

The Pacific Climate Change Science Program funded by the Australian Government undertook comprehensive research into the climate and ocean projections for 14 Pacific nations. The projections for temperature, rainfall, and sea-level rise are based on the output from 24 global climate models and the Coupled Model Intercomparison Project Phase 3 (CMIP3) (Meehl et al., 2007), and the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Hennessey et al., 2007), focusing on projections for 2030, 2055, and 2090 under high, medium and low greenhouse-gas emissions scenarios. The projections and predictions are the result of joint research by the Australian Bureau of Meteorology and the Commonwealth Scientific and Industrial Research Organisation (Australian Bureau of Meteorology and CSIRO, 2011).

The summary of predictions for Kiribati include the following:

- Annual average air temperature will increase. By 2030 it is predicted to increase by 0.7°–0.8° C (moderate confidence).
- There will be a general increase in rainfall, > 5% by 2030 (low confidence).
- Intensity of extreme rainfall and frequency of days on which it occurs are projected to increase (high confidence).
- Drought is expected to decrease (moderate confidence).
- Sea level will continue to rise. By 2030, sea-level rise is expected to be 5-14 cm (moderate confidence).

A rising sea level will increase the impact of coastal inundation from extreme wave and seawater levels, with potential impact on the freshwater lens from inundation (Australia Bureau of Meteorology and CSIRO, 2011).

### 3.3 Geology and Hydrogeology

No detailed geology of Nikunau is available but general observations confirm the presence of two major geological units, namely surficial, poorly sorted and unconsolidated gravelly-silty coral sands unconformably overlying an older well-indurated, weathered, and moderately fractured and porous limestone. Previous studies by Falkland and Woodroffe (1997) and Falkland (2004), suggest that the geological framework for Nikunau is similar to that in Tarawa, with unconsolidated Holocene sediments unconformably overlying the more permeable Pleistocene limestone.

The thickness of the unconsolidated sediments for Nikunau and the depth to the unconformity on more porous limestone is not known with confidence without drilling of investigation boreholes on Nikunau. It is assumed that the depth to the more permeable Pleistocene limestone will be similar to Tarawa, which is 12-21 m.

The occurrence of freshwater underlying atoll islands like Nikunau has been well documented elsewhere (Falkland and Woodroffe (1997), Alam et al. (2002), Falkland (2003), Hunt and Peterson (1980)) and the reader is directed to these documents. Figure 7, after Falkland (2003) illustrates the generally accepted conceptual model for groundwater occurrence in atolls, with the expected position and stratified nature of the freshwater lens relative to basal sea water and the transitional zone.

For resource assessment purposes in the Pacific, electrical conductivity is used as a measure of groundwater salinity. An electrical conductivity of 2.5 mS/cm or 2500 µS/cm, is widely accepted as the base or upper limit of the freshwater zone, and will be used as guideline value for freshwater lens salinity.

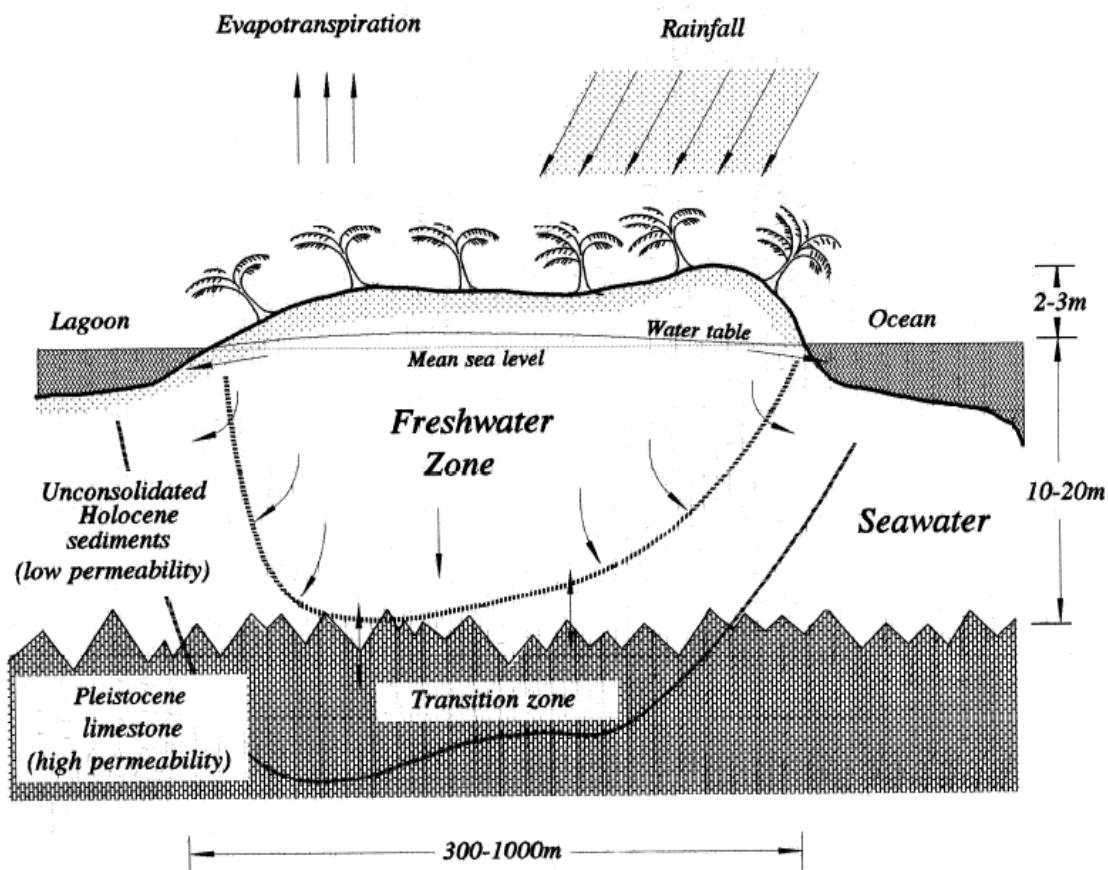


Figure 7. Freshwater lens configuration typical in atoll environments like Nikunau Island (Falkland 2003).

Estimates of annual rainfall recharge and sustainable yield for Kiribati islands had also been made by previous studies, where a simple relationship between annual rainfall and annual recharge can be made based on water-balance studies on a number of islands (UNESCO, 1991), Figure 8. A first estimate of recharge using data collected from recharge studies for several atoll and coral islands, including Tarawa has derived an empirical relationship between mean annual rainfall and calculated mean annual recharge for a number of low-lying islands. Falkland (2003), in using this approach, developed a spreadsheet based on the resulting polynomial equation from the plotted data to allow the estimation of recharge 'Rainfall vs Recharge.xls' for the islands of Kiribati. Using the average annual rainfall for Nikunau (1242 mm), the estimated mean annual recharge for Nikunau was 284 mm, which accounted for an estimated 23% of annual rainfall.

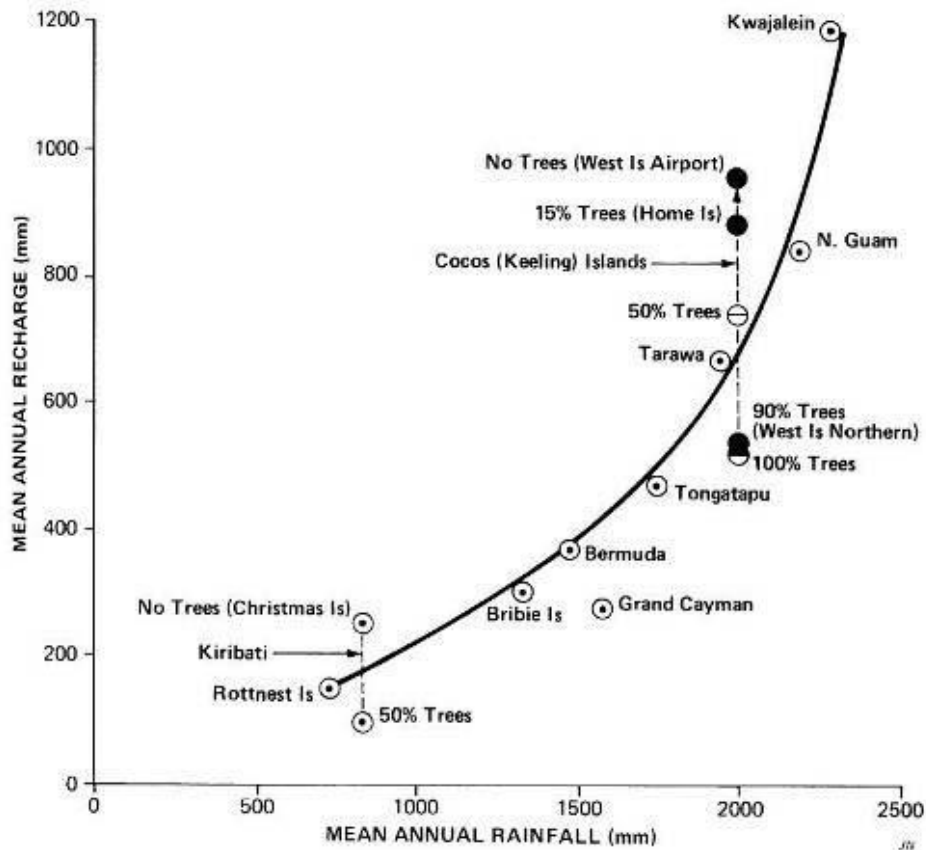


Figure 8. Annual rainfall – recharge relationship for a few studied small islands (UNESCO 1991).

Falkland (2003) has also developed a conservative assessment of sustainable yield, based on a relationship between sustainable yield and recharge, whereby the sustainable yield increases as the percentage of recharge increases, and is based on modelling studies in high rainfall areas and a study of Christmas Island in 1993. The relationship being:

$$y = x - 10$$

whereby:      x = recharge (% of rainfall)  
                     y = sustainable yield (% of recharge)

Applying this approach for Nikunau with a mean annual rainfall of approximately 1242 mm and an estimated mean annual recharge of 284 mm with 23% of rainfall; a conservative preliminary sustainable yield of 13% of annual recharge is determined which correlates with the estimated sustainable yield for Nikunau by Falkland (2003).

It should be noted that this is a conservative approach to the estimation of sustainable yield, but it is useful as a first estimate in lieu of specific studies.

### 3.4 Water supply and sanitation

Groundwater is the primary water source for drinking and domestic purposes on Nikunau (96%), whilst rainwater is used as the primary drinking water source for less than 4% of households (Table 5, National Statistics Office, 2012).

**Table 5. 2010 Census data on primary drinking water sources commonly used on Nikunau atoll (National Statistics Office, 2012).**

Main source of drinking water 2010					
NIKUNAU	Rain water tank	Pipe system (PUB)	Open well water	Protected well water	Total
	16	0	214	135	365
Muribenua	3	0	31	19	53
Tabutoa	0	0	22	6	28
Rungata	7	0	85	84	176
Manriki	2	0	13	20	35
Nikumanu	2	0	50	4	56
Tabomatang	2	0	13	2	17

Previous inspection of the water supply systems in most settlements in Nikunau was documented by Falkland (2003), providing a summary of the status of the water supply systems at the time of that inspection. As part of the water resources assessment, an update of the status of the water supply systems for the target villages under KIRIWATSAN I has been undertaken and the original table updated for those systems inspected (Table 6).

**Table 6. Updated water supply systems summary table (after Falkland 2003).**

Village/ School	2000 Population	Description and Condition of Water Supply System – 2003	2010 Population	Description and Condition of Water Supply System – KIRIWATSAN survey 2013
<b>Muribenua</b>	228	1 solar pump, 27 taps, 1 tank, 4 <i>Tamana</i> pumps. Wind mill not working	240	36 household wells surveyed, 1 solar pump (not working), 12 <i>Tamana</i> pumps and 3 rainwater tanks connected to KPC church
<b>Muritoa Primary School</b>		1 solar pump, 4 taps, 1 tank – all working		Surveyed under Tabutoa Village
<b>Tabutoa</b>	157	1 solar pump, 26 taps, 1 tank, 1 <i>Tamana</i> pump – all working	154	28 household wells, 2 solar pumps, 6 <i>Tamana</i> pumps and 2 rainwater tanks, including Muritoa Primary School
<b>Rungata</b>	813	Wind mill needs spare parts - not working	976	107 household wells, 2 solar pumps (both working), 4 electrical pumps (1 not working), 13 storage tanks, including Mwarunga Primary School and Nikunau JSS
<b>Manrunga Primary School</b>		1 solar pump, 5 taps, 1 tank – system not working		Surveyed under Rungata Village
<b>Manriki</b>	186	1 solar pump, 27 taps, 2 <i>Tamana</i> pumps – all working. Wind mill not working	184	Not surveyed
<b>Nikumano</b>	281	1 <i>Tamana</i> pump operating	265	54 household wells, 1 solar pump, 4 <i>Tamana</i> pumps, 6 rainwater tanks, including Nikumatang Primary School
<b>Nikumatang Primary School</b>		1 solar pump, 3 taps, 1 tank – all working		Surveyed under Nikumano Village
<b>Tabomatang</b>	68	1 solar pump, 25 taps, 1 tank, 1 <i>Tamana</i> pump – all working. Wind mill not working	88	Not surveyed
<b>Bukerua</b>		1 solar pump, 9 taps and 1 tank – all working		Not surveyed

The 2010 census also indicates that 36% of households on Nikunau practise open defecation – beach (122) and bush (10). Flush toilets (217), including pour flush, are increasingly being used and account for 59% of households, whilst the atollite (14), sea (1) and pit latrines (1), are the least practised sanitation options accounting for 5% of the sanitation practices for households (Table 7).

**Table 7. Sanitation systems in use on Nikunau. (National Statistics Office, 2012)**

Census year	Flush PUB	Flush Own	Latrine	Atolette	Beach	Bush	Sea	Number of Households
2005	1	1	186	2	175	102	65	335
2010	0	217	1	14	122	10	1	365

A comparison of the sanitation systems indicated in the census data over time suggests that there is an increase of improved sanitation practices over time and a general move away from open defecation. The greatest significance is the trend of increased flush and pour-flush toilets. This trend towards flush and pour-flush toilets is likely to increase the usage of water per capita. The potential for groundwater contamination is increased where poorly designed flush and pour-flush toilets are used.

### 3.5 Previous work

A summary of previous water supply improvement work on Nikunau Island, as documented by Falkland (2003) and the Water Unit (2002) is provided below:

1. World Health Organisation funded wind powered water supply systems for seven (7) villages on Nikunau in the 1970s. The wind pumps were later replaced by solar pumps (partly funded by the South Pacific Commission).
2. The Norwegian Government assisted PUB with the installation of solar-powered pumping systems for two (2) villages on Tabiteuea North and Nikunau in 1985.
3. The United Nations Capital Development Fund's Outer Island Community Water Supply Project (UNCDF/OICWSP) provided village wells, solar pumps, elevated tanks and taps to three (3) primary schools as detailed in Table 8.

**Table 8. Infrastructural assistance on three (3) primary schools in Nikunau Island under the UNCD Project (Water Unit, 2002).**

Village	Primary School	No. of Wells	No. of Hand Pumps	No. of Solar Pumps	No. of Elevated Tank Stands	Length of Pipes (m)	No. of Taps
Tabutoa	Muritoa	1	-	1	-	210	3
Rungata	Manrunga	1	-	1	1	220	5
Nikumanu	Nikumatang	1	-	1	-	160	3
<b>Total</b>		3	-	3	1	590	11

Key challenges and conclusions of the UNCDF/OICWSP Project are summarised in the Table 9.

**Table 9. Summary of the UNCDF/OICWSP challenges and conclusions (Water Unit, 2002).**

Major challenges	Major conclusions
Unreliability of flight schedules to the outer islands for about 60% of the project period resulting in difficulty in project supervision and implementation	The value and benefit of having very competent and dedicated local staff resulted in the project's overall satisfactory achievement
Difficulty in mobilising volunteer labour through the island and village councils caused significant delays	The installation of water supply systems in schools had a positive impact on the health of school children through the observed usage of hand-washing facilities
Considerable shortage of staff in 1996 hampering production progress	The establishment of Water Technicians on every outer island by the Ministry of Works and Energy has facilitated project implementation and maintenance of the water supply
Difficulty in securing adequate ship space for material shipment to the islands caused slow progress in project implementation	Noticeable improvement in water quality was observed through the bacteriological sampling and tests whereby protected wells installed by the project showed no E.coli bacteria, in contrast to all the unprotected (existing) wells, which showed positive results

Falkland (2003), in analysing previous water supply improvement works in Kiribati, noted that although the UNCDF/OICWSP had a substantial coverage of installing 263 improved water systems in 73 villages, none of the community water supply systems is currently operating. Several of these water systems failed within 6 months of installation. These failures were mainly attributed to the lack of:

- island community ownership;
- local training on operation and maintenance;
- any system for recovering the operating and maintenance costs;
- capacity and resources of the lead agency; and
- appreciation by the donor of the complexity of small island subsistence in Kiribati.

It is worth noting that many of those observations were also made by this survey team and remain valid.

## 4.0 FIELD SURVEY

This section presents the results from the current water resource assessment investigations undertaken, using geophysics and water resource assessment techniques to determine the status of the:

- rainwater harvesting systems;
- well infrastructure and reliance; and
- groundwater potential for water supply purposes.

Investigations were undertaken jointly by SPC and the Water Engineering Unit staff of the GoK Ministry of Public Works and Utilities.

### 4.1 Survey methodologies

The assessment methods are as outlined below.

1. Assessment of existing rainwater harvesting infrastructure included:
  - the measurement of roof-catchment dimensions and the effective roof area;
  - assessing condition of guttering, fascia board and down-pipes; and
  - storage dimensions and condition.
2. Assessment of well infrastructure included:
  - construction features and materials, abstraction types;
  - measurement of water salinity and depth to water table;
  - water sampling from selected wells and rainwater tanks for microbiological analysis; and
  - identifying well features which reduce the potential risk of contamination to the well and the groundwater.
3. Cross-island transects with EM34 electromagnetic surveys to determine the lateral variability in bulk ground conductivity as a guide to the estimation of fresh groundwater thickness.
4. Conducting community awareness meetings on identified water resource and sanitation issues and discussions on potential strategies to improve water resources management.

The field information was collected using GPS-enabled Trimble Juno 3 series handheld computers and project-developed standardised templates, attached in Annexes 3 and 4.

The data were compiled and uploaded onto a web-based spatial database developed under this project. The site is currently hosted and maintained by SPC with administrator rights held by SPC and WEU staff. It is proposed that the database will be cloud based in the future with read only

accessibility available for all users logging onto the site with the exception of assigned administrators.<sup>1</sup>

A non-editable standalone version on a DVD is being made available for use where internet connectivity is difficult.

## 4.2 Rainwater harvesting (RWH) survey and assessment

A total of 61 buildings were surveyed in the target villages on Nikunau atoll, for assessment on the suitability and potential for RWH and its improvements (Table 8). The assessment included:

- effective catchment area and condition;
- transmission type and efficiency;
- storage condition and dimensions; and
- contamination potential.

The main groups of buildings were:

### 1. Schools near and/or within target village boundary

The following schools were surveyed:

- Muritua Primary School (in Tabutoa Village);
- Mwarunga Primary School and Nikunau JSS (Rungata Village); and
- Nikumatang Primary School (Nikumanu Village).

All, but one of the schools have considerable potential for increasing rainwater harvesting (RWH) water supply with good roofing materials and substantial catchment area, but will need significant improvements in infrastructure, such as down pipes, fascia boards, guttering, and additional storage. Muritua Primary School, having thatched roofed classrooms, requires the construction of a new RWH structure because of its isolated location in relation to existing RWH buildings, and the need to meet substantial water demand from students and teachers.

### 2. Churches

Both Kiribati Protestant Church (KPC) and Catholic Church (the main religious denominations) buildings were surveyed for their existing RWH status and potential. A total of seven (7) churches were surveyed. Most of these church buildings make good communal RWH centres because of their accessibility and substantial roof catchments, but were identified as needing considerable improvements to infrastructure for collection, transmission, storage and abstraction. Specifically, repairs or replacements are required for fascia boards, gutters, down pipes, tanks and taps.

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<sup>1</sup> <http://ict.sopac.org/kiriwatsan/login/index>

### 3. *Maneaba*

Four (4) *maneaba* (including village-owned and church-owned) were surveyed for their existing RWH status and potential. Similar to the churches, *maneaba* also make good communal RWH centres because of their communal accessibility and substantial roof catchment but lack collection, transmission, storage and abstraction facilities as indicated above.

### 4. Village clinics

The three (3) newly constructed village health clinics at Nikumanu, Rungata and Muribenua were surveyed and do not require any immediate infrastructural improvements.

### 5. Private buildings

Several privately owned buildings were also surveyed because of their adequate roofing materials/ conditions. As the rainwater harvested from private buildings would be used by the owners and their families, with limited communal access, it is expected that costs of any infrastructural improvements to these buildings for RWH would be borne by the household owners.

**Table 10. Summary of surveyed buildings in the target villages.**

Village	Muribenua	Tabutoa	Rungata	Nikumanu
Number of buildings surveyed	9	9	34	9
Buildings with proper roofing materials	4	2	7	1
Buildings without fascia board	5	5	13	2
Buildings without guttering	3	7	16	5
Buildings without down pipes	7	7	29	5
Buildings with overhanging vegetation	1	0	15	5
Buildings with tanks connected	3	2	11	6

It was assessed that:

- 23% of the buildings have good roof conditions – with the remaining 77% requiring minor repairs to total replacement of roofs.
- 41% of the suitably roofed buildings do not have fascia boards, 51% do not have guttering, and 79% do not have down pipes, demonstrating that the buildings are inadequately equipped for optimum rainwater collection, and transmission.
- 34% appear to be partially covered with vegetation with potential of rainwater contamination, and guttering blockages and overflow.
- 36% of the buildings have storage tanks, suggesting that most buildings will require suitably sized rainwater tanks to be installed for secure and adequate storage/conservation.

It should be noted that inspections of roofing conditions are limited to what could be observed at the time of the survey from the ground. Experience suggests that some roofs may require additional repairs and/or replacement that cannot be identified without a more detailed inspection.

Suggested upgrades to improve RWH potential include the following:

- Repair or replacement of roofing materials, preferably with corrugated zinc-aluminium coated steel.
- Repair or replacement of fascia board and guttering to cover the entire roofing dimension.
- Installation of standard designed guttering, vertical down pipes and transmission pipes to improve the flow of rainwater towards the storage tanks, with improved construction and maintenance.
- Where appropriate, the installation of first-flush mechanisms to reduce the transmission of potential contaminants and organic matter into the transmission and storage systems.
- Selection of appropriately sized tanks with proper piping and distribution.
- Construction of standard and protected tank stands and outlet taps to both improve access and manage freshwater.
- Construction of concrete cisterns (1) to store rainwater for low-roof *maneaba* and abstract it by *Tamana* pumps, and (2) as a conservation strategy for areas with poor groundwater potential.
- Inclusion of access points on transmission pipes and storage units to permit periodical system purging and allow blockages to be cleared.

### 4.3 Groundwater Survey

In Nikunau, groundwater is the reliable water source for most communities for drinking and domestic needs. Generally groundwater is accessed by shallow wells and unprotected or poorly protected wells<sup>2</sup> (Figure 9) with an estimated 73% of households abstracting the groundwater with the use of bailers (Figure 10). Most wells are poorly sited and constructed. Many wells have inadequate casing or are unlined, and constructed with minor consideration to reducing the potential for contamination or with regard to optimal water quality.

The groundwater survey collected information on 225 wells across four (4) villages in Nikunau (Table 11). Standard techniques for water resource assessment for the groundwater survey were used. These included surveying all wells in the target villages to help determine:

- well location;
- construction type;
- general condition;
- contamination risk;
- salinity; and

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<sup>2</sup> Presence of a casing, parapet, cover, fence, well apron, with increased distance from contamination source will improve well protection in most cases.

- usage and reliance on groundwater by the community.

The survey information was collected using a handheld field computer (Juno Trimble) which allowed the location details to be recorded with the GPS location; and the data directly entered in digital format.

The 2010 census indicated that 96% of all households in the target villages on Nikunau rely on groundwater for their potable and domestic water needs. This is reflected in the high percentage of well ownership for households, from 61% to 100%<sup>3</sup>, depending on the village. Well ownership data indicates that:

- there is an apparent social and economic relationship attached to well ownership, with some villages demonstrating increased well ownership by household.
- There is an established culture of households sharing access to water from wells.
- Some wells may have been recently abandoned because of poor water quality.

For the surveyed villages, there does not appear to be a correlation between salinity of the groundwater, depth to the water table, and the percentage of ownership of wells by households. Other factors may be at play to account for the difference in well ownership by households, which may include access to land suitable for construction, or economic factors.



**Figure 9. Typical household well excavated down to bedrock and using coral rock as casing materials, without parapet and fence.**

<sup>3</sup> More wells surveyed than households indicate that some households have more than one well, and/or there are communal wells providing water supply.



**Figure 10.** Typical bailer used for abstraction of groundwater from a local well, Nikumanu, Nikunau.

**Table 11. Summary of the state of groundwater wells surveyed within the target villages.**

Village	Muribenua	Tabutoa	Rungata	Nikumau	Total
Number of wells surveyed	36	28	107	54	225
Number of households (2010 census)	53	28	176	56	313
% of households with access to individual wells	68	100	61	96	
% of households relying on groundwater for water needs (Census 2010)	94	100	96	96	
<b>INFRASTRUCTURE</b>					Total
Wells with coral rock casing	25	17	81	41	164
Wells with cement blocks	3	1	3	6	13
Wells with cement ring casing	6	9	23	7	45
Wells with no casing information recorded	2	0	0	0	2
Wells without parapet	30	19	85	43	177
Wells without cover	26	24	94	51	195
Wells without apron	23	25	92	39	179
Wells with no fence	34	27	104	48	213
<b>ABSTRACTION</b>					Total
Wells using <i>Tamana</i> pumps	12	6	8	4	30
Wells using solar pumps	1	2	2	1	6
Wells using electrical pumps	0	0	4	0	4
Wells using bailers	20	16	83	45	164
Wells not used (Abandoned)	3	4	10	4	21
<b>CONTAMINATION</b>					Total
Wells located ≤20 m from contaminant sources	32	25	102	52	211
<b>WATER QUALITY – PHYSICAL PROPERTIES</b>					Average
Average total depth (m bgl)	3.34	2.71	2.24	3.18	2.87
Average depth to water table (m bgl)	2.98	2.51	1.99	2.95	2.61
Maximum salinity (mS/cm)	3.33	7.31	8.17	3.64	8.17
Minimum salinity (mS/cm)	0.38	0.78	0.79	0.08	0.08
Average salinity (mS/cm)	1.24	2.51	3.40	1.33	2.48
Median salinity (mS/cm)	1.10	2.56	3.01	1.08	2.10
Number of wells exceeding 2.5 mS/cm	3	11	67	5	86
<b>WATER QUALITY – BACTERIOLOGICAL TESTS</b>					Total
Number of E.coli samples taken	17	11	30	27	85
Number of samples showing E.coli contamination	16	10	30	25	81
% of samples indicating contamination	94	91	100	93	

The well survey suggests that most wells (> 90%) are located within 20 metres of an identified contamination source increasing the risk to water quality for these wells.

#### 4.3.1 Well construction, condition and maintenance

The status of construction, condition and maintenance of surveyed wells, from households, community, church, clinic and schools, is summarised below:

- For accessible wells surveyed, 73% use coral rocks, 20% use locally-made cement rings, and 6% use cement blocks. The remaining 1% is completely covered with no information recorded on construction details.
- 79% of the wells do not have parapets and 80% do not have adequate aprons, suggesting that they are at greater risks of surface water ingress and contamination.
- 87% of the wells do not have proper covers and 95% do not have fence, which are issues for both security and safety of the well and increased potential for algal growth.

The above shows that most household wells are poorly constructed, increasing their susceptibility to contamination from:

- surface water run-off washing in contaminants from nearby sources such as rubbish, and faecal matter;
- falling debris or side-wall collapse;
- close proximity to faecal sources such as pig pens and pit-toilets;
- organic matter including leaves and coconuts; and
- algal growth.

#### 4.3.2 Abstraction and usage

Abstraction of groundwater wells is characterised by:

- 13% use of the locally-made *Tamana* or hand pump (Figure 11);
- 3% of wells using solar pumps, 1 of which was not working;
- 2% of wells use electric-powered submersible pumps;
- 73% of wells use bailers, namely buckets, tins and containers – most bailers were found unprotected, lying on the ground, thereby increasing potential for contamination (Figure 10); and
- 9% of wells were unused and abandoned because of poor water quality, particularly very high salinity.

A few of the abandoned wells are currently used for rubbish disposal – acting as a potential contaminant pathway into the groundwater. Unused wells should be covered and abandoned wells backfilled with clean sediments to help minimise contamination risk.



**Figure 11.** *Locally-made Tamana pump or hand pump used for abstraction of groundwater from a nearby local well, Nikumanu, Nikunau.*

### 4.3.3 Water sampling and testing

#### *Salinity measurements*

Measurements of groundwater salinity are taken using electrical conductivity (EC). Electrical conductivity gives a measure of saltiness and was recorded for all wells in the target villages at both the top of the well and the base of the well using a calibrated portable EC meter (TPS-WP84).

The EC results were used to define the extent of the fresh groundwater resources. Previous studies in Kiribati use the accepted EC limit of ‘freshwater resources’ to be 2500  $\mu\text{S}/\text{cm}$ . This limit is used in many parts of the Pacific. Salinity ranges are listed in Table 12.

There are no practical health reasons for imposing an upper limit of salinity on drinking water as it will be determined by the palate sensitivities of the individuals. That is, some individuals and communities will be used to slightly more brackish water than others. At other times a community

may be willing to accept slightly more brackish water during extended dry conditions to ensure sufficient water supply for their demands.

The World Health Organization (WHO Guidelines for Drinking Water 4th Edition) states that high concentrations of chloride can give a salty taste to water.<sup>4</sup>

Concentrations in excess of 250 mg/L are increasingly likely to be detected by taste, where the chloride ion concentration of 250 mg/L has an equivalent salinity (EC) of 706  $\mu\text{S}/\text{cm}$  ([http://www2.vernier.com/sample\\_labs/WQV-15-COMP-chloride\\_salinity.pdf](http://www2.vernier.com/sample_labs/WQV-15-COMP-chloride_salinity.pdf), accessed 28/07/2014). WHO does not provide health-based guidelines for chloride in drinking water.

The determination of salinity is therefore, subjective and any guidelines should take into consideration access to alternative supplies as well as include the ability to vary this during times of need, such as extended dry periods based on pre-determined acceptance by the community.

**Table 12. Guide to salinity threshold values for consideration by the communities of Nikunau and to provide guidance for management purposes.**

Salinity $\mu\text{S}/\text{cm}$	% Seawater	Comments
< 200	< 0.5%	Rainwater
200 – 1100	0.5 – 2.2%	Slight taste of salinity may be perceptible to people at the upper end of this range
1100 – 1500	2.2 – 2.5%	Upper desirable range for drinking water, where salinity in water will be perceptible to most people, but tolerated
1500 – 2500	5%	Salty taste in the water will be perceptible to all and unacceptable to many Upper limit of freshwater
50,000	100%	Seawater

Summary of the field measurements from surveyed wells are as follows:

- The average EC value of the 225 wells at the time of the survey was 2.10 mS/cm suggesting the dominance of fresh groundwater wells.
- The average depth to the water table is 2.10 m bgl for all wells; and the maximum and minimum depths for the water table based on all sites are 4.1 and 0.22 m bgl, respectively.

Of the surveyed wells, 86 (36%) exhibited salinity levels in excess of the 2500  $\mu\text{S}/\text{cm}$  adopted limit for freshwater resources. These higher-salinity wells are likely to be due to close proximity to the coastline, or geological features such as higher permeability or preferential pathways allowing mixing with saline water. Given the low use of abstraction by solar or electric pumps, over pumping effects are expected to be low.

<sup>4</sup> [http://www.who.int/water\\_sanitation\\_health/dwq/guidelines/en/](http://www.who.int/water_sanitation_health/dwq/guidelines/en/)

The number of freshwater wells present indicates both a moderate to high potential of usable groundwater, as well as a high reliance on groundwater. The majority of wells are dug close to houses along the coast.

### *Bacteriological analysis – E. coli contamination*

Groundwater is used for both drinking and domestic water needs in outer islands. Whilst boiling of all well water prior to drinking is recommended, treatment of water prior to consumption is not uniformly undertaken for household wells or village and communal wells in outer islands. In order to better understand the groundwater vulnerability and presence of bacteriological contamination, a standard E.coli count test, was undertaken to determine the degree of contamination. The compact dry plate filtration membrane method was used on samples collected from selected groundwater wells and rainwater storage tanks around the target villages. A sample preparation and analysis, together with the results, are provided in Annex 5, with village contamination maps shown in Annex 6.

Table 11 shows that more than 90% of the wells or rainwater tanks sampled have E.coli bacteria. This can be attributed to:

- the close proximity of groundwater wells to numerous contaminant sources: pit toilets, poorly designed septic tanks, pig pens, *bwabwai* pits and general household point-source contamination;
- wells and rainwater tanks not having adequate protection; including functioning covers and parapets to help prevent the entry of contaminated water or other contaminant sources;
- poor storage and handling of bailers used for abstracting groundwater and rainwater; and
- ingress of contaminated surface runoff during heavy rainfall.

The results from the well water sampling represent the bacteriological status of the tested wells or rainwater tanks at the time of the survey, and are likely to change over time. Whilst no safe set-back distances from contaminant sources can be confidently assigned for village and household wells, Overmars (2004) suggests a set-back distance of at least 25 m between water sources and contaminant activities such as pig pens and toilets. Whilst this is considered to be an estimate provided for guidance purposes, in lieu of any specific investigations, it would seem a reasonable precautionary distance where well construction and abstraction protection measures are also undertaken. Measures which contribute to the protection of wells from bacteriological contamination include the installation of fitted well covers, well aprons, fencing, and well parapets and the use of hand pumps.

#### 4.3.4 Well improvements

Water supply and water quality can be improved through the use of the following measures:

- Casing materials made from concrete rings ensuring structural integrity to the well and allowing improvements such as the introduction of hand pumps, well parapets, aprons and well covers.
- Construction of a parapet to prevent the ingress of surface runoff.
- Fitted well covers to prevent foreign matter from being introduced into the well and to reduce algae growth.
- Concrete aprons surrounding the wells to prevent the infiltration of surface water from the sides.
- Fencing to restrict access by animals and others trespassing into the well area.
- Installation of hand pumps such as the locally-made *Tamana* pump, which:
  - is relatively easy to operate and maintain at a community level;
  - uses locally available materials for repairs;
  - permits low-yield abstraction that minimises up-coning and saline intrusion; and
  - reduces the need for activities to be centred around the well, thereby reducing the potential of contamination.
- Bailer stands to keep the bailers off the ground.
- Decommissioning of abandoned wells to reduce their use as waste disposal receptacles that potentially act as a pathway for groundwater contamination.

## 4.4 Electromagnetic SURVEYS – EM34

### 4.4.1 Introduction

The use of electromagnetic (EM) geophysical surveys to map the freshwater lens thickness in atoll environments is well established, being successfully used on Kiribati in recent times by Falkland (2004) and GWP (2011a). A Geonics EM34 electromagnetic instrument was used during the current groundwater resource investigations to provide a rapid assessment of the subsurface ground conductivity, which can be converted to an effective thickness of the freshwater lens.

Geophysical surveys were conducted in all target villages on Nikunau Island from the 6<sup>th</sup> to the 15<sup>th</sup> of August 2013, using the MPWU-owned Geonics EM34 equipment.

A standard approach to EM34 surveys was used to provide consistency between surveys, as outlined in Annex 7.

#### 4.4.2 Survey location

Twenty-one (21) EM34 survey lines were completed across the target villages. The focus for geophysical investigations was the areas within the immediate vicinity of the target villages, as these were the areas of most interest for the villages. It was considered that undertaking detailed investigations targeting the village area and surrounds would 'localise' the collective village ownership and responsibility for the water source and thereby help address issues over access and economic considerations to piping. It was generally observed that:

- the collective 'village' has more influence over individuals from that village who are benefitting from the water source, which may assist with the access, use and management of the groundwater resources; and
- there is a preference by village communities for water supply infrastructure to be located within or close to the village boundaries, promoting improved ownership and accountability for the operation, maintenance and ongoing management of water supply infrastructure.

The locations of EM surveys on the target villages are shown in Annex 6.

Traverse lines were undertaken between the lagoon and the ocean at 200-m spacing, using established paths where possible. Readings were taken every 30 m using the 10-m and 20-m cables in the horizontal dipole position (coils vertical). Some survey lines had to be slightly diverted or cut short because of the presence of *bwabwai* pits, dense vegetation and areas of flooding.

Please note that during the survey, it was found that the geophysical equipment was constantly giving erroneous responses with alternating gains and losses recorded in both 10-m and 20-m coil measurements. This was initially thought to be a battery and/or power problem but after repeatedly conducting proper operating procedures of battery charging and/or replacement, this problem persisted. Alternating very high and low readings recorded, even around the middle of the island where consistently low bulk conductivity readings are expected because of the anticipated increased freshwater lens thickness and greater distance from the shoreline. It was later noticed that a number of connection pins on both EM34 coils were either broken or worn out. Even though all the target villages were adequately covered during the survey, the reliability of the field results was far too low to warrant any useful analysis. The equipment was sent to the Geonics Ltd in Canada for repair straight after the Nikunau Island visit, with the problem attributed to wear and tear. A return EM34 survey trip was considered by the survey team, once the survey machine was repaired but this did not eventuate because of budgetary and time limitations.

#### 4.4.3 Interpretation of results

The poor quality data generated during the survey precludes any useful interpretation; hence assessment and estimation of the thicknesses of freshwater lens underlying and/or adjacent to the target villages were not undertaken. It is strongly recommended that a return EM34 survey be conducted around the target villages to ascertain the extent and thickness of freshwater lens and

determine the sustainable yield prior to any infrastructural assistance and implementation work under KIRIWATSAN Phase 2.

## 4.5 Groundwater Monitoring – tidal lag and efficiency

Time-series groundwater monitoring was conducted in selected wells within the surveyed villages to determine the hydraulic connection between the unconsolidated sediments and oceanic influences, and as a guide to the tidal influence on the aquifer. Schlumberger CTD (conductivity, temperature and depth) 'diver' loggers were installed in wells, recording data every 15 minutes for a minimum of one complete tidal cycle to indicate the range of tidal effect and observed tidal lag. The 'divers' were installed at the start of each survey and retrieved prior to moving onto the next target village. The data were downloaded onsite.

### 4.5.1 Tidal lag and tidal efficiency

As the tide rises and falls in the ocean and lagoon, it forces the aquifer water to also fluctuate, albeit with smaller amplitude and a time lag. The tidal signal is attenuated or damped by friction as the aquifer water is forced to move through pores in the sands and gravels, and the nature of the aquifer materials determines the efficiency with which the tidal pulse is transmitted from place to place.

Tidal lag is simply the time difference between, for instance, high tide in the ocean and high tide at some location in the aquifer. Tidal efficiency is the ratio of well water-level fluctuation to that of the ocean. For example, on a spring tide with a tidal variation of 1.5 m, the water level fluctuation in one well might be 0.75 m, with a resulting tidal efficiency of  $1.5/0.75 = 50\%$ .

Representative lags and efficiencies for the selected wells in the target villages are provided in Table 13.

Tidal efficiencies and lags reflect the amount of tidal influence or "hydraulic communication" of various portions of the aquifer with either the ocean or lagoon. Higher efficiencies and shorter lags indicate a greater amount of influence, and are expected to be found at sites relatively close to the shoreline; however, this is not always the case. In general, tidal efficiencies increase consistently with depth whilst the opposite relationship is expected with tidal lags and depths (Hunt and Petersen, 1980).

Several factors also complicate the tidal picture. These are:

- pockets of heterogeneous material which may produce tidal efficiencies and lags somewhat higher or lower than expected, such as coral rubble and reef rock;
- tidal stresses from both the ocean and the lagoon sides creating complicated interference effects, especially toward the centre of the island;

- permeabilities on the ocean side of the island are expected to be greater than on the lagoon side; creating additional complications in the tidal response; and
- the depth to the underlying geologic/hydrologic unconformity, which separates an underlying high permeability zone from overlying less permeable materials, exists at unknown depths, albeit expected to be between 8 and 25 m.

Tidal measurements are not available for Nikunau. In the absence of actual measurements, a tidal prediction calculator was used to calculate tides. The spreadsheet was developed by Doug Ramsay (NIWA) at the request of the Ministry of Public Works and Utilities, recognising that current tide predictions for Tarawa are not accurate for other islands in Western Kiribati. The predictions used here are from Version 2, 18 April 2008. Comparisons were made with regard to the calculated values for recorded values in Tarawa and reasonable fit was observed.

Because of the limited harmonic datasets used, the accuracy of the tide predictions for the other atolls will be limited. Times of high and low tides are likely to be within  $\pm 30$  minutes. The predictions will also not quite capture the magnitude of the very highest or lowest tides.

A summary of tidal lag and efficiencies for Bonriki water reserve is provided (Table 14) for comparison with the data collected from Nikunau as well as data from other KIRIWATSAN I surveyed islands, namely Abaiang, Nonouti, Maiana and Beru (see Figure 14).

The monitoring records from all the selected wells in Nikunau are presented in Annex 8.

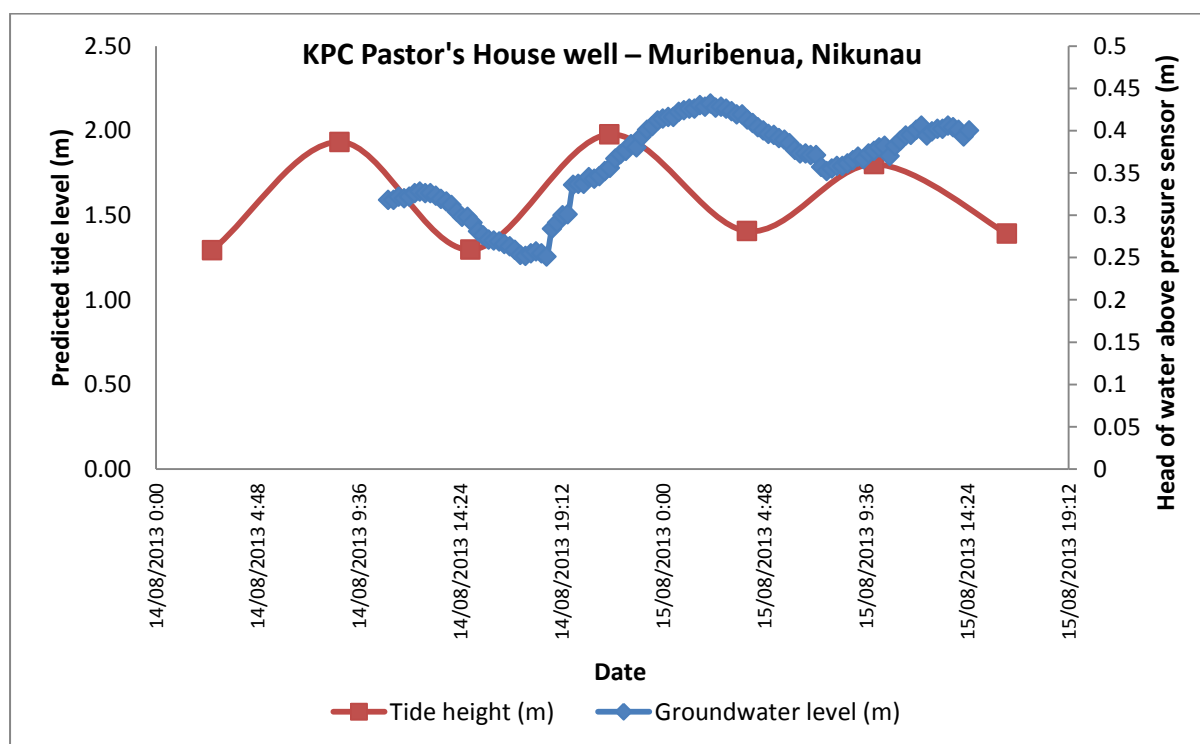
**Table 13. A summary of the logger data records and calculated tidal lags and efficiencies for Nikunau. (See also Annex 9)**

Village	Well Owner	Diver number	Distance from closest water body, ocean or lagoon	Start Date and time	End date and time	Length of record (hrs)	Tidal lag	Tidal efficiency
Nikumanu	Nikumatang Primary School well	P5144	160	6/08/2013 11:00	7/08/2013 11:15	24.25	2.29	7%
	Awaki Head Teacher's well	K6813	110	6/08/2013 11:00	7/08/2013 12:15	25.25	2.25	7%
Rungata	Tione	K6813	105	8/08/2013 11:00	11/08/2013 8:15	69.25	1.59	15%
	Health Clinic	P5144	50	8/08/2013 11:00	11/08/2013 8:30	69.5	2.37	10%
Tabutoa	Tittu	K6813	70	12/08/2013 11:00	13/08/2013 16:30	29.5	3	10%
	Rubataake	P5144	105	12/08/2013 11:00	13/08/2013 11:30	24.5	2.45	12%
Muribenua	KPC pastor's house	P5144	110	14/08/2013 11:00	15/08/2013 14:30	27.5	3.53	17%
	Rewii	K6813	44	14/08/2013 10:00	15/08/2013 14:15	26.25	3.25	12%
<b>Average</b>						37	2.59	11%

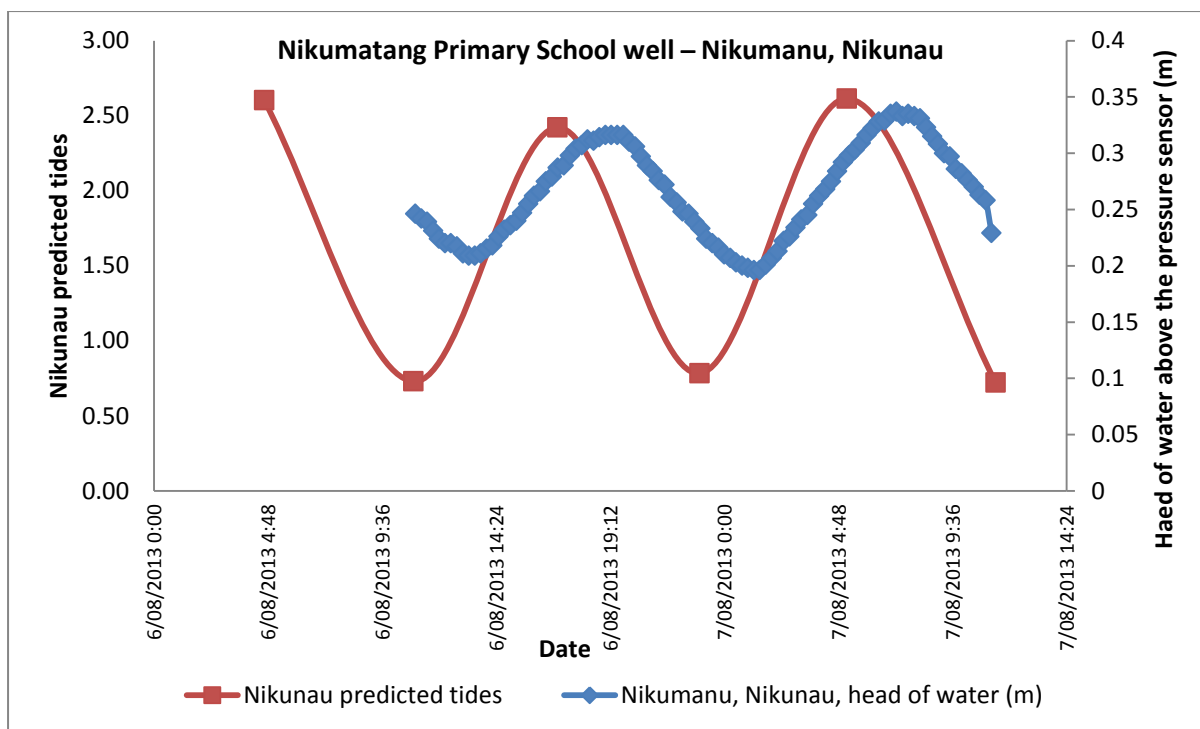
**Table 14. Summary of tidal lag and tidal efficiency of monitoring bores in Bonriki.**

Location	Name	Distance from closest water body, ocean or lagoon (m)	Tidal lag (hrs)	Tidal efficiency	Estimated Depth of Holocene sands to Pleistocene limestone (mbgl)
Bonriki, Tarawa	BN1B	80	1.85	7.9%	-17.7
Bonriki, Tarawa	BN2B	270	2.25	5.9%	-11.7
Bonriki, Tarawa	BN4C	500	0.5	31.7%	-11.8
Bonriki, Tarawa	BN7B	90	1.5	6.7%	-11.1
Bonriki, Tarawa	BN21	380	0.9	17.0%	-15.1
Bonriki, Tarawa	BN26	260	1.1	14.0%	-11.6
Bonriki, Tarawa	BN36	110	1.25	14.3%	-11.9
Bonriki, Tarawa	BN32	450	0.65	8.9%	-10.7
Bonriki, Tarawa	BN29	90	2	5.5%	-9.0
Bonriki, Tarawa	PS1	130	2.5-3	4.0%	-10.0
Bonriki, Tarawa	PS7	350	2.5	4.0%	-12.8
Bonriki, Tarawa	PS16	275	2-2.25	6.6%	-11.6
Bonriki, Tarawa	PS18	365	2.75	5.0%	-10.9

Figures 12 and 13 below graph the results from the monitoring wells at Muribenua and Nikumanu villages (~15 km apart).



**Figure 12. Predicted tidal height and measured groundwater level at the KPC pastor's well at Muribenua Village, with groundwater monitoring commencing at 11 am (14<sup>th</sup> August 2013) and terminated after 27.5 hours.**



**Figure 13. Predicted tidal height and measured groundwater level at Nikumatang Primary School well in Nikumanu Village, abstracted by a solar pump system, with groundwater monitoring commencing at 10 am (6<sup>th</sup> August 2013) and terminated after 24.25 hours.**

It is noted that from the data collected, there is a general relationship of increased tidal lag resulting in a reduced tidal efficiency as distance increases from the lagoon or ocean source.

Compared with Tarawa, Nikunau’s groundwater response is similar albeit there is stronger correlation with Abaiang, Nonouti, Maiana and Beru islands (see Figure 14). This suggests a similarity in geology of the islands, although sediments are likely to be more permeable for Nikunau than those in Bonriki, to account for the decreased tidal lag and with shallower depths to the Pleistocene limestone to account for the greater tidal efficiency values compared with Bonriki. Additional data are required to assess this suggested variation between the islands.

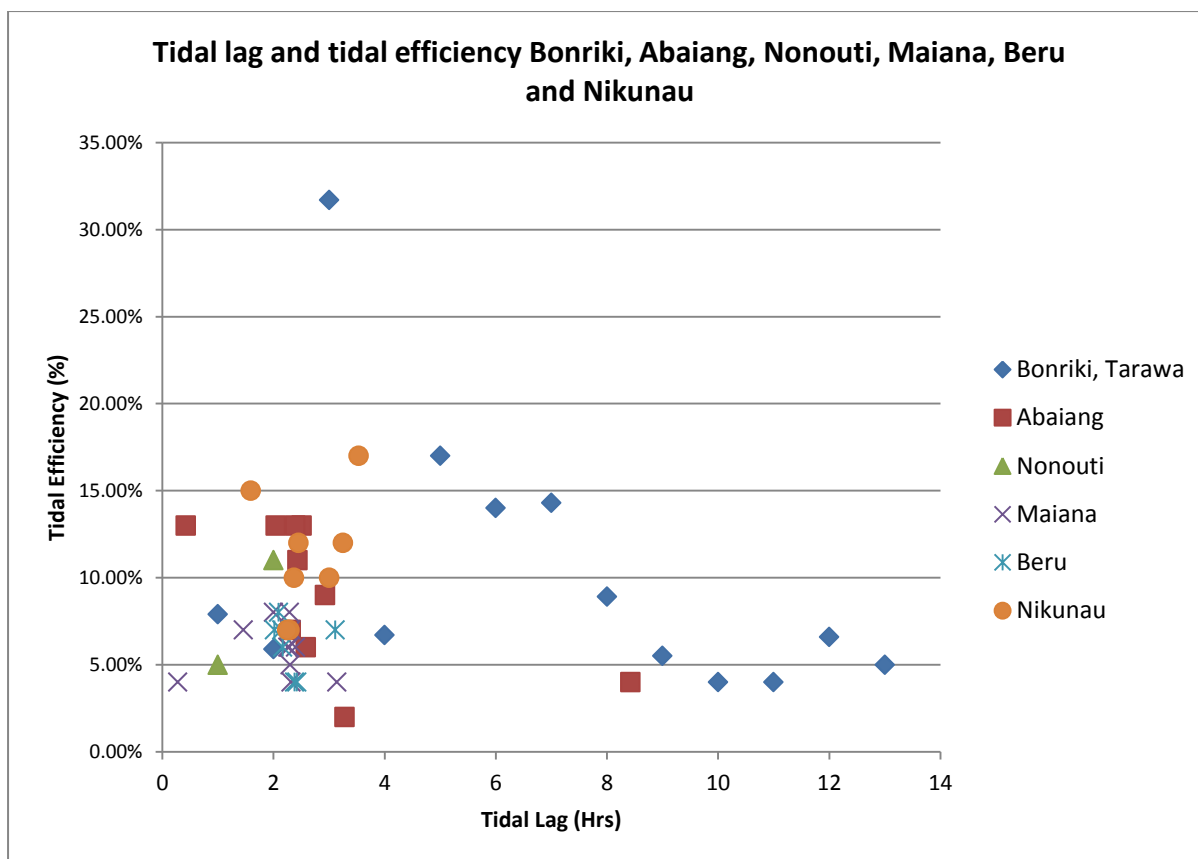


Figure 14. Tidal lag and tidal efficiency for Nikunau and Bonriki (Tarawa), Abaiang, Nonouti, Maiana, Beru and Nikunau islands with anomalous values removed.

## 5.0 WATER RESOURCES ASSESSMENT

### 5.1 Rainwater Harvesting (RWH)

The surveyed buildings were classified as either private or communal buildings. For the purpose of improving water supply, communal buildings, namely churches and *maneaba*, were deemed suitable because of their relatively substantial roof catchment and the possibility of allowing access for most parts of the community. The measured roof dimensions of these communal buildings were then analysed for their capacity to collect rainfall, based on the guttering coverage and condition and available storage. Using the available Nikunau monthly rainfall record (from November 1904 to May 2014), the RWH potentials of the communal buildings were assessed through the White (2010) rainwater calculator spreadsheet (Annex 9).

A summary of all the communal buildings and subsequent analyses are presented in Table 15, assuming that all roofs are equipped with proper facilities.

From Tables 15 and 16, it is clear that most communal buildings need substantial roof improvements to maximise the catchment area and to allow optimum rainwater collection. This implies the addition of various storage volumes to optimise water storage and availability for use. Clearly, the estimation of a storage volume appropriate to a given roof will vary and depend on the roof catchment, how much water is needed, and the number of users or population. Since the roof catchment is fixed, the ratio of increasing the storage volume to an increase in water demand for a fixed population will gradually decrease once the maximum roof area is reached. An analysis was conducted using the White (2010) rainfall calculator to determine the ideal storage for a range of roof catchment areas in Nikunau (see Figure 15). This was conducted using:

- a roof area range of 50 – 450 m<sup>2</sup>;
- storage tank volumes of 5000 L; 10 000 L; 15 000 L; 20 000 L; 25 000 L; and 30 000 L;
- a fixed number of users at 100; and
- a limit of 84% satisfaction, which will be equivalent to 2 months of failure in any one year.

**Table 15. Summary of potential communal RWH centres. (See also Annex 10)**

Village	Building Type	Owner	<sup>1</sup> Roof area (m <sup>2</sup> )	Building ID	Percentage of roof covered by guttering	<sup>2</sup> Collecting Roof Area (m <sup>2</sup> )	<sup>3</sup> Guttering Condition	<sup>4</sup> Guttering Efficiency	<sup>5</sup> Effective Roof Area (m <sup>2</sup> )	<sup>6</sup> Improved Roof Area (m <sup>2</sup> )	<sup>7</sup> Rain Tank Capacity (L)
Nikumanu	Maneaba	KPC	318	Ni1	0%	0	None	0	0	239	0
Nikumanu	Church	KPC Church	185	Ni2	0%	0	None	0	0	139	0
Nikumanu	Church	Catholic Church	192	Ni3	75%	144	Repair	0.35	50	144	0
Muribenua	Church	Catholic	126	Mu1	0	0	None	0	0	95	10 000
Muribenua	Maneaba	KPC	502	Mu3	100%	502	Adequate	0.55	276	377	0
Muribenua	Church	KPC	386	Mu4	25%	97	Repair	0.35	34	290	0
Rungata	Church	KPC	430	Ru2	0%	0	None	0	0	323	5000
Rungata	Church	KPC	243	Ru3	100%	243	Good	0.75	182	182	5000
Rungata	Church	Catholic	97	Ru4	50%	49	Repair	0.35	17	73	5000
Rungata	Church	Catholic	24	Ru6	0%	0	None	0	0	18	5000
Tabutoa	Church	KPC	103	Ta1	50%	52	Repair	0.35	18	77	5000

**Notes:**

<sup>1</sup> Represents the product of the measured catchment length and width

<sup>2</sup> The product of the roof catchment area and the current guttering coverage

<sup>3</sup> Guttering condition observed on site

<sup>4</sup> Guttering efficiency values are derived from White (2010) shown in Table 16. This assigns 0.75 efficiency to “good” guttering – this also considers the runoff coefficient as specified in the White (2010) rainfall calculator spreadsheet

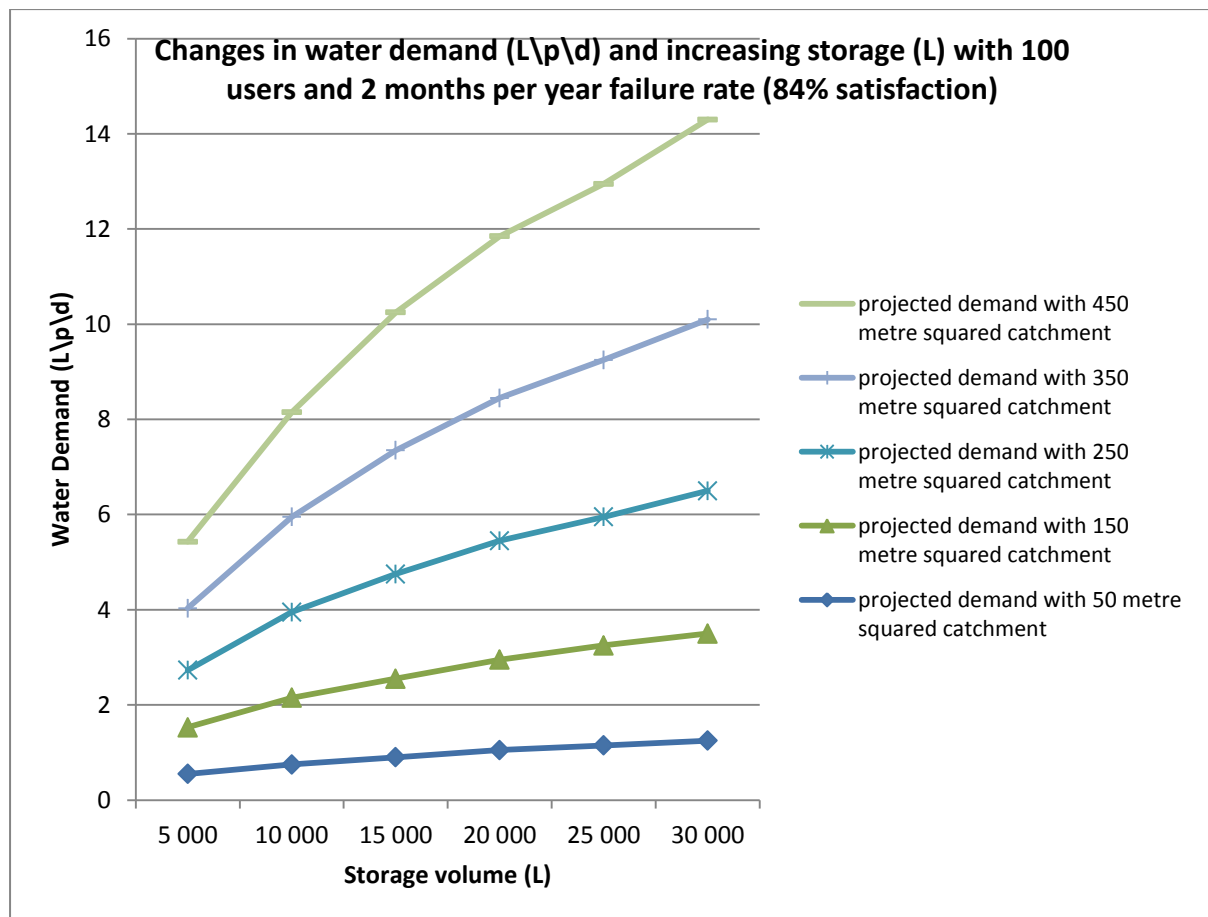
<sup>5</sup> The product of collecting roof area and guttering efficiency

<sup>6</sup> Assumes that an improved catchment, through the installation of good guttering material, will yield a 0.75 guttering efficiency; hence this is a product of the roof area x 0.75

<sup>7</sup> Existing rainwater storage volume

**Table 16. RWH parameters suggested by White (2014).**

Attribute	Explanation
Building ID Number	Unique number identifying building
Type of building	Commercial, Community, Government, Other, Residential
Rain Tank Capacity (L)	$S = \text{Tank Capacity}/1000 \text{ (L)}$
Roof Area ( $\text{m}^2$ )	A
% Guttering	Percentage of roof edge bordered by guttering
Collecting Roof Area ( $\text{m}^2$ )	$A_{\text{col}} = (\% \text{ Guttering}) \times A/100$
Guttering Condition (Capture Efficiency, C, where $0 \leq C \leq 1$ )	Good (C = 0.75) Adequate (C = 0.55) Repair (C = 0.35) Replace (C = 0.15)
Effective Roof Area ( $\text{m}^2$ )	$A_{\text{eff}} = C \times A_{\text{col}}$



**Figure 15. Changes in water demand ( $L/p/d$ ) in relation to changing roof catchment and increasing storage volume based on 2 months failure rate in any one year (84% satisfaction).**

Table 17, Figures 16 and 17 indicate that most of the communal buildings, namely church and *maneaba* have the potential to provide adequate drinking water to the target communities. It is recommended that all the suggested improvements, outlined in Section 4.2, be implemented for optimum rainwater storage and conservation.

**Table 17. Analysis of combining all target communal buildings in each village to serving the current and future populations (after White, 2010). (See also Annex 9)**

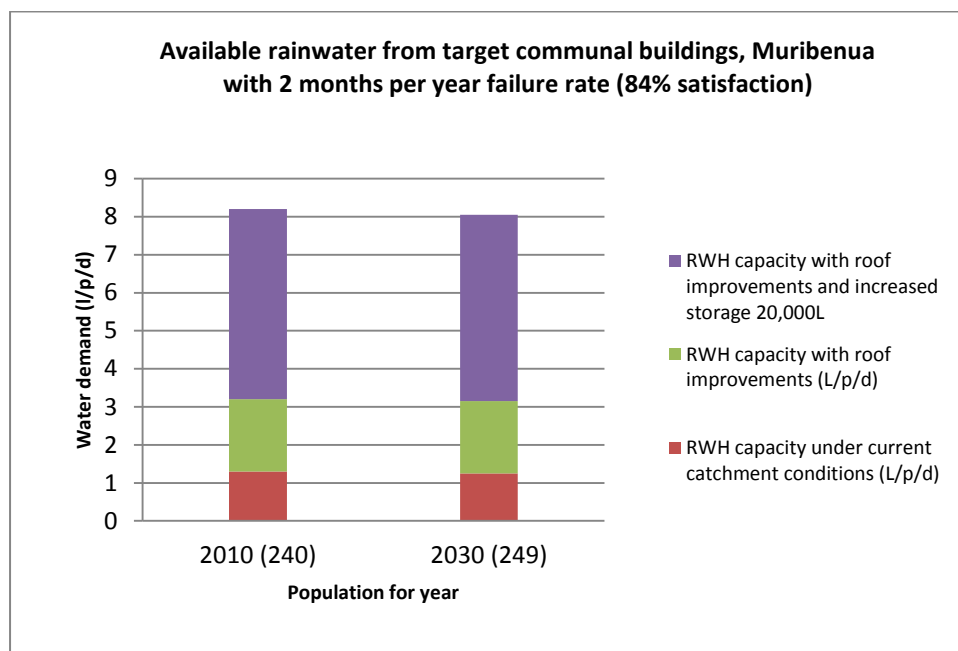
Building ID	Population	<sup>1</sup> RWH capacity under current catchment conditions (L/p/d)	<sup>2</sup> RWH capacity with roof improvements (L/p/d)	<sup>3</sup> RWH capacity with roof improvements and increased storage 20 000 L (L/p/d)
Nikumanu	2010 (265)	0	0	3.8
	2030 (188)	0	0	5.4
Muribenua	2010 (240)	1.3	1.9	5
	2030 (249)	1.25	1.9	4.9
Rungata	2010 (976)	0.32	0.59	1.2
	2030 (1253)	0.25	0.49	0.92
Tabutoa	2010 (154)	0.275	0.75	1.4
	2030 (117)	0.38	0.98	1.85

**Note:**

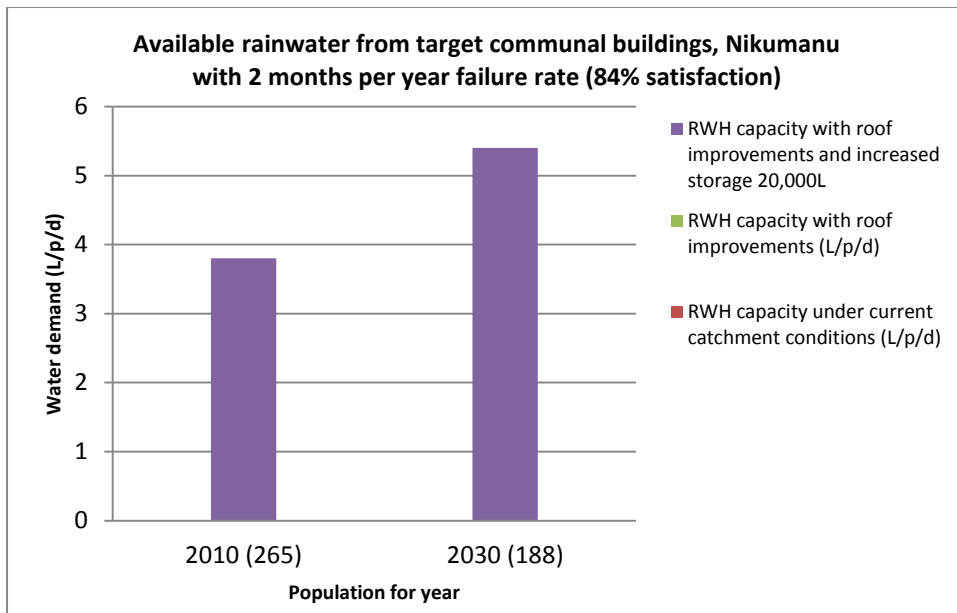
<sup>1</sup> Water demand under normal condition uses the current roof condition (effective roof area from Table 15, the 2010 and 2030 population and considers a 2 months per year failure rate (84% satisfaction) using White (2010) rainfall calculator.

<sup>2</sup> Water demand under improved condition, uses the improved roof catchment from Table 15, the 2010 and 2030 population and considers a 2 months per year failure rate (84% satisfaction) using White (2010) rainfall calculator.

<sup>3</sup> Water demand under improved condition and storage, assigns a 20 000 L storage increase to all buildings and utilises Table 15, the 2010 and 2030 population and considers a 2 months per year failure rate (84% satisfaction) using White (2010) rainfall calculator (Annex 10).



**Figure 16. Analysis of water demand for all target communal buildings in Muribenua Village on 2 months per year failure rate (84% satisfaction).**



**Figure 17. Analysis of water demand for all target communal buildings in Nikumanu Village on 2 months per year failure rate (84% satisfaction).**

For villages which have access to good quality groundwater, rainwater harvesting is considered to be a diversification of water source reliance. It can provide lower salinity water, which has a growing preference amongst villagers; with rainwater considered to be a ‘better’ source of freshwater.

Whilst rainwater often has lower salinity than groundwater, it has limited drought reserve potential and unless storage is well maintained, is susceptible to contamination. The use of RWH in areas of accessible fresh groundwater should be considered primarily as a supplementary resource and not as an alternative main water source to be developed. Groundwater will in most cases be more cost effective with improved water security.

Where groundwater is available, it is recommended that it be developed to ensure continued access to suitable freshwater resources. If financial resources exist to improve the RWH potential of permanently roofed communal buildings then this would be recommended as it will provide water source diversification, improve water security, and address issues of water source preferences for specific water needs such as drinking and cooking. In cases where RWH is promoted, then the system should be optimised to provide a minimum per capita requirement for nominated population with an agreed failure rate of 60-90% dependent on circumstances.

It is also recommended that formal agreements regarding the access, security and protection of RWH facilities be developed in consultation with village community groups including *Unimwane*, church leaders, women, and youth. This may also include agreed rules for water abstraction and use, with restriction of a maximum of 5 L/p/d or alternatives.

## 5.2 Groundwater Resources

### 5.2.1 Freshwater lens location and thickness

The erroneous EM34 geophysics results, as presented in Annex 8, precluded the mapping of freshwater lens thickness and extent. Consequently, there are not sufficient data to confidently conduct analysis on population and climate change effect on the fresh groundwater resources underlying the target villages. It is suggested that another round of geophysical survey be conducted around all target villages, to ascertain the freshwater lens dimensions and potential, prior to any water supply assistance work in KIRIWATSAN Phase 2.

## 5.3 Community Awareness and Consultation

Community awareness raising and consultation meetings were held in all, but one, villages to present the WRA preliminary findings to the target communities and to establish the major water and sanitation problems and/or identify appropriate preferences from the perspectives of the villagers.

Villagers of Rungata were engaged in several pre-arranged functions. Information provided by householders during the WRA household interviews in all the villages would provide insight into the needs and preferences of villagers.

Key issues raised by the villagers include:

1. *Willingness to improve water quality*

During the survey and at the village meetings, more questions were raised regarding the standard salinity limit for drinking, with the E.coli presentation gaining widespread response. Villagers, especially women, questioned why some wells showed better E.coli results than others, with the majority recognising the importance of having improved infrastructure and the need to relocate groundwater sources as far away as possible from potential contamination sources.

2. *Recognition of the need to establish governance and protection mechanisms for water supply systems*

Villagers of Tabutoa, Muribenua and Nikumanu experienced the benefits of having improved water supply systems from previous projects. With all their village systems either broken or not fully functional, villagers realised that the responsibility of water supply improvement and management lies within the communities, as opposed to the existing understanding of Government or Island Council being responsible for the operation and maintenance of village water systems. Members of the community showed support for the establishment of relevant governance and protection policies to help safeguard the operation and maintenance of water supply in the long term, should further assistance be provided in the future.

### 3. *Request for water supply infrastructural improvements*

Ubiquitous in all the villages is the need for more taps and rainwater tanks, as well as the replacement or repair of existing solar-powered systems. These are related to the potential increase in village population raised by some elders, as well as for convenience.

The above highlights the following:

- The communities' need for improved water supply systems based on the status, and associated challenges, of existing systems.
- Moderate awareness of water quality issues and eagerness to address this through improved water supply infrastructure.
- Willingness of communities to embrace the concept of village action plans, through the provision of land and voluntary labour.  
Willingness to accept the responsibilities of fundraising to safeguard the long-term operation and maintenance of water supply systems, which is a significant contrast to the existing notion of government and/or island council being responsible for the maintenance of their water supply.

See also Annex 10 for village meeting notes.

## 6.0 WATER RESOURCES DEVELOPMENT OPTIONS

### 6.1 Existing Water Supplies

A survey of the status of existing water supplies was undertaken by Falkland in 2003. This was reviewed at the time of this survey and an updated status of the water-supply systems is provided in Table 7 for the four (4) target villages in this study.

As previously described (Section 3.4), the surveyed villages rely upon groundwater for drinking and domestic purposes. The use of bailers dominated groundwater abstraction whilst locally-made *Tamana* or hand pumps are widely used. The hand pumps appeared to be functional during the survey mainly because of their low maintenance cost, ease of operation, and availability of spare parts. Solar pumps were observed in a number of village wells and schools, a few of which are damaged. Electric pumps are installed mainly in medical clinics, some of which were not operating because of electrical faults.

RWH is not widely practised around Nikunau. The reasons for lack of interest in RWH include:

- buildings with suitable permanent roofs being limited; and
- settlements being sparsely distributed, making access to centralised RWH facilities difficult. Most villages are linear developments along the lagoon shoreline, with no natural centre where RWH could provide resources to a concentrated number of residents.

## 6.2 Freshwater Development Options

Options for improved water supplies from groundwater and rainwater sources have been considered based on accessibility to water sources and existing infrastructure with consideration for sustainability, reasonable construction and maintenance costs, social acceptance and gender appropriateness.

### 6.2.1 Rainwater harvesting

Community buildings, such as schools, *maneaba* and churches, often have permanent roofing with substantial roof catchment areas, and are focal points for the community, making them ideal RWH centres. The proposed target communal buildings for RWH are listed in Table 15 with suggested infrastructural improvements. Designs proposed for RWH systems have been developed in consultation with the Government of Kiribati, villages and with recent practitioners. Refer to KIRIWATSAN Technical Notes on Water Supply Design Principles (Sinclair et. al., 2015).

## 6.3 Groundwater Development

The failure of the EM34 survey equipment did not permit the mapping of the freshwater lens underlying or adjacent to each target village. Hence, the following groundwater development options are provided as guidance to future development plans. It is strongly recommended that a return EM34 survey be conducted to determine the freshwater lens thickness and potential prior to the implementation of these groundwater supply options.

### 6.3.1 Household well improvements

This option targets the improvement and protection of household wells and will be recommended where freshwater wells are located within the residential areas. General features of improved groundwater abstraction systems are outlined in Section 4.3.4. Design features for standard household wells are provided in the KIRIWATSAN Technical Notes on Water Supply Design Principles (Sinclair et. al., 2015). In general, there is a preference for promoting and developing communal water supply systems that are more cost efficient; however, in some cases it may be preferable to consider improving individual household wells. The current designs are promoted for general uptake by the individual. It is recommended that the individual households, as the beneficiaries of the water supply infrastructure, would contribute towards the cost of improvements.

Note that it is recommended that all water used for drinking should first be boiled.

### 6.3.2 Communal wells

Communal wells allow a number of households to access and abstract their water from the same well – this option may be considered where a suitable groundwater resource is available within the village residential area. This option can provide for potable and non-potable domestic water, and should be considered when households agree to access, manage and maintain a shared well.

It is suggested that the ownership would remain with one household, with a formal arrangement that allows other nominated parties to access and abstract water through a hand pump for domestic purposes. Shared wells should be sited away from contamination sources and at distances suitable for the use of hand pumps (*Tamana* pumps) to abstract the groundwater and deliver to the household.

Detailed designs are provided in KIRIWATSAN Technical Notes on Water Supply Design Principles (Sinclair et. al., 2015).

### 6.3.3 Village wells

Village wells are proposed for villages which have limited groundwater potential close to the village. This option is recommended if the community prefers a village water supply and there is a “village action plan” to address issues of maintenance, repair/replacement, access and ownership. The village well would be sited in the thickest part of the freshwater lens at a location confirmed in consultation with community members and the village *Unimwane*. The well would be equipped with an appropriately selected solar pump and distributed through a header tank to tap stands at distribution locations. Detailed designs are provided in KIRIWATSAN Technical Notes on Water Supply Design Principles (Sinclair et. al., 2015).

### 6.3.4 Infiltration galleries

Horizontal infiltration galleries are proposed where there is a large village population and there is an adequate freshwater lens. This option should be further explored in consultation with the community and landholders to discuss long-term operations, management, and land access issues as well as future projected demands. Gallery designs are based on the previous and existing work of Falkland, and the GWP, incorporating experience from KAPII and KAPIII. Detailed designs are provided in KIRIWATSAN Technical Notes on Water Supply Design Principles (Sinclair et al., 2015).

## 6.4 Groundwater Protection

To keep the groundwater abstracted from well and gallery systems as safe as possible, it is recommended that groundwater protection zones are established around the groundwater abstraction areas for village and infiltration gallery systems. Nominal set-back distances suggested are 50 m for infiltration galleries (Falkland, 2003). Formalised agreements with communities and landowners will be required to allow continued access; the clearance of vegetation; and the restriction of certain land-use practices (e.g. siting of cemeteries and latrines; wastewater disposal; and certain agricultural usage such as pig pens and *bwabwai* pits), to minimise any potential groundwater contamination.

## 6.5 Sanitation Design Options and Improvements

The shallow groundwater found in many atoll islands of Kiribati is easily affected by certain land-use practices including poor sanitation options. The survey of wells in the target villages in this study shows that more than 90% of the wells are located within 20 m of an identified contamination source – and the majority (well over 80%) of the wells surveyed indicated the presence of E.coli in the water supply.

The 2010 census data indicate a growing preference by the community for pit and flush toilets. The census data also indicate that a good portion of surveyed households (36%) still practise open defecation. It is appropriate to use this growing awareness for improved sanitation and the recent success of compost toilets in Tuvalu to recommend them for use in the outer islands of Kiribati, which shares similar coral atoll environment challenges. It is well established that inappropriately designed and sited pour-flush systems will only further exacerbate the groundwater contamination issues of coral atoll environments, contributing to WASH-related diseases.

The selection of appropriate sanitation should also consider the hydrogeological conditions, cultural preferences and affordability of the improved system.

The underlying hydrogeological system is characterised by the following:

- Coarse-textured surficial coral sand underlain by porous and moderately fractured limestone.
- Shallow water table.
- Relatively permeable unconfined aquifer.
- Low hydraulic heads and gradients controlling groundwater movement, depending on the volume and frequency of groundwater abstraction.

These characteristics of the groundwater system suggest that pit and improperly designed septic toilets have the potential to permit the growth and transmission of pathogens. This, coupled with ambient temperature, moisture content and hydraulic conductivity, will influence the travel time and residence time of pathogens (Dillon, 1997), creating conditions which are favourable for the extended survival and transport of pathogens.

A suitable sanitation design for atoll environments, such as compost toilets, should be considered. As trialled on Christmas Island (Depledge, 1997), it is proposed that dry compost toilets, which utilises dry vegetation to assist decomposition, with adequate aeration vent and urine-separator should be designed. This will minimise water content, allow evaporation of liquids, and allow sufficient air circulation ideal for complete decomposition and composting.

To ensure that this sanitation option works, it is suggested that:

- widespread community consultation, education and awareness be conducted to ensure its acceptance in communities and the associated behavioural change.
- Toilets are designed to meet the people’s expectations of improvement to their situation.
- Efforts are made to ensure that the technology is affordable for outer island communities.
- Additional benefits to health and agricultural productivity are promoted.

An initial design that has been modified after the success in Tuvalu is proposed and will be considered for implementation in Phase II.

## 6.6 Water System Management

### 6.6.1 Village Water Action Plan (VWAP)

Because of the nature of the proposed water supply system; the operation, maintenance and management of each system is best conducted at village and household levels.

A “Village Water Action Plan” (“VWAP” or “the action plan”) is considered an appropriate approach for promoting a village-oriented approach. The action plan approach, developed after the Nikunau WRA survey, is designed by the village to formalise arrangements within the community to permit the protection, operation and sustainable management of water supply systems. The plan should reflect the initiative, support and commitment of each target village to address and eliminate long-standing issues of access, management, operation, maintenance, ownership, responsibility and fundraising. The VWAP will ideally become a living document and is suggested to address or include the following:

- i. Selection of water supply options, agreed with the community.
- ii. Agreed procedure for operation and maintenance of water supply infrastructure.
- iii. Nominated caretakers to conduct routine maintenance.
- iv. Accessibility of water supply facilities through:
  - a. formal consent of landowners for the conversion of their heritage land into a water reserve for village water supply; and
  - b. formal agreements for church leaders and *Unimwane* for usage and accessibility of churches and *maneaba* communal RWH centres.
- v. Agreed method and schedule of revenue generation, be it communal fundraising activities or household levy collection, to permit the procurement of spare parts and routine maintenance.

- vi. Proposed penalties for deliberate damage to water supply or failure to meet agreed water management rules.

The action plan can be used as an indicator for the community-based management and governance system, and can be used as a guideline within which the nominated village water committee should operate.

As no village water action plan has been formulated for the villages in Nikunau, it is suggested that a specific phase of community consultation should be undertaken at all the villages prior to any infrastructure assistance. The consultation should target different segments of the village, including youth and women, as well as religious leaders to permit the adequate participation and support for the village action plan.

### 6.6.2 Water resources monitoring

The monitoring of freshwater on the island is critical to determine the localised extent of climate variability, expressed through the spatial and temporal changes in groundwater salinity and depth to water level. Monitoring guidelines are provided by Loco et al. (2015) and outline the essential steps pertinent to the monitoring of rainfall and selected wells for salinity and water level for freshwater development and management.

A network of wells, selected across the island for periodic and long-term monitoring, will be needed and this will require adequate logistical support, including transport, technical equipment (salinity meters and calibration solutions), and storage of data. Recording the impact of drought and extreme wave or tidal events on the monitoring bores will further assist with understanding the effects on the groundwater resources from these extreme events.

Quantitative microbiological assessment (Annex 5) should also be considered, to be conducted on selected wells and rainwater tanks, preferably on six-monthly to annual bases, and could be undertaken by the WEU staff with assistance from island water technicians. This could be incorporated as a future training and management programme.

To better understand the dynamic nature of freshwater lens and the impact from extreme events, where the opportunity presents itself for village wells and infiltration galleries, it is suggested that multi-level groundwater wells are constructed.

## 7.0 RECOMMENDATIONS

- 1) A return EM34 survey must be conducted around the target villages prior to any water supply infrastructural assistance under KIRIWATSAN Phase 2.
- 2) Standard well improvements are recommended for household wells.
- 3) Communal and village wells and infiltration galleries are recommended as the preferred option for abstraction of groundwater from suitable locations. The location of proposed communal and village wells and gallery systems will have to be confirmed through thorough community consultation.
- 4) RWH improvements would complement the water diversification for Nikunau and meet the expectations and preferences of villagers for increased access to rainwater resources. RWH should be considered for communal buildings, where formal agreement between community members and property owners over access to stored rainwater is in place.
- 5) Periodic groundwater monitoring of wells at selected locations on Nikunau Island is recommended to provide important information on the variance of groundwater quality over time. Guidelines on the selection and monitoring of wells are provided in Loco et al. (2015). Where village wells and infiltration galleries are being constructed, consideration should be given to the installation of multi-level groundwater wells which allow improved understanding of the freshwater lens over time for these important water abstraction areas. In addition, repeated EM34 geophysical surveys would be useful to indicate variations in the lens over time.
- 6) Introduction of appropriate sanitation options is essential to the long-term development and health of the communities. Composting toilets are the most appropriate sanitation option. The introduction of composting toilets will require extensive community consultation and awareness to ensure that this option is socially and culturally accepted and that the technology is made affordable.
- 7) It is recommended that another round of community awareness and engagement meetings is conducted to finalise and formalise the Village Action Plan prior to any infrastructural assistance. This will be used to confirm the proposed water and sanitation designs that will be considered and ensure that the communities agree to support, safeguard and protect all water supply improvements.

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## 9.0 ANNEXES



A UNICEF project in partnership with the European Union and SPC for Kiribati

### Water and Sanitation in the Outer islands of the Republic of Kiribati (KIRIWATSAN)

#### NIKUNAU ATOLL, KIRIBATI

- Annex 1. Survey Schedule around Nikunau
- Annex 2. Historical Monthly Rainfall Data
- Annex 3. Groundwater Well Field Survey Sheet
- Annex 4. Rainwater Harvesting Field Survey Sheet
- Annex 5. E.coli Compact Dry Plate Filtration Membrane Procedures and Results
- Annex 6. Nikunau Village Water Resources Assessment Maps
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- Annex 9. Rainwater Harvesting Analysis Calculator and Results
- Annex 10. Village Meeting Notes
- Annex 11. Selection of Nikunau Survey Photos

# Annex 1

## Survey Schedule around Nikunau

This annex presents the water resources assessment schedule around Nikunau Island as discussed and agreed upon between the Island Council OIC and the SPC survey team.

**Table A1-1. Survey schedule around Nikunau Island between 5<sup>th</sup> and 19<sup>th</sup> August 2013.**

Date	Villages	Activities
05/8/2013		Team travelled to Nikunau Held a meeting with Island Council OIC to agree on a survey schedule and arrange logistical needs
06/8/2013	Nikumanu	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse
07/8/2013	Nikumanu	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse
08/8//2013	Rungata	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse
09/8/2013	Rungata	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse
10/8/2013	Rungata	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse
11/8/2013		Team rested at the guesthouse
12/8/2013	Tabutoa	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse
13/8/2013	Tabutoa	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse
14/8/2013	Muribenua	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse
15/8/2013	Muribenua	Conducted groundwater well assessment, rainwater harvesting survey and and EM34 geophysics E.coli sample preparation and incubation held at the guesthouse Team prepared for village consultation meetings
16/8/2013	Nikumanu, Rungata, Tabutoa and Muribenua	Conducted community consultation meetings in all the villages. Note that the scheduled meeting in Rungata Village was not held because of miscommunication and villagers were engaged in other activities as a result.
17/8/2013		Team prepared for return trip and settled all pending payments
18/8/2013		Team rested in the Island Council's guesthouse
19/8/2013		Team returned to Tarawa

## Annex 2

# Historical Monthly Rainfall Data, Nikunau

This annex provides the historical monthly rainfall data for Nikunau Island, together with a basic statistical summary.

**Table A2-1. Historical monthly rainfall data on Nikunau Island for 1955-2011 (with gaps).**

NIKUNAU	J62400		LAT	01 20S	LONG	176 26E	HT-3M						
RAINFALL (mm)													
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1955	119	15	76	56	27	18	32	50	36	18	3	2	452
1956	21	1	18	5	44	15	202	83	20	33	18	8	468
1957	57	40	12	99	113	155	234	93	45	258	417	350	1873
1958	293	269	490	656	161	38	79	11	9	36	91	304	2437
1959	260	240	225	25	84	86	14	59	8	6	2	16	1025
1960	151	46	0	44	65	1	32	100	35	41	81	72	668
1961	84	31	70	75	108	106	176	112	43	90	102	0	997
1962	0	0	10	65	49	74	109	116	34	5	0	40	502
1963	44	0	40	125	11	140	143	102	25	114	258	290	1292
1964	450	418	40	0	0	34	32	81	50	0	19	105	1229
1965	2	168	93	56		134	317	356	384	362	254	130	2256
1966	401	378	172	132	9	5	215	18	0	105	14	44	1493
1967	101	0	17	183	25	42	36	64	81	0	34	264	847
1968	228	0	0	27	0	1	2	2	2	12	6	29	309
1969	395	318	413	129	2	117	138	151	33	35	14	210	1955
1970	199	65	131	158	17	55	41	42	25	0	8	2	743
1971	0	10	6	42	80	44	63	53	3	32	79	4	416
1972	134	10	0	319	138	121	226	250	267	155	109	111	1840
1973	695	325	133	5	69	15	7	38	67	7	1	215	1577
1974	0	0	0	0	329	45	464	197	32	6		765	
1975	92	0											
1976	160	35	122	177	319	695	499	337	101	237	3	121	2806
1977	111	11	22	200	81	140	210	71	80	91	201	36	1254
1978	31	65	80						11	8	0	62	

<b>1979</b>							104	28	55	107			
<b>1980</b>			192	25	39	8	12	103	5	5	28	114	
<b>1981</b>	5	42	249	295	43	116	100	1	0	7	0	94	<b>952</b>
<b>1982</b>	4	16	7	23	92	114	354	320	153	232	88	248	<b>1651</b>
<b>1983</b>	167	95	55	157	165	212	250	42	27	2	15	34	<b>1221</b>
<b>1984</b>	0	37	15	55	23	24	79	7	11	50	84	34	<b>419</b>
<b>1985</b>	20	1	90	2	76	35	45	34	163	8	24	42	<b>540</b>
<b>1986</b>	6	31	6	6	45	50	171	114	249	209	263		<b>1150</b>
<b>1987</b>	381	618	439	460	258	153	401	114	94	103	16	295	<b>3332</b>
<b>1988</b>	568	221	215	46	29	32	40	71	20				
<b>1989-2009</b>													
<b>2010</b>												30.3	
<b>2011</b>	17.8			71.5	66.0								

**Table A2-2. Basic statistical analysis of discontinuous 1955-2011 monthly rainfall.**

STATISTICS FOR FULL PERIOD, 1955-2011													
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean (mm)	157	110	107	116	83	91	151	101	66	74	74	131	<b>1275</b>
Standard deviation (mm)	181	156	133	144	86	125	137	95	87	94	104	159	<b>776</b>
CV*	1.15	1.43	1.24	1.24	1.04	1.38	0.91	0.94	1.33	1.26	1.39	1.21	<b>0.61</b>
Maximum (mm)	695	618	490	656	329	695	499	356	384	362	417	765	<b>3332</b>
Minimum (mm)	0	0	0	0	0	1	2	1	0	0	0	0	<b>309</b>
No. Years	33	32	32	32	31	31	32	32	33	32	30	31	<b>28</b>

\*CV: Coefficient of variation = standard deviation/mean, a measure of rainfall variability, the higher the CV the greater the variability from the average.

## Annex 3

# Groundwater Well Field Survey Sheet

**Annex 3 - KIRIWATSAN - Well survey**

Island name:    Team number:  Village Name: \_\_\_\_\_

Well Number:   Name of well owner: \_\_\_\_\_

Location: of well N:     Date:  /  /

E:     Time:  :

**Well Characteristics - Record the following information for the household survey. CIRCLE the appropriate response code and ENTER in the box (es) provided**

**1 Casing Type**

1. Cement

2. Coral rock

3. Steel

4. PVC/PE

5. Unlined

6. Other

**2 Well Covering**

1. None

2. Covered

3. Uncovered

4. Partially covered

**3 Well Covering condition**

1. None

2. Replace/repair

3. Adequate

4. Good

**4 Well Covering Material**

1. Cement

2. Coral rock

3. Steel

4. PVC/PE

5. Unlined

6. Other

**5 Fencing condition**

1. None

2. Replace/repair

3. Adequate

4. Good

**6 Fencing material**

1. None

2. Steel

3. Timber

4. Other

**7 Well Apron**

1. None

2. <0.3

3. 0.3-0.8m

4. >0.8m

**8 Well Apron Material**

1. None

2. Cement

3. Coral rock

4. Timber

5. Other

**9 Well Apron Condition**

1. None

2. Cracked

3. Adequate

**24 No. Of photos taken**

Photo nos. \_\_\_\_\_

**10 Abstraction type**

1. None

2. Bucket/tin

3. Tamana pump

4. Diesel or electric pump

5. Solar pump

6. Other

**11 Pump Status**

1. None

2. Working

3. Not working

**12 Use of Water**

1. Drinking/cooking

2. Washing/gardening/toilet

3. All of the above

4. Not used

**13 No of Households using the well**

**14 No. Of people using the well**

**15 Sanitation Practice**

1. Ikiribati pit toilet

2. Imatang - Pour/flush

3. Beach/Bush

4. Other

**16 Distance to toilet (m)**

**17 Contamination source**

1. None

2. latrine

3. Pig Pen

4. Rubbish

5. Vegetation

6. Fuel depot

7. Other

**18 Contamination distance (m)**

**19 Internal well diameter (m)**

**20 Parapet height above ground (m)**

**21 DTWT from parapet measuring point (m)**

**22 TD from measuring point (m)**

**23 Salinity Top mS/cm**

**24 Salinity Bottom mS/cm**

**25 Bacteriological sample** Yes  No

**26 Improvements**

1. Fencing

2. improved well cover

3. Concrete Apron

4. Increase well parapet

5. Bucket off ground

6. Replace tamana pmp

7. Remove rubbish

8. Cut vegetation back

9. Clean out well

10. Relocate pig pen

11. Relocate toilet

12. Other

**24 Comments**

\_\_\_\_\_

**KIRIWATSAN - Well survey**

Island name:    Team number:  Village Name: \_\_\_\_\_

Well Number:   Name of well owner: \_\_\_\_\_

Location: of well N:     Date:  /  /

E:     Time:  :

**Well Characteristics - Record the following information for the household survey. CIRCLE the appropriate response code and ENTER in the box (es) provided**

<p><b>1 Casing Type</b></p> <p>1. Cement ..... <input type="checkbox"/></p> <p>2. Coral rock ..... <input type="checkbox"/></p> <p>3. Steel ..... <input type="checkbox"/></p> <p>4. PVC/PE ..... <input type="checkbox"/></p> <p>5. Unlined ..... <input type="checkbox"/></p> <p>6. Other ..... <input type="checkbox"/></p> <p><b>2 Well Covering</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. Covered ..... <input type="checkbox"/></p> <p>3. Uncovered ..... <input type="checkbox"/></p> <p>4. Partially covered ..... <input type="checkbox"/></p> <p><b>3 Well Covering condition</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. Replace/repair ..... <input type="checkbox"/></p> <p>3. Adequate ..... <input type="checkbox"/></p> <p>4. Good ..... <input type="checkbox"/></p> <p><b>4 Well Covering Material</b></p> <p>1. Cement ..... <input type="checkbox"/></p> <p>2. Coral rock ..... <input type="checkbox"/></p> <p>3. Steel ..... <input type="checkbox"/></p> <p>4. PVC/PE ..... <input type="checkbox"/></p> <p>5. Unlined ..... <input type="checkbox"/></p> <p>6. Other ..... <input type="checkbox"/></p> <p><b>5 Fencing condition</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. Replace/repair ..... <input type="checkbox"/></p> <p>3. Adequate ..... <input type="checkbox"/></p> <p>4. Good ..... <input type="checkbox"/></p> <p><b>6 Fencing material</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. Steel ..... <input type="checkbox"/></p> <p>3. Timber ..... <input type="checkbox"/></p> <p>4. Other ..... <input type="checkbox"/></p> <p><b>7 Well Apron</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. &lt;0.3 ..... <input type="checkbox"/></p> <p>3. 0.3-0.8m ..... <input type="checkbox"/></p> <p>4. &gt;0.8m ..... <input type="checkbox"/></p> <p><b>8 Well Apron Material</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. Cement ..... <input type="checkbox"/></p> <p>3. Coral rock ..... <input type="checkbox"/></p> <p>4. Timber ..... <input type="checkbox"/></p> <p>5. Other ..... <input type="checkbox"/></p> <p><b>9 Well Apron Condition</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. Cracked ..... <input type="checkbox"/></p> <p>3. Adequate ..... <input type="checkbox"/></p>	<p><b>10 Abstraction type</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. Bucket/tin ..... <input type="checkbox"/></p> <p>3. Tamana pump ..... <input type="checkbox"/></p> <p>4. Diesel or electric pump ..... <input type="checkbox"/></p> <p>5. Solar pump ..... <input type="checkbox"/></p> <p>6. Other ..... <input type="checkbox"/></p> <p><b>11 Pump Status</b></p> <p>1. None ..... <input type="checkbox"/></p> <p>2. Working ..... <input type="checkbox"/></p> <p>3. Not working ..... <input type="checkbox"/></p> <p><b>12 Use of Water</b></p> <p>1. Drinking/cooking ..... <input type="checkbox"/></p> <p>2. Washing/gardening/toilet ..... <input type="checkbox"/></p> <p>3. All of the above ..... <input type="checkbox"/></p> <p>4. Not used ..... <input type="checkbox"/></p> <p><b>13 No of Households using the well</b> ..... <input type="text"/> <input type="text"/></p> <p><b>14 No. Of people using the well</b> ..... <input type="text"/> <input type="text"/></p> <p><b>15 Sanitation Practice</b></p> <p>1. Ikiribati pit toilet ..... <input type="checkbox"/> 3. Beach/Bush ..... <input type="checkbox"/></p> <p>2. Imatang - Pour/flush ..... <input type="checkbox"/> 4. Other ..... <input type="checkbox"/></p> <p><b>16 Distance to toilet</b> ..... <input type="text"/> <input type="text"/></p> <p><b>17 Contamination source</b></p> <p>1. None ..... <input type="checkbox"/> 5. Vegetation ..... <input type="checkbox"/></p> <p>2. latrine ..... <input type="checkbox"/> 5. Agriculture ..... <input type="checkbox"/></p> <p>3. Pig Pen ..... <input type="checkbox"/> 6. Fuel depot ..... <input type="checkbox"/></p> <p>4. Rubbish ..... <input type="checkbox"/> 7. Other ..... <input type="checkbox"/></p> <p><b>18 Contamination distance</b> ..... <input type="text"/> <input type="text"/></p> <p><b>19 Internal well diameter (m)</b> ..... <input type="text"/> <input type="text"/></p> <p><b>20 Parapet height above ground (m)</b> ..... <input type="text"/> <input type="text"/></p> <p><b>21 DTWT from parapet measuring point</b> ..... <input type="text"/> <input type="text"/></p> <p><b>22 TD from measuring point</b> ..... <input type="text"/> <input type="text"/></p> <p><b>23 Salinity Top mS/cm</b> ..... <input type="text"/> <input type="text"/></p> <p><b>24 Salinity Bottom mS/cm</b> ..... <input type="text"/> <input type="text"/></p> <p><b>25 Bacteriological sample</b> Yes <input type="checkbox"/> No <input type="checkbox"/></p> <p><b>26 Improvements</b></p> <p>1. Fencing ..... <input type="checkbox"/> 7. Remove rubbish ..... <input type="checkbox"/></p> <p>2. improved well cover ..... <input type="checkbox"/> 8. Cut vegetation back ..... <input type="checkbox"/></p> <p>3. Concrete Apron ..... <input type="checkbox"/> 9. Clean out well ..... <input type="checkbox"/></p> <p>4. Increase well parapet ..... <input type="checkbox"/> 10. Relocate pig pen ..... <input type="checkbox"/></p> <p>5. Bucket off ground ..... <input type="checkbox"/> 11. Relocate toilet ..... <input type="checkbox"/></p> <p>6. Replace tamana pmp ..... <input type="checkbox"/> 12. Other ..... <input type="checkbox"/></p> <p><b>24 No. Of photos taken</b> ..... <input type="checkbox"/></p> <p>Photo nos. ....</p> <p><b>24 Comments</b> .....</p>
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## Annex 4

# Rainwater Harvesting Field Survey Sheet

**Annex 4 - KIRIWATSAN - RWH survey**

Island name:    Team number:  Village Name: \_\_\_\_\_

Building Number:   Name of well owner: \_\_\_\_\_

Location: Building N:     Date:  /  /

E:     Time:  :

Record the following information for the household survey. CIRCLE the appropriate response code and ENTER in the box (es) provided

**Roof Area**

1 Length (m)

2 Width (m)

3 Height (m)

**4 Roof material**

1. Metal .....

2. Thatch .....

3. Other .....

**5 Roof condition**

1. Replace/repair .....

2. Adequate .....

3. Good .....

**6 Building Type**

1. Church .....

2. Manneba .....

3. Government .....

4. Private .....

5. Other .....

**6 Fascia board condition**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

**7 Guttering condition**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

**8 Guttering coverage of roof area**

1. <25% .....

2. 50% .....

3. 75% .....

4. 100% .....

**9 Downpipe condition**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

5. House .....

6. Other .....

**10 Screens on tank entry points**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

**11 Abstraction type**

1. None .....

2. Tap .....

3. Bucket .....

4. Pump .....

5. House .....

6. Other .....

**13 Storage dimensions**

Storage	Height	Diameter	Type
<input type="text"/>	<input type="text"/>	<input type="text"/>	eg Plastic, Cement, Steel, Fibreglass, Wood, Other
<input type="text"/>	<input type="text"/>	<input type="text"/>	
<input type="text"/>	<input type="text"/>	<input type="text"/>	
<input type="text"/>	<input type="text"/>	<input type="text"/>	

Storage	Height	Width	Length
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

**14 Storage condition**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

**15 Overhanging Vegetation** Yes  No

**16 Bacteriological sample** Yes  No

**17 Improvements**

1. Fencing ..... <input type="text"/>	5. Clean Gutters ..... <input type="text"/>
2. Drainage ..... <input type="text"/>	6. Repair gutters ..... <input type="text"/>
3. Leaking tap ..... <input type="text"/>	7. Connect downpipe ..... <input type="text"/>
4. Spring loaded tap ..... <input type="text"/>	8. Connect tank ..... <input type="text"/>
	9. Other ..... <input type="text"/>

**18. Comments**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

No. Of photos taken

Photo nos. \_\_\_\_\_

**KIRIWATSAN - RWH survey**

Island name:    Team number:  Village Name: \_\_\_\_\_

Building Number:   Name of well owner: \_\_\_\_\_

Location: Building N:     Date:  /  /

E:     Time:  :

Record the following information for the household survey. CIRCLE the appropriate response code and ENTER in the box (es) provided

**Roof Area**

1 Length (m)

2 Width (m)

3 Height (m)

**4 Roof material**

1. Metal .....

2. Thatch .....

3. Other .....

**5 Roof condition**

1. Replace/repair .....

2. Adequate .....

3. Good .....

**6 Building Type**

1. Church .....

2. Manneba .....

3. Government .....

4. Private .....

5. Other .....

**6 Fascia board condition**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

**7 Guttering condition**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

**8 Guttering coverage of roof area**

1. <25% .....

2. 50% .....

3. 75% .....

4. 100% .....

**9 Downpipe condition**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

5. House .....

6. Other .....

**10 Screens on tank entry points**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

**11 Abstraction type**

1. None .....

2. Tap .....

3. Bucket .....

4. Pump .....

5. House .....

6. Other .....

**13 Storage dimensions**

Storage	Height	Diameter	Type
<input type="text"/>	<input type="text"/>	<input type="text"/>	eg Plastic, Cement, Steel, Fibreglass, Wood, Other
<input type="text"/>	<input type="text"/>	<input type="text"/>	
<input type="text"/>	<input type="text"/>	<input type="text"/>	
<input type="text"/>	<input type="text"/>	<input type="text"/>	

Storage	Height	Width	Length
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

**14 Storage condition**

1. None .....

2. Replace/repair .....

3. Adequate .....

4. Good .....

**15 Overhanging Vegetation**      Yes       No

**16 Bacteriological sample**      Yes       No

**17 Improvements**

1. Fencing ..... <input type="text"/>	5. Clean Gutters ..... <input type="text"/>
2. Drainage ..... <input type="text"/>	6. Repair gutters ..... <input type="text"/>
3. Leaking tap ..... <input type="text"/>	7. Connect downpipe ..... <input type="text"/>
4. Spring loaded tap ..... <input type="text"/>	8. Connect tank ..... <input type="text"/>
	9. Other ..... <input type="text"/>

**18. Comments**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

No. Of photos taken .....

Photo nos. \_\_\_\_\_

# **E.coli Compact Dry Plate Filtration Membrane Sampling Procedures and Nikunau Island Results**

## Standard Membrane Filtration Method

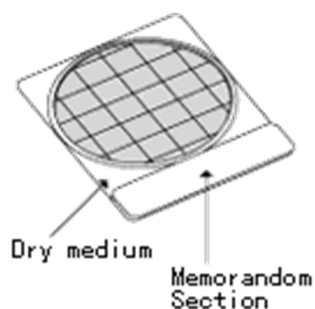
(Adapted from the US Environmental Protection Agency (EPA) and American Public Health Association (APHA) methods (EPA, 2000; APHA, 1995))

**Samples:** Collect water samples in sterile bottles (left in boiling water for 10 minutes and cooled) or bottles that have been rinsed three times at the site with well water, rainwater or water to be tested.

**Storage:** Store samples as cool as possible and in the dark, but not in a freezer – so either in a chilly bin or a bag with cool elements is good. Samples need to be processed within 12 hours of collection, make sure no melted water comes into contact with the sample.

**Equipment:** Need per sample, all sterile (boiled sterile or three times rinsed with sterile/boiled water between samples):

3 X Compact Dry Plates



These plates contain dehydrated agar that allow the bacteria to grow once rehydrated

1 X 50 ml sterile syringe

1 X 20/15/10 ml syringe

1 X sterile filter housing

2 X GN6 Metricell gridded white filters (PallGellman)

Tweezers for filters (not sterile)

Bleach

Sterile/Boiled Water

1 X 20/10 ml syringes

**Suggested volumes:** 1 ml, 10 ml and 50 ml for each sample

The cleaner the water the more volume you need to filter, never more than 100 ml. If the water is heavily contaminated and you get more than 200 colonies on your 1 ml plate you will need to dilute the sample, e.g. 1 in 10 ml and then filter 1 ml of this (or even 1 in 100 ml). Just remember to add the dilution in your final calculation.

## Procedure

### 1) Field Sampling Procedure

- a. Rinse sample bailer three times with sample water before rinsing sample bottles.
- b. Fill bottle with sampled water.
- c. Label sample with water source details (e.g. W001 for well 1 and T001 for rainwater tank 1). Make sure that other relevant details, such as sample collection time, village name and well or tank owner's name is also recorded.
- d. Place sample bottle carefully in a cooler box and close lid properly.
- e. Samples should be analysed within 12 hours post-sample collection.

### 2) Pre-sampling procedure (sample bottles sterilisation)

- a. Rinse and clean sample bottles thoroughly with clean water (preferably boiled water).
- b. Rinse bottles in a covered bucket or cooler box with 5% bleach for at least 30 minutes.
- c. Again, rinse bottles thoroughly in boiled water to clean and remove residual bleach.
- d. Sanitise your hands with soap before taking the bottles out and drying them using tissue paper.
- e. Clean storage container with bleach and boiled water prior to placing the sample bottles inside prior to field visit.

### 3) Lab Sampling Preparation

#### *Set-up procedures*

- a. Make sure there is enough boiled water, sterile water and bleach to conduct the whole procedure.
- b. Prepare the three sanitised containers for holding boiled water, sterile water and 5% bleach.
- c. Prepare a 1 ml, 50 ml and filter housing (all adequately sanitised).
- d. Prepare filter papers.
- e. Prepare and sanitise a pair of tweezers for transferring filter papers to the filter housing and onto the re-hydrated plates.
- f. Prepare and clean a table with bleach and boiled water.
- g. Prepare tissue papers for drying/cleaning any sample water on the table.
- h. Prepare a bucket or container for storing all unused sample water and wastewater.

#### *1 ml sample preparation*

- a. Label all 1 ml dry compact plates with sample details (e.g. sample number, team number etc.)
- b. Purge 1 ml syringe with boiled water before filling and pouring 1 ml sterile water onto the first plate for our 1 ml CONTROL.
- c. Rinse the 1 ml syringe thoroughly with boiled water (3 times) to clean it before filling it up with sterile water to cool it down.
- d. Fill the 1 ml syringe with sample water and then pour the sample into its labelled compact dry plate.

- e. Repeat the above, until all samples have been prepared for 1 ml analysis.
- f. Store all the rehydrated 1 ml plates in a cooler box and record the incubation start time.

*50 ml sample preparation*

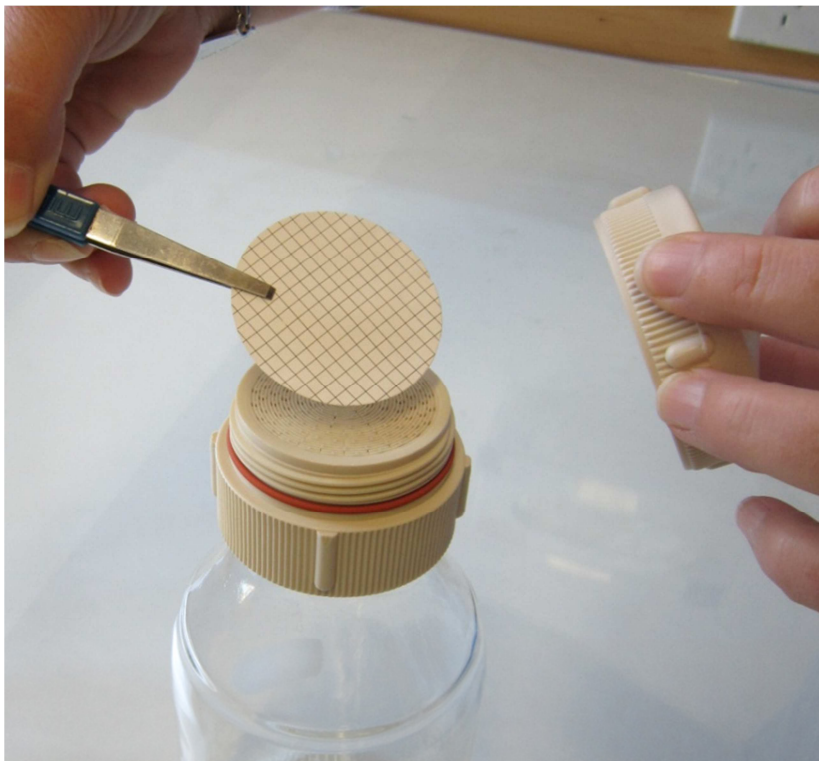
- a. Label all 50 ml dry compact plates with sample details (e.g. sample number, team number etc.), including the CONTROL.
- b. All plates will need to be rehydrated with 1 ml sterile water prior to placement of sample-rinsed filter papers (see below).



- c. Purge 1 ml syringe with boiled water before filling and pouring 1 ml sterile water onto all labelled dry plates to rehydrate the agar.
- d. Fill and rinse the 50 ml syringe with boiled water 3 times. The first rinse should be discharged into the wastewater bucket, while the next two rinses should be run through the filter housing to clean it. Make sure the housing is closed (hand-tight).



- e. Rinse the 50 ml syringe now with sterile water and push water through the filter housing to cool both the syringe and filter housing, and at the same time keep filter housing sanitised.
- f. Now rinse the 50 ml syringe with the sampled water 3 times. These should be dumped in the wastewater bucket.
- g. Sanitise the pair of tweezers through 5% bleach and then sterile water. The latter is aimed at removing any residual bleach.
- h. Get a filter paper using the sanitised tweezers and place it on the filter housing, place filter (grid side up) on the filter support and close the housing tightly carefully, make sure that the o-ring (orange) is in the correct place (Do not touch the inside of the housing) (see below).



- i. Sanitise the tweezers again in bleach and sterile water.
- j. Fill the 50 ml syringe with the sample and run this through the filter housing (with the filter paper in). After emptying the syringe, push air through the filter housing (2 or 3 times) to remove any residual water from the filter housing (see below).



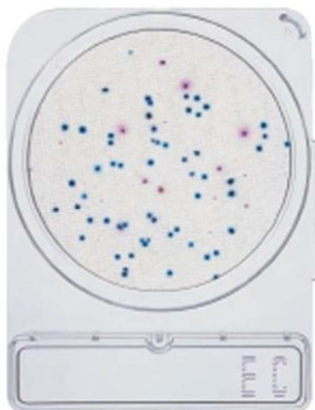
- k. Use the sanitised tweezers to transfer the filter paper from the housing to the re-hydrated plate.
- l. Repeat steps **d to e** until all samples have been prepared for 50 ml analysis.
- m. For the CONTROL, use sterile water, instead of sample water, and subsequent to thoroughly rinsing the syringe and filter housing with boiled and sterile water.
- n. Store all the rehydrated 1 ml plates in a cooler box and record the incubation start time.

#### 4) Post sampling procedure

- a. Repeat pre-sampling routine to prepare for the next sampling phase

#### Counting Procedure:

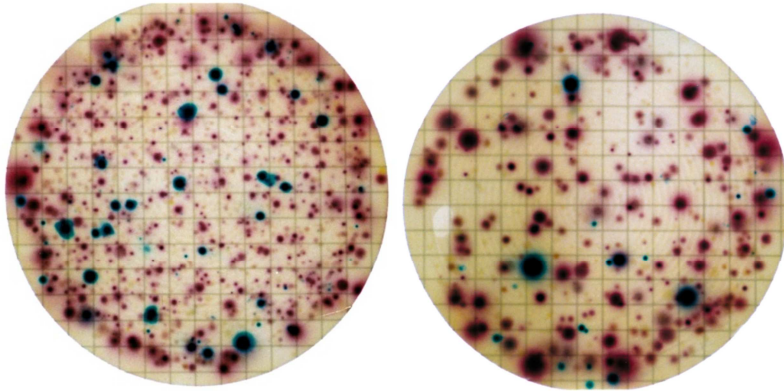
*Compact Dry plates:* Count the number of red and blue colonies



The number of red and blue colonies = Total Coliforms

The number of blue colonies = E.coli

Or the filters on Compact Dry may look like this, again count the number of blue and red colonies.



**Note:** The left plate would not be counted as there are too many colonies to count (>200). Count only plates that have between 20 and 200 colonies on them. If the count is too high, count 10 squares randomly on the filter, work out the average per square and multiply by 100 to get a count per filter. This is not a good way of doing it but will give you an estimate from which you can decide what volume you should have filtered. Calculate all your final numbers as bacteria per 100 ml. If you get no growth on 50 ml the result is <1 per 50 ml, you would need to repeat this with 100 ml of new sample as the drinking water standard is 100 ml.

### **Cleaning of Equipment:**

Clean the syringes and filter housing using 5% bleach and then **three (3)** times with boiled water to remove any residual bleach. Then put a large pot of water on the stove to boil. Let this come to the boil and boil it for 10 minutes to kill any pathogens in it. Then place the syringes and filter housings in it and boil it for a further 10 minutes. Turn off the stove and let the syringes and filter housings cool down in the water with a lid on the pot and remove while they are still hot, but not so hot as to burn you; and place them in a clean plastic container or zip lock bags.

### **Boiled Water:**

Make fresh boiled water each night for the following day of sample processing. Bring a pot of water to the boil and boil continuously for 10 minutes, pour while still hot into a glass bottle that you have previously cleaned with 5% bleach and rinsed 3 times with boiling water. Let the water cool overnight and use the next day for your sample analysis.

## Nikunau Data and Results

**Table A5-1. E.coli results for the sampled groundwater wells and rainwater tanks around the target villages.**

Village	Sample #	Owner	Well or Rainwater tank	Date	1 ml Sample E.coli Count /100 ml	50 ml sample E.coli Count /100 ml	Average E.coli Count/100 ml
Nikumanu	W001	Awati Primary School Head Teacher	RWT	6/08/2013	0	14	7
Nikumanu	W002	Primary School Well	W	6/08/2013	200	98	149
Nikumanu	W003	Mikaere	W	6/08/2013	0	4	2
Nikumanu	T001	Health Clinic	T	6/08/2013	0	0	0
Nikumanu	W005	Teaiwaa	W	6/08/2013	4400	800	2600
Nikumanu	W007	Neeru	W	6/08/2013	0	330	165
Nikumanu	W009	Terimate	W	6/08/2013	300	194	247
Nikumanu	W011	Kabenguu	W	6/08/2013	0	42	21
Nikumanu	W012	Mouritau	W	7/08/2013	1200	0	600
Nikumanu	W014	Tarooka	W	7/08/2013	100	40	70
Nikumanu	W017	Tekieru	W	7/08/2013	800	4	402
Nikumanu	W019	Kaatata	W	7/08/2013	900	60	480
Nikumanu	W021	Tiibi	W	7/08/2013	0		0
Nikumanu	W025	Tongauea	W	7/08/2013	0	2	1
Nikumanu	W027	Ruutoaba	W	7/08/2013	0	0	0
0	0	CONTROL	0	7/08/2013	0	0	0
Nikumanu	BW001	Eroria	W	7/08/2013	0	0	0
Nikumanu	BW003	Piota	W	7/08/2013	0	40	20
Nikumanu	BW005	Tatentoa	W	7/08/2013	200	32	116
Nikumanu	BW007	Moaiti	W	7/08/2013	100	62	81
Nikumanu	BW009	Ienraku	RWT	7/08/2013	1200	400	800
Nikumanu	BW011	Biitam W2	W	7/08/2013	0	60	30

Village	Sample #	Owner	Well or Rainwater tank	Date	1 ml Sample E.coli Count /100 ml	50 ml sample E.coli Count /100 ml	Average E.coli Count/100 ml
Nikumanu	BW015	Karawa	W	7/08/2013	300	36	168
Nikumanu	BT001	Catholic Church Rainwater Tank	T	7/08/2013	0	6	3
Nikumanu	AW001	Teitoi	W	7/08/2013	900	200	550
Nikumanu	AW004	Tewaea	W	7/08/2013	100	98	99
Nikumanu	AW007	Tebwato	W	8/08/2013	2200	500	1350
Nikumanu	AW008	Wirara	W	8/08/2013	100	72	86
Nikumanu	AW011	Catholic church well	W	8/08/2013	400	6	203
Rungata	AW003	Tambura	W	8/08/2013	100	38	69
Rungata	AW018	Akau	W	8/08/2013	0	140	70
Rungata	AW002	Aroito	W	8/08/2013	100	14	57
Rungata	AW005	Tionee	W	8/08/2013	100	60	80
Rungata	AW015	Unnang	W	8/08/2013	1900	0	950
Rungata	AW004	Women Centre Office Well	W	8/08/2013	100	26	63
Rungata	AT001	Health Clinic Rainwater Tank	RWT	8/08/2013	0	0	0
Rungata	AW001	Health Clinic well	W	8/08/2013	1600	384	992
Rungata	BT005	Primary School Rainwater Tank	RWT	8/08/2013	0	184	92
Rungata	BW019	Mameko	W	8/08/2013	6100	TNTC	6100
Rungata	BW009	Kaburara	W	8/08/2013	500	184	342
Rungata	BW016	Teneti	W	8/08/2013	3700	tntc	3700
Rungata	BW025	Pito	W	8/08/2013	200	12	106
Rungata	BW021	Tuatu	W	8/08/2013	600	0	300
Rungata	BT007	Kirabuke	RWT	9/08/2013	600	408	504
Rungata	BW005	Tiamako	W	9/08/2013	0	4	2
Rungata	BW002	JSS and Primary School	W	9/08/2013	0	2	1
Rungata	BW030	Old JSS well	W	9/08/2013	0	12	6
Rungata	BW031	Old well 1	W	9/08/2013	500	800	650

Village	Sample #	Owner	Well or Rainwater tank	Date	1 ml Sample E.coli Count /100 ml	50 ml sample E.coli Count /100 ml	Average E.coli Count/100 ml
Rungata	AW005	Bwauro	W	9/08/2013	400	TNTC	400
Rungata	AW004	Kabunaree	RWT	9/08/2013	300	192	246
Rungata	BW033	Old well 2	W	9/08/2013	100	64	82
Rungata	AW001	Mataaba	W	9/08/2013	100	30	65
Rungata	AT001	KPC tank	T	9/08/2013	0	20	10
Rungata	AW003	Aroito	W	9/08/2013	5000	TNTC	5000
Rungata	AW002	KPC well	W	9/08/2013	100	34	67
Rungata	BW024	Tetiura	W	9/08/2013	8000	24	4012
Rungata	BW021	Terimwa	W	9/08/2013	0	72	36
Rungata	BW025	Catholic church well	W	9/08/2013	1800	800	1300
Rungata	BW007	Kaipakia	W	9/08/2013	0	78	39
Rungata	BW017	Ngamea	W	9/08/2013	400	150	275
Rungata	BW004	Ikaasi	W	12/08/2013	500	800	650
Rungata	BW022	lowane	W	12/08/2013	700	368	534
Tabutoa	BW010	Kapeia	W	12/08/2013	3900	46	1973
Tabutoa	AW08	Riiro	W	12/08/2013	2700	50	1375
Tabutoa	AW15	Tiimea	W	12/08/2013	300	70	185
Tabutoa	AW05	Konaba	W	12/08/2013	4900	182	2541
Tabutoa	AW01	Tiitu	W	12/08/2013	500	90	295
Tabutoa	BW007	Aoniba	W	12/08/2013	3700	146	1923
Tabutoa	BW005	Primary	RWT	12/08/2013	900	40	470
Tabutoa	BW011	Tabokai	W	12/08/2013	100	54	77
Tabutoa	BW002	Village	W	12/08/2013	0	10	5
Tabutoa	BW003	Rubetaake	W	14/08/2013	600	30	315
Tabutoa	AW019	Rest house	W	14/08/2013	1070	16	543
Muribenua	AW011	KPC	W	14/08/2013	0	126	63

Village	Sample #	Owner	Well or Rainwater tank	Date	1 ml Sample E.coli Count /100 ml	50 ml sample E.coli Count /100 ml	Average E.coli Count/100 ml
Muribenua	AWO3	Manueta	W	14/08/2013	100	0	50
Muribenua	ATO1	Clinic	T	14/08/2013	1300	16	658
Muribenua	AWO6	Taboi	W	14/08/2013	100	102	101
Muribenua	AW01	Mabutonga	W	14/08/2013	200	34	117
Muribenua	AW014	Village	W	14/08/2013	0	54	27
Muribenua	AW08	Tabera	W	14/08/2013	0	0	0
Muribenua	BW017	Touriri	W	14/08/2013	200	14	107
Muribenua	BW015	Taraatau	W	14/08/2013	200	148	174
Muribenua	BW011	Katatia	W	14/08/2013	2800	174	1487
Muribenua	BW09	Kirataruru	W	14/08/2013	1900	60	980
Muribenua	BW013	Atereti	W	14/08/2013	0	100	50
Muribenua	BW019	Teang	W	14/08/2013	2100	124	1112
Muribenua	BW07	labeta	W	14/08/2013	3100	68	1584
Muribenua	BW03	Boboi	W	14/08/2013	900	178	539

Note: "TNTC" denotes E.coli "too numerous to count"; and is assigned the value 999 to permit numerical calculation

# Nikunau Village Water Resources Assessment Maps

Annex 6 presents the water resources assessment maps for each target village in Nikunau, including:

- A survey map showing the locations of buildings, storage tanks, EM34 traverse lines and household wells within the target village area – a distinction is made between freshwater and saline wells based on the 2.5 mS/cm cut-off limit.
- Target rainwater-harvesting buildings map showing communal buildings which have potential for rainwater harvesting.
- CTD diver location map showing selected wells in the villages where the data loggers were installed for water level, conductivity and temperature monitoring.
- Contamination map showing the status of E.coli contamination in tested wells and rainwater tanks (using the compact dry plate filtration membrane procedure) to determine the current status of contamination around the target villages, particularly around the drinking water household wells.

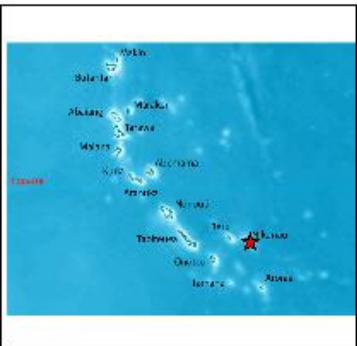
Please note that the freshwater lens contour maps were not generated for each village because of the anomalous EM34 responses recorded during the field survey – this was attributable to wear and tear of the survey equipment. This prohibited the mapping of freshwater lens extent and thickness. Hence, it is recommended that another round of EM34 survey must be conducted around the target villages to determine the villages' freshwater lens potential pertinent to the feasibility of developing groundwater resources for village water supply.

Scalable versions of these maps are available electronically at the following address:

<http://ict.sopac.org/kiriwatsan/login/index>

# Figure A6.0 – NIKUNAU ATOLL INDEX MAP

## GILBERT ISLAND GROUP



### LEGEND:

- ★ - Nikunau Atoll
- - WRA target villages

### NOTES

\* index of target village maps

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment  
Nikunau Atoll Index Map

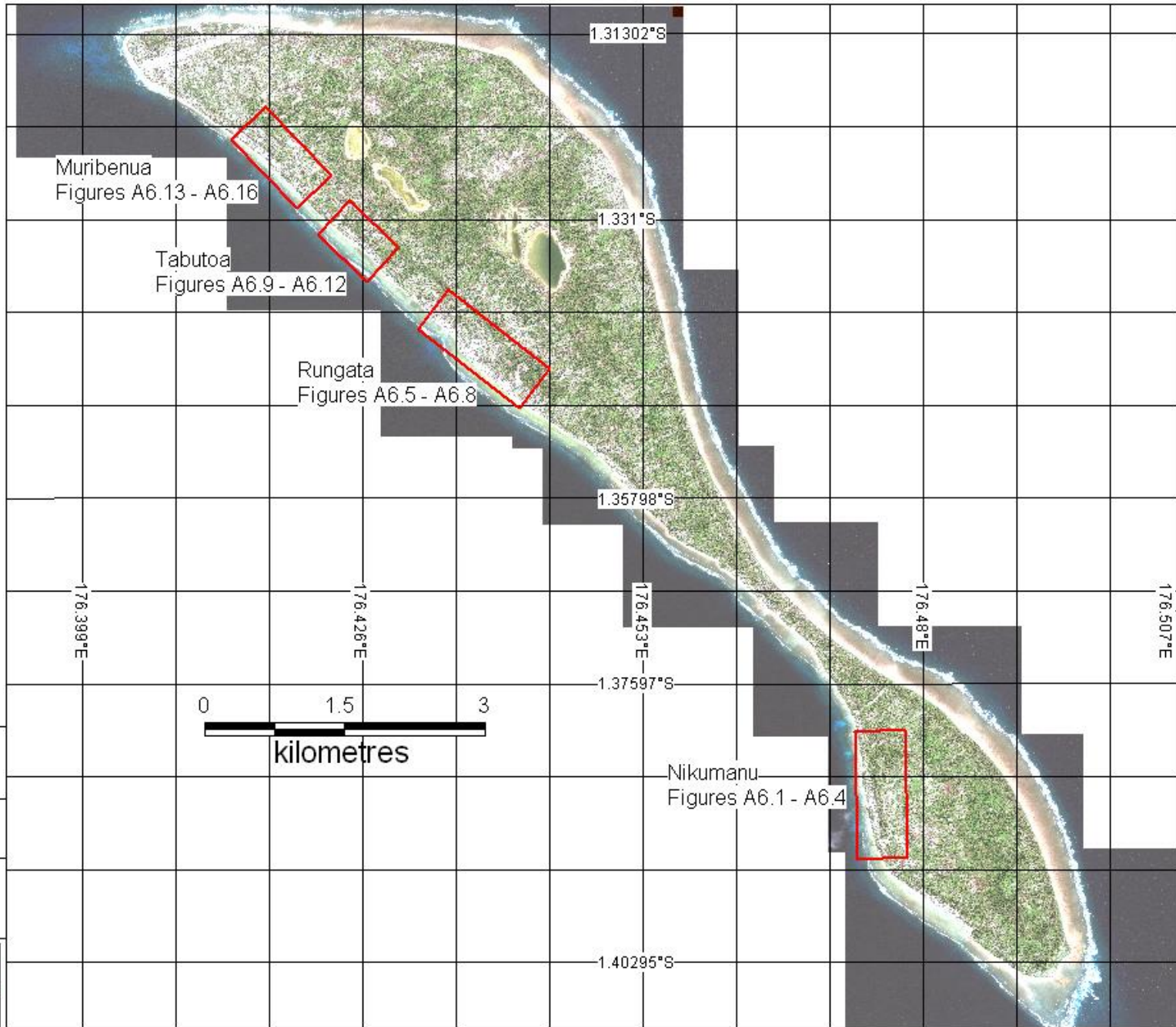


Figure A6.1 – NIKUMANU, NIKUNAU – WATER RESOURCES SURVEY MAP

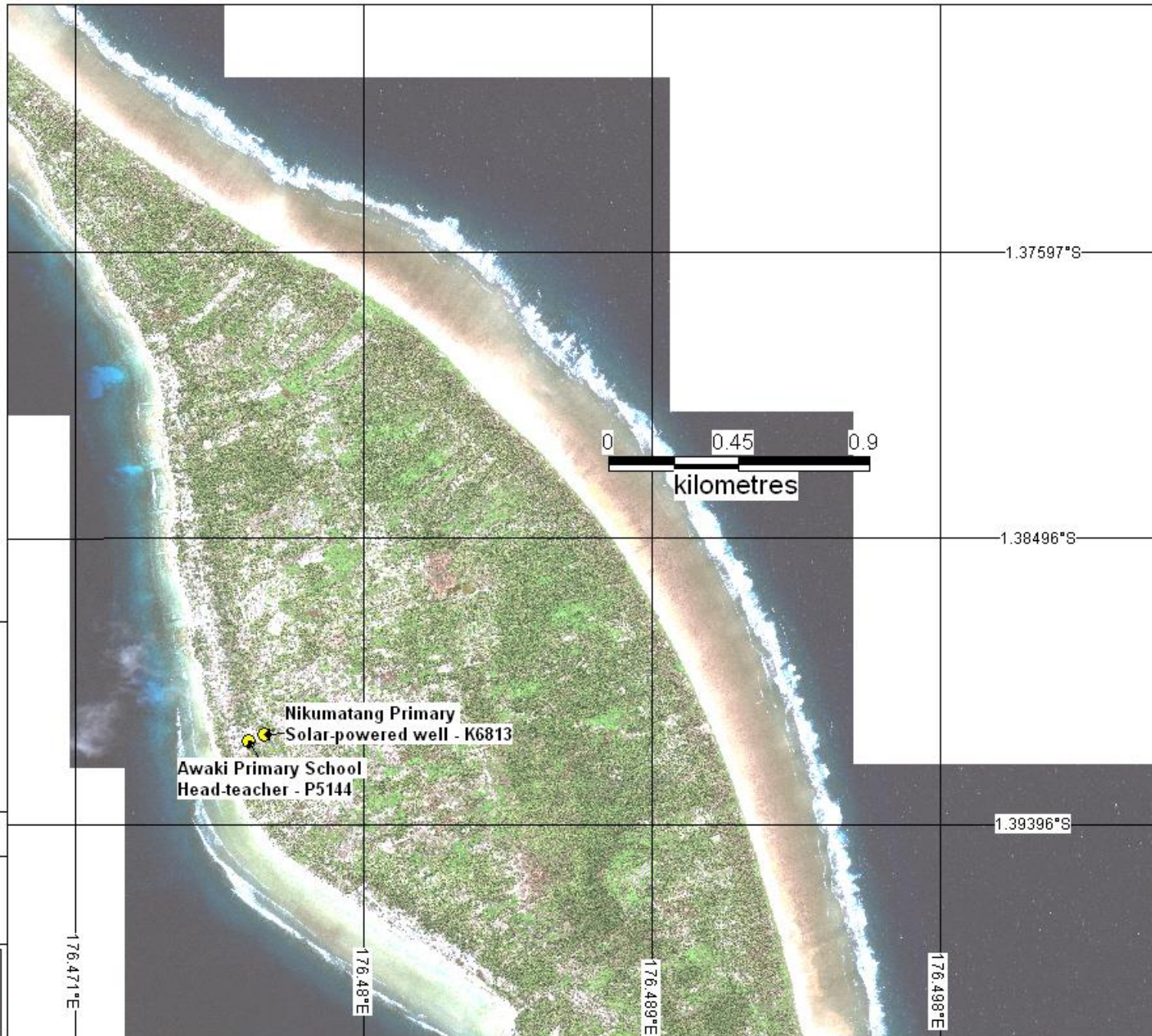
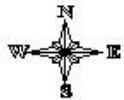


Figure A6.2 – NIKUMANU, NIKUNAU - TARGET COMMUNAL BUILDING FOR RWH



Figure A6.3 – NIKUMANU, NIKUNAU – CTD DIVER LOCATIONS

**NIKUNAU ATOLL**



**LEGEND:**

● - location of CTD divers

**NOTES**

- \* real-time groundwater monitoring devices installed in selected wells
- \* consultation with the household well owners was made prior to the installation of the monitoring device

**Client: Government of Kiribati**

**Project: KIRIWATSANI I**

Water Resources Assessment  
Nikumanu, Nikunau Atoll



Figure A6.4– NIKUMANU, NIKUNAU – BACTERIOLOGICAL SAMPLING

**NIKUNAU ATOLL**



**LEGEND:**

- - unsampled wells
- E. coli bacteria count
- - guideline compliant (0 count/100 ml)
- - tolerable limit (1-10 count/100 ml)
- - requiring some treatment (11-100 count/100 ml)
- - unsuitable without proper treatment (>100 count/100 ml)

**NOTES**

- \* bacteriological testing.  
Compact dry plate filtration membrane method
- \* the option and location of groundwater development around the village will be confirmed after the following:
  - a second round of EM34 survey around the village to determine the freshwater lens thickness and spatial extent
  - consultation with the landholders and village council with consideration to freshwater lens thickness and potential contamination sources

**Client: Government of Kiribati**

**Project: KIRIWATSANI**

Water Resources Assessment  
Nikumanu, Nikunau Atoll

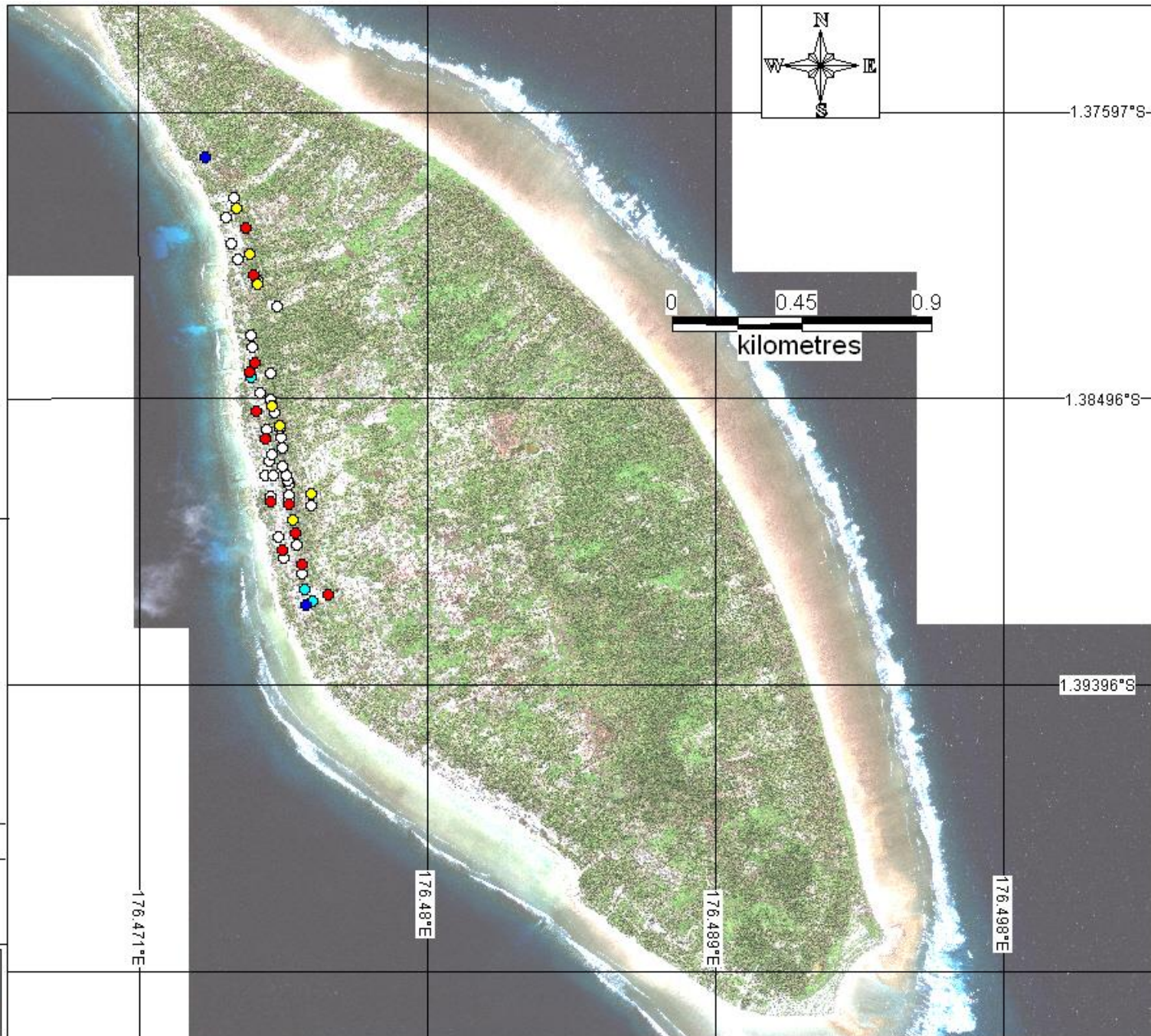
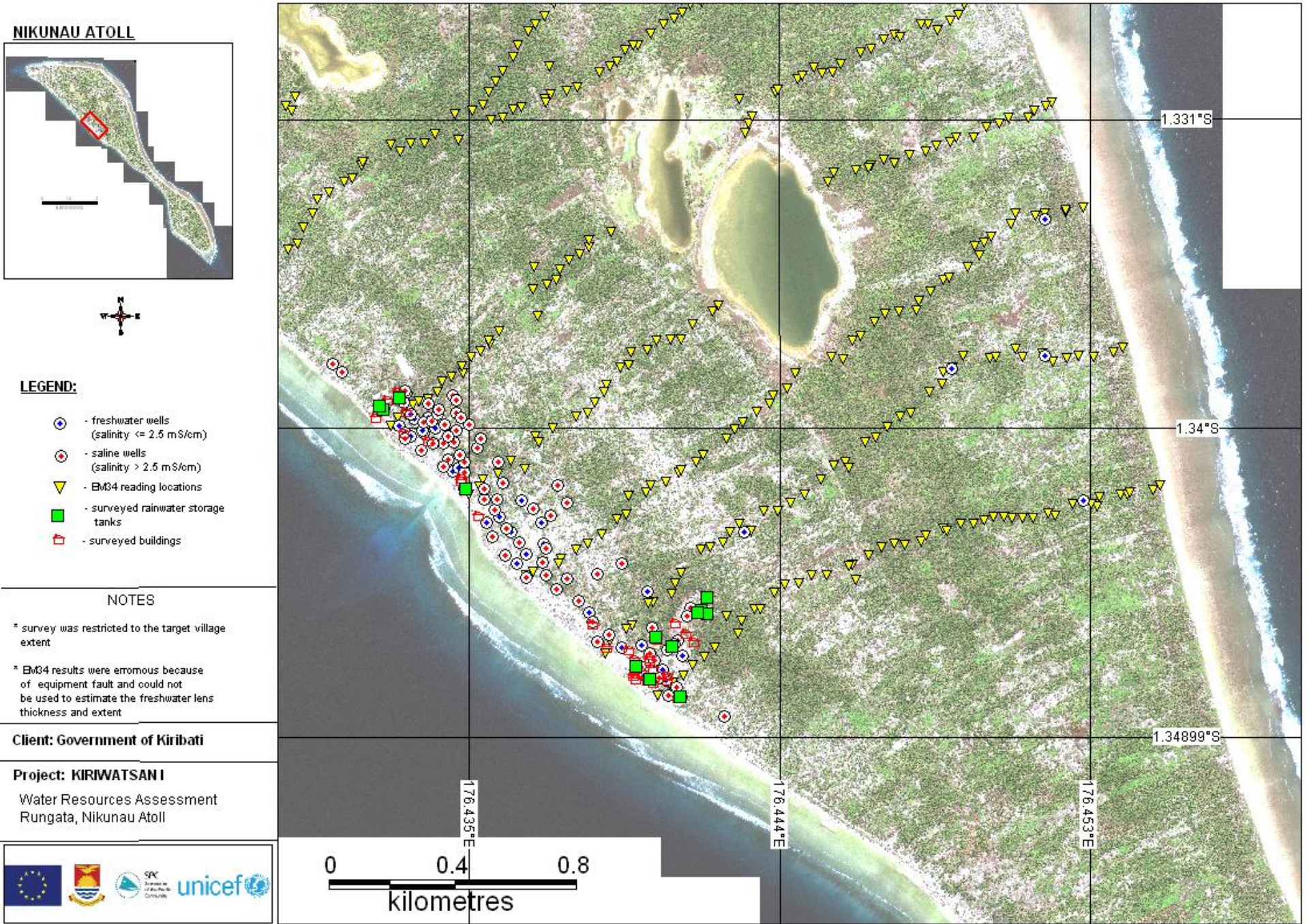




Figure A6.5 – RUNGATA, NIKUNAU WATER RESOURCES SURVEY MAP



**NIKUNAU ATOLL**



**LEGEND:**

-  - freshwater wells (salinity  $\leq 2.5$  mS/cm)
-  - saline wells (salinity  $> 2.5$  mS/cm)
-  - BM34 reading locations
-  - surveyed rainwater storage tanks
-  - surveyed buildings

**NOTES**

- \* survey was restricted to the target village extent
- \* BM34 results were erroneous because of equipment fault and could not be used to estimate the freshwater lens thickness and extent

**Client: Government of Kiribati**

**Project: KIRIWATSAN I**  
Water Resources Assessment  
Rungata, Nikunau Atoll

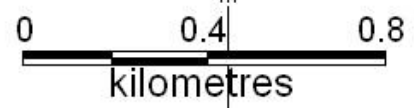


Figure A6.6 – RUNGATA, NIKUNAU - TARGET COMMUNAL BUILDING FOR RWH

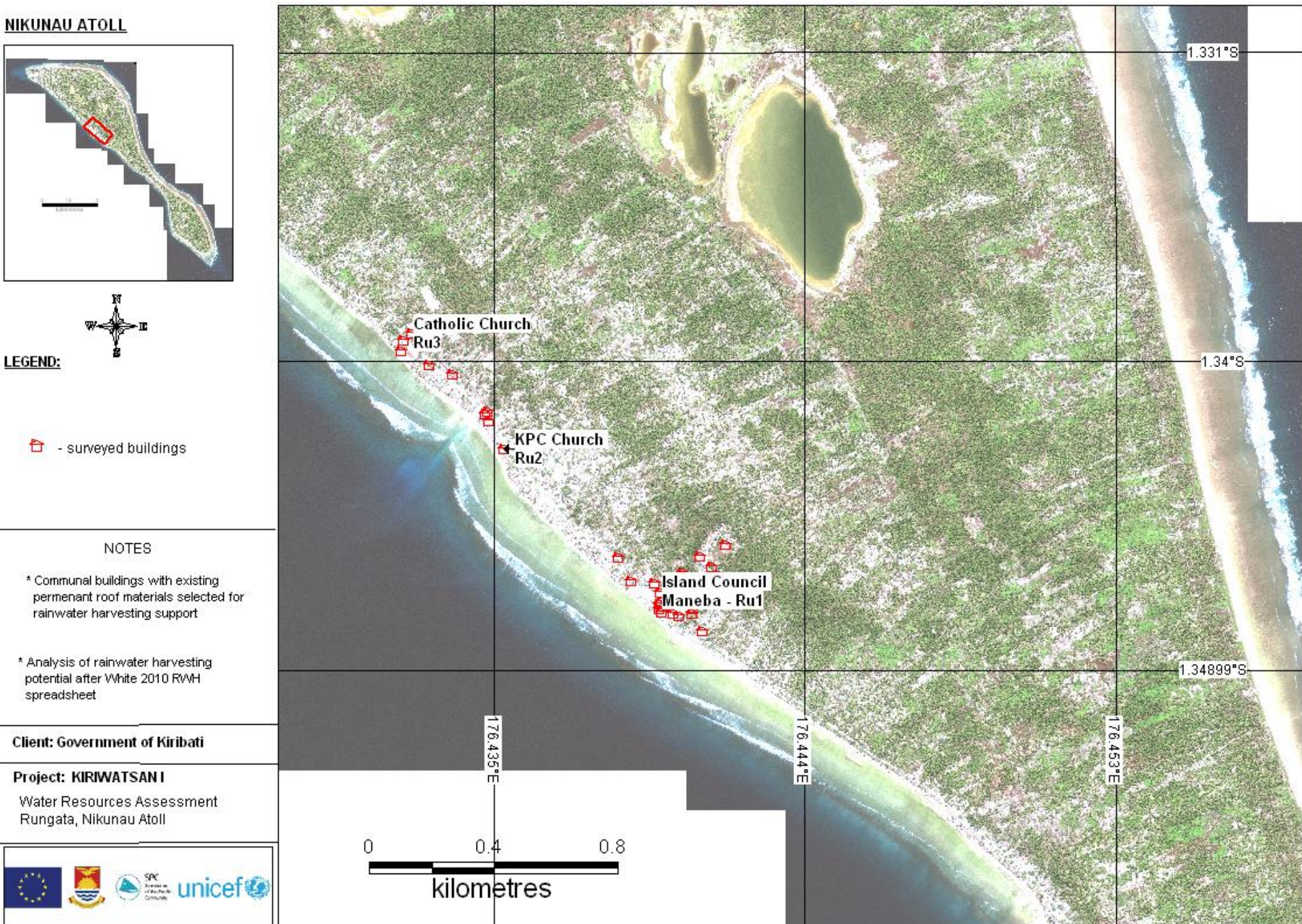
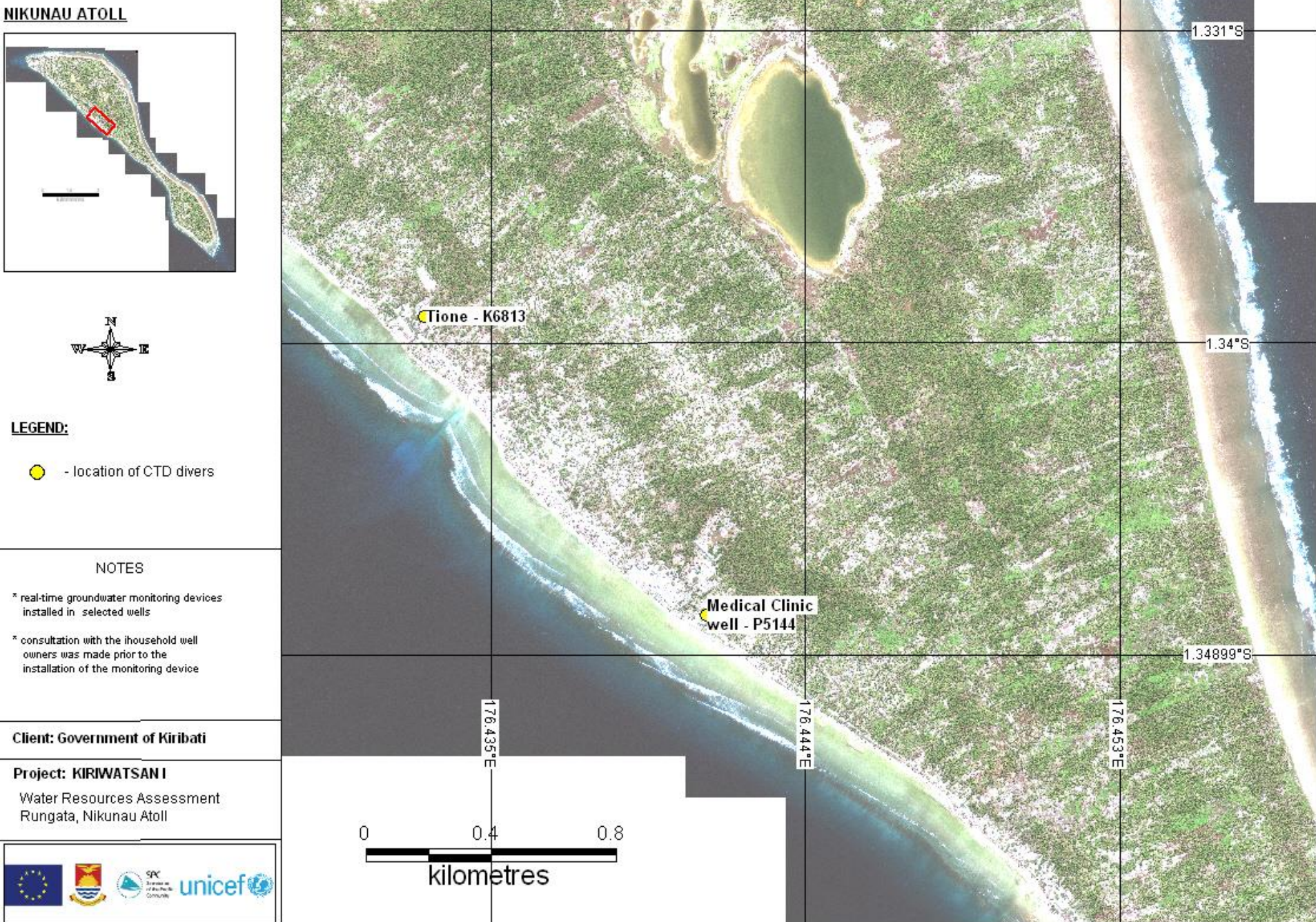


Figure A6.7 – RUNGATA, NIKUNAU - CTD DIVER LOCATIONS



# Figure A6.8– RUNGATA, NIKUNAU - BACTERIOLOGICAL SAMPLING

## NIKUNAU ATOLL



### LEGEND:

- - unsampled wells
- E. coli bacteria count
- - guideline compliant (0 count/100 ml)
- - tolerable limit (1-10 count/100 ml)
- - requiring some treatment (11-100 count/100 ml)
- - unsuitable without proper treatment (>100 count/100 ml)

### NOTES

\* bacteriological testing.  
Compact dry plate filtration membrane method

\* the option and location of groundwater development around the village will be confirmed after the following:

- a second round of EM34 survey around the village to determine the freshwater lens thickness and spatial extent
- consultation with the landholders and village council with consideration to freshwater lens thickness and potential contamination sources

**Client: Government of Kiribati**

**Project: KIRIWATSANI**  
Water Resources Assessment  
Rungata, Nikunau Atoll

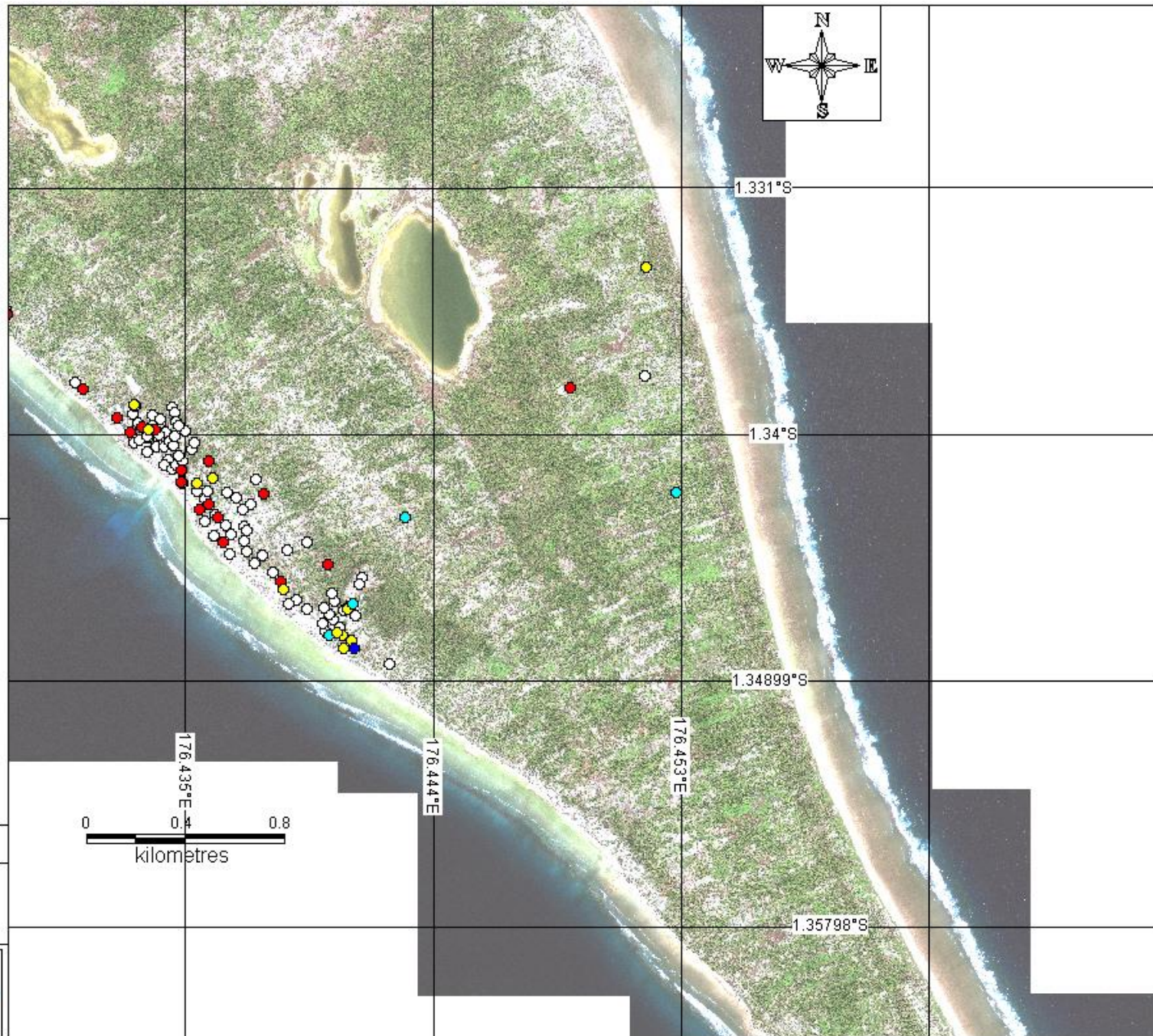


Figure A6.9 – TABUTOA, NIKUNAU WATER RESOURCES SURVEY MAP

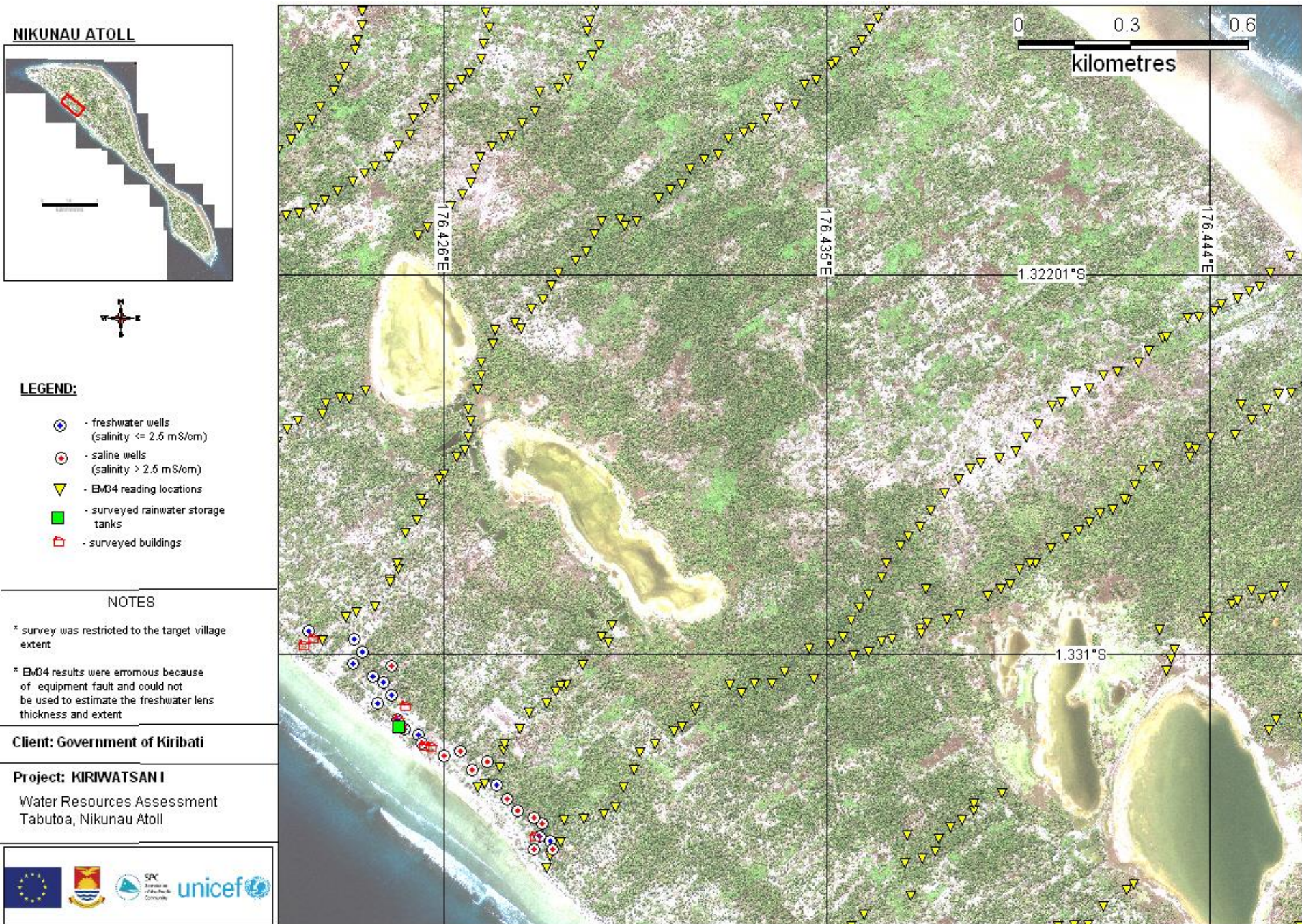



Figure A6.10 – TABUTOA, NIKUNAU -TARGET COMMUNAL BUILDINGS FOR RWH

**NIKUNAU ATOLL**



**LEGEND:**

 - surveyed buildings

**NOTES**

\* Communal buildings with existing permanent roof materials selected for rainwater harvesting support

\* Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

**Client: Government of Kiribati**

**Project: KIRIWATSANI**

Water Resources Assessment  
Tabutoa, Nikunau Atoll



Figure A6.11 – TABUTOA, NIKUNAU - CTD DIVER LOCATIONS

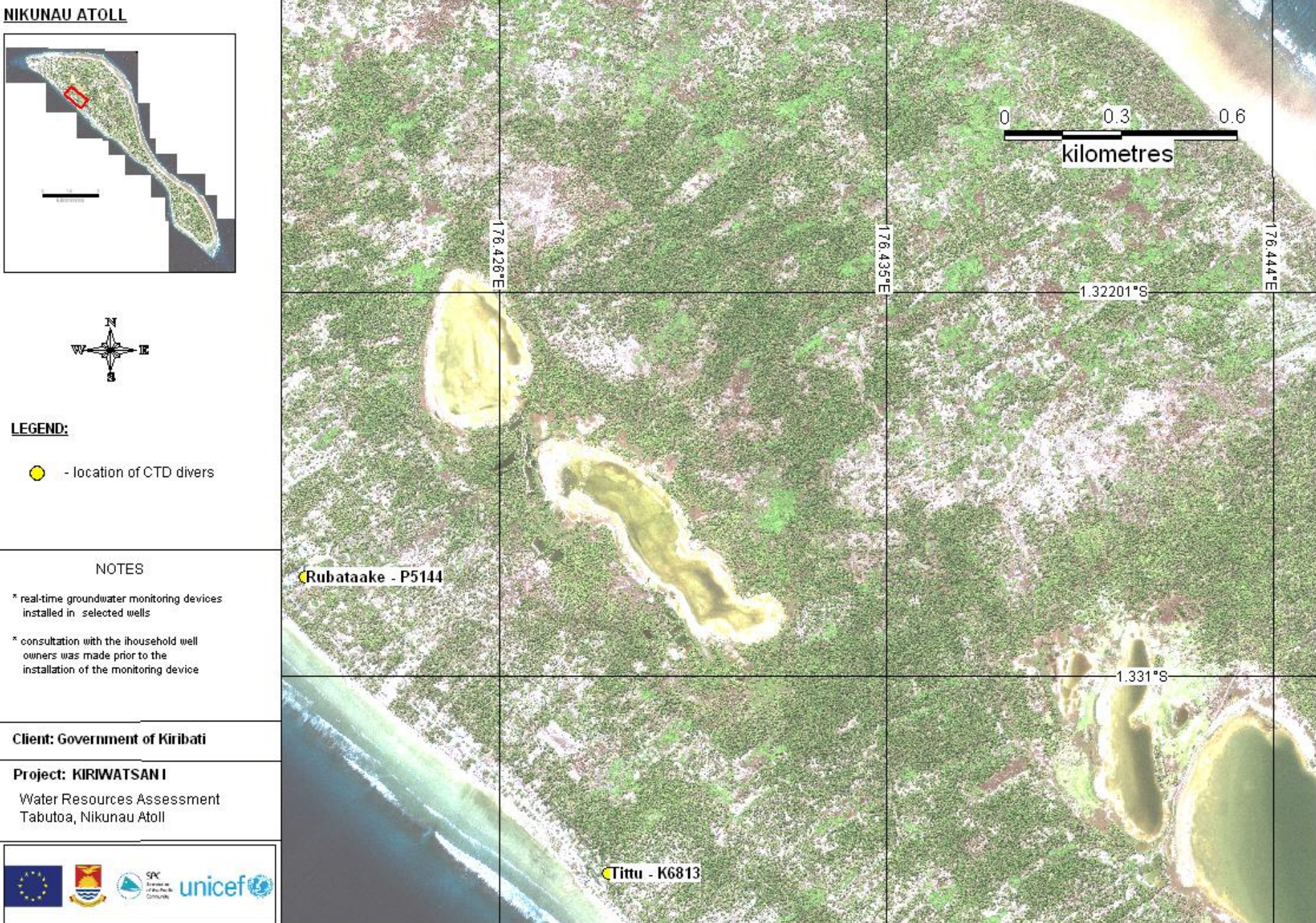
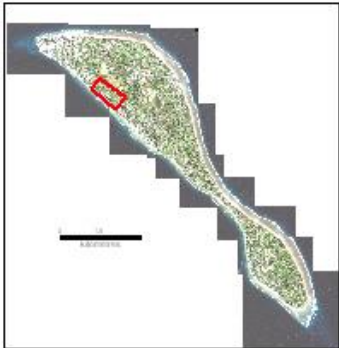


Figure A6.12– TABUTOA, NIKUNAU - BACTERIOLOGICAL SAMPLING

**NIKUNAU ATOLL**



**LEGEND:**

- - unsampled wells
- E. coli bacteria count
- - guideline compliant (0 count/100 ml)
- - tolerable limit (1-10 count/100 ml)
- - requiring some treatment (11-100 count/100 ml)
- - unsuitable without proper treatment (>100 count/100 ml)

**NOTES**

- \* bacteriological testing.  
Compact dry plate filtration membrane method
- \* the option and location of groundwater development around the village will be confirmed after the following:
  - a second round of EM34 survey around the village to determine the freshwater lens thickness and spatial extent
  - consultation with the landholders and village council with consideration to freshwater lens thickness and potential contamination sources

**Client: Government of Kiribati**

**Project: KIRIWATSANI**

Water Resources Assessment  
Tabutoa, Nikunau Atoll



Figure A6.13– MURIBENUA, NIKUNAU - WATER RESOURCES SURVEY MAP




Figure A6.14– MURIBENUA, NIKUNAU - TARGET COMMUNAL BUILDINGS FOR RWH

NIKUNAU ATOLL



LEGEND:

 - surveyed buildings

NOTES

\* Communal buildings with existing permanent roof materials selected for rainwater harvesting support

\* Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

Client: Government of Kiribati

Project: KIRIWATSANI

Water Resources Assessment  
Muribenua, Nikunau Atoll



Figure A6.15– MURIBENUA, NIKUNAU - CTD DIVER LOCATIONS

**NIKUNAU ATOLL**



**LEGEND:**

● - location of CTD divers

**NOTES**

- \* real-time groundwater monitoring devices installed in selected wells
- \* consultation with the household well owners was made prior to the installation of the monitoring device

**Client: Government of Kiribati**

**Project: KIRIWATSANI**  
Water Resources Assessment  
Muribenua, Nikunau Atoll

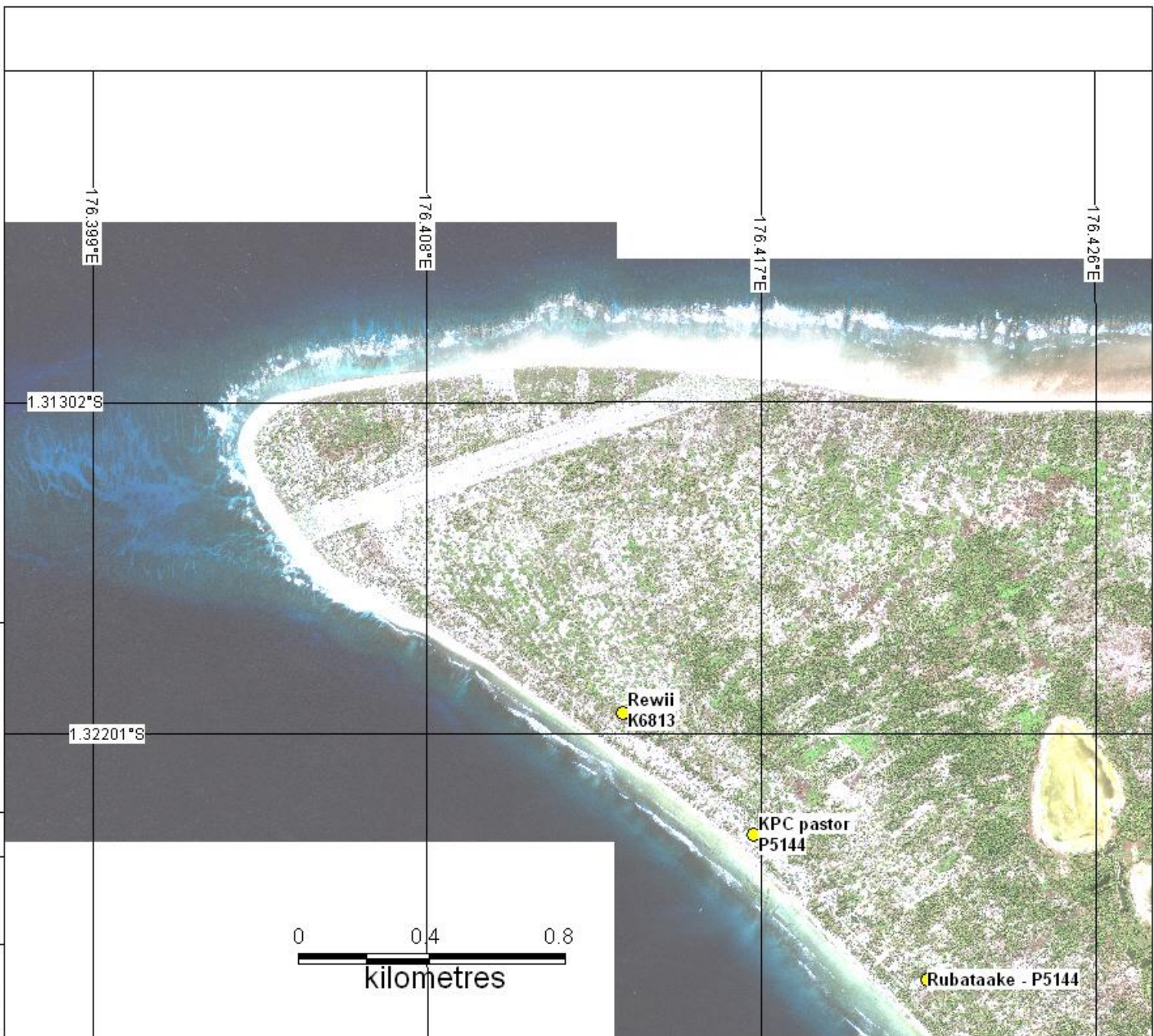


Figure A6.16– MURIBENUA, NIKUNAU - BACTERIOLOGICAL SAMPLING

**NIKUNAU ATOLL**



**LEGEND:**

- - unsampled wells
- E. coli bacteria count
- - guideline compliant (0 count/100 ml)
- - tolerable limit (1-10 count/100 ml)
- - requiring some treatment (11-100 count/100 ml)
- - unsuitable without proper treatment (>100 count/100 ml)

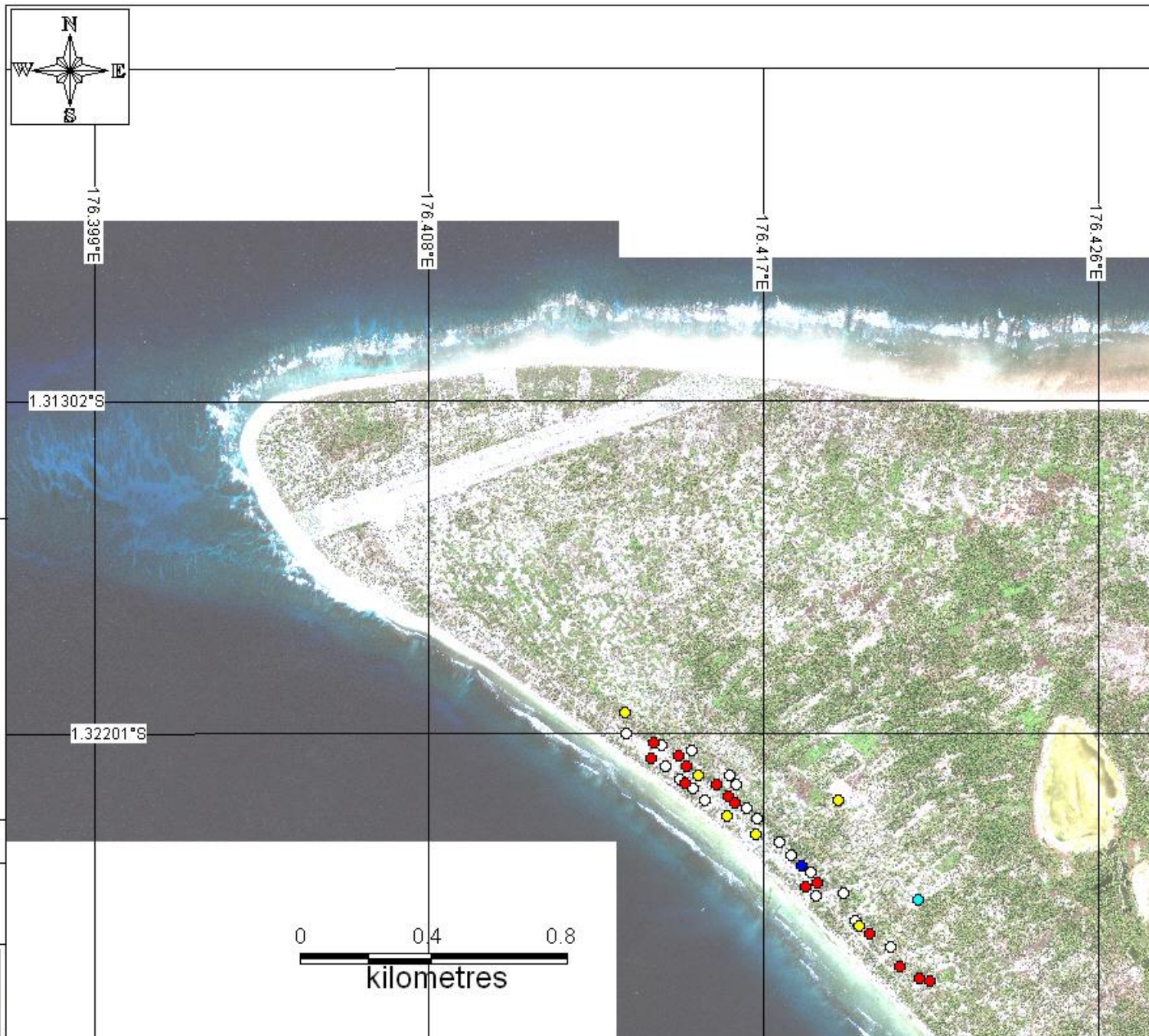
**NOTES**

- \* bacteriological testing.  
Compact dry plate filtration membrane method
- \* the option and location of groundwater development around the village will be confirmed after the following:
  - a second round of EM34 survey around the village to determine the freshwater lens thickness and spatial extent
  - consultation with the landholders and village council with consideration to freshwater lens thickness and potential contamination sources

**Client: Government of Kiribati**

**Project: KIRIWATSANI**

Water Resources Assessment  
Muribenua, Nikunau Atoll



## Annex 7

# EM34 Geophysics Principles & Nikunau Survey Results

## Electromagnetic Surveys – EM34 Geophysics

The use of electromagnetic (EM) geophysical methods for freshwater lens mapping in atoll environments is well established and has been successfully used on Kiribati in recent times by Falkland (2004) and GWP (2011a).

### 1) Objective and background

A Geonics EM34 electromagnetic instrument was used during the current groundwater resource investigation to undertake a rapid assessment of the subsurface ground conductivity, which can be converted to an effective thickness of the freshwater lens.

A good explanation of the EM34 technique is provided by Falkland (2004).

“The EM34 instrument uses two coils, a transmitter and a receiver, linked by a reference cable. The transmitter and receiver coils, held by two operators, are spaced apart at defined distances of 10 m, 20 m or 40 m, using the respective reference cables lengths. The coils can be placed either in a vertical (horizontal dipole) or horizontal (vertical dipole) position. When the transmitter is switched on, it is energised with an alternating current, which generates a primary magnetic field. This time-varying magnetic field induces small currents in the ground that generate a secondary magnetic field. The secondary magnetic field generated depends on the coil spacing, the operating frequency and the ground conductivity. Both magnetic fields are sensed by the receiver coil and a reading of apparent conductivity (or EM conductivity), based on the ratio of the secondary to the primary magnetic fields, is given. The magnitude of the ground conductivity depends on a number of factors. For coral atolls the most important factors are the porosity of unconsolidated sediments and the conductivity of pore-infilling fluids (either freshwater or saline water).” (Anthony, 1992)

A guidance note on the use of EM34, including calibration, was thoroughly prepared by GWP (2011).

### 2) Calibration

EM34 measurements used to estimate freshwater lens thickness should be calibrated against known freshwater thickness, measured from multi-depth monitoring bores. The relationship between measured EM34 apparent ground conductivity readings and known freshwater lens thickness is best represented and interpreted using a logarithmic relationship (Falkland, 2004).

Multi-depth groundwater monitoring wells are not available on Nikunau Island to allow calibration. In the absence of salinity monitoring bores specific to the investigation site, a calibration exercise was conducted at the Bonriki water reserve to approximate the field conditions expected.

One week prior to the survey, field equipment and techniques were tested and reviewed. Salinity readings and water level depths from multi-depth tubes at six (6) selected monitoring bores (BN1, BN2, BN21, BN26, BN27 and BN11) were taken to determine the freshwater lens thickness. EM34 measurements were taken at the boreholes of known salinity, using horizontal dipole (vertical coil alignment) and the 10-m and 20-m coil spacing. The apparent ground conductivity readings were then compared to the measured depth salinity to help determine the relationship between EM apparent conductivity and freshwater lens thickness. The limit of conductivity of the freshwater lens to which the EM34 readings were calibrated is 2500  $\mu\text{S}/\text{cm}$ .

To provide increased confidence in the determination of freshwater lens thickness from the EM34 measurements, three (3) calibration datasets were considered to allow comparison between results. These include:

- EM34 readings conducted at boreholes on Abatao, Tabiteuea and Bonriki in October – November during the SAPHE Project 2003 (hereafter referred to as “SAPHE 2003”) (Falkland et al., 2003);
- March 2013 results of the KIRIWATSAN Project field measurements; and
- the combined KIRIWATSAN and SAPHE datasets.

The resulting logarithmic relationship generated from each set of calibration periods were considered during the analysis to better accommodate the variances in topography, soil, water table depths, hydrogeological conditions and climatic conditions encountered in the Gilbert Island group at the time of the survey.

The three calibration datasets are presented as logarithmic curves and equations which are used to calculate freshwater thickness Figure A7-1 below.

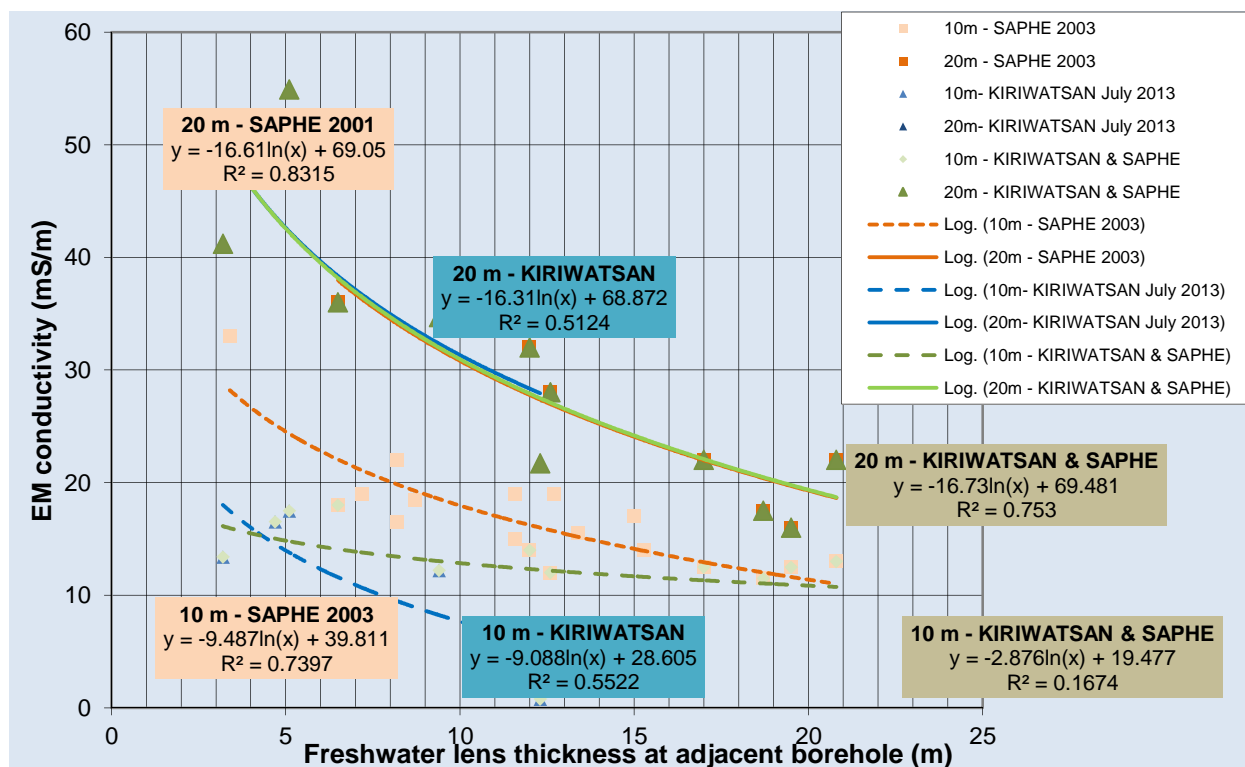


Figure A7-1. Calibration data from (1) SAPHE; (2) KIRIWATSAN; and combined (3) KIRIWATSAN & SAPHE. Note that (3) was used to estimate the freshwater lens thickness for 10-m and 20-m separations.

SAPHE 2003 data shows a good fit for Nov-2003 20 m spacing measurements, expressed by the high coefficient of determination of 0.81 ( $R^2$ ), whilst the 10 m responses showed slightly more variability and a slightly lower  $R^2$  of 0.73. The 10 m spacing result is effective in exploring areas of shallow depths (< 8 m) whereas the increasing depth of exploration from the 20 m spacing yields minor differences in conductivity measurements, making it more difficult during interpretation (Falkland, 2004 & GWP, 2011a).

KIRIWATSAN data shows a similar trend and slightly more scatter for both the 10-m and 20-m responses, expressed by a lower  $R^2$  value of 0.5, in relation to the SAPHE – 20 m. Hence, the SAPHE measurements showed a more reasonable fit due to its slightly higher  $R^2$  value. This overall low EM response generated in the KIRIWATSAN dataset may be attributable to the subsurface condition and may better represent the climatic and ground conditions prevalent during the Nikunau Island field assessment.

The combined SAPHE-KIRIWATSAN readings provided an average of both the datasets. The 20-m SAPHE-KIRIWATSAN trend showed a reasonable trend (-16.7 in relation to the other two trends) and good scatter (0.75). It is clear that the 10-m trend for SAPHE-KIRIWATSAN shows a significant low slope (-2.87 as opposed to -9.49 and -9.09 for the other two datasets) and highly scattered response (0.17 as opposed to 0.74 and 0.55 for the other two datasets). This suggests that the 10-m SAPHE-KIRIWATSAN relationship will have the least accuracy and reliability in estimating the freshwater lens thickness. Hence, it would be appropriate to utilise the following relations to estimate the freshwater lens for 10-m and 20-m readings:

- 20-m SAPHE-KIRIWATSAN relation
- 10-m SPAHE 2003 relation

Additional “rules of thumb” or practical guidance notes, used to interpret the freshwater lens thickness at each measurement point include the following:

- If both the 10-m and 20-m EM34 apparent conductivities estimate the lens to be less than 8 m, the 10-m estimate will be adopted.
- If both the 10-m and 20-m EM34 apparent conductivities estimate the lens to be more than 8 m, the 20-m estimate will be adopted.

### 3) Interpretation of results

The above mentioned logarithmic relationships, namely the 20-m SAPHE-KIRIWATSAN and 10-m SAPHE as shown on Figure A7-1, was used on all 10-m and 20-m field measurements to estimate the freshwater lens thickness, whilst the adopted lens thickness at each survey point was guided by the specific conditions and “rules of thumb”. Summary of all the survey lines in the different target villages and the maximum freshwater lens thickness readings are presented in Table A7-1. These readings are deemed inaccurate and unreliable for future fresh groundwater planning and development purposes.

### 4) Summary of findings

Anomalous responses generated in the field survey, attributable to faulty EM34 equipment, made the estimation of freshwater lens thicknesses difficult and subsequently prohibited the generation of 2.5-m contour intervals of the ground conductivity to indicate groundwater salinity less than 2500  $\mu\text{S}/\text{cm}$  – the proxy to show the spatial extent and depth variability of freshwater across the target villages.

A 2<sup>nd</sup> round of geophysical survey is recommended to determine the spatial extent and thickness of freshwater lens underneath each target village prior to any construction or rehabilitation assistance in KIRIWATSAN Phase 2.

**Table A7-1. Summary of EM34 survey lines in each target village. Note the anomalously high freshwater lens thickness readings; attributed to faulty survey equipment.**

Village	Survey No.	Date	Width of island from lagoon to ocean side (m)	Maximum estimated freshwater thickness (m)
Nikumanu	NIG1	6/08/2013	930	36.4
Nikumanu	NIG2	6/08/2013	1020	39.2
Nikumanu	NIG3	7/08/2013	870	33.1
Nikumanu	NIG4	7/08/2013	750	31.8
Nikumanu	NIG5	7/08/2013	540	31.8
Nikumanu	NIG6	7/08/2013	390	8.0
Rungata	NIG7	8/08/2013	1410	21.1
Rungata	NIG8	8/08/2013	1350	28.6
Rungata	NIG9	9/08/2013	1500	31.8
Rungata	NIG10	9/08/2013	1320	22.9
Rungata	NIG11	10/08/2013	1590	19.1
Rungata	NIG12	10/08/2013	720	5.9
Tabutoa	NIG13	12/08/2013	1740	30.5
Tabutoa	NIG14	12/08/2013	420	25.2
Tabutoa	NIG15	13/08/2013	1920	73.8
Tabutoa	NIG16	13/08/2013	900	67.5
Muribenua	NIG17	14/08/2013	1320	54.4
Muribenua	NIG18	14/08/2013	1200	59.8
Muribenua	NIG19	15/08/2013	1020	52.1
Muribenua	NIG20	15/08/2013	930	62.4
Muribenua	NIG21	15/08/2013	1440	65.7

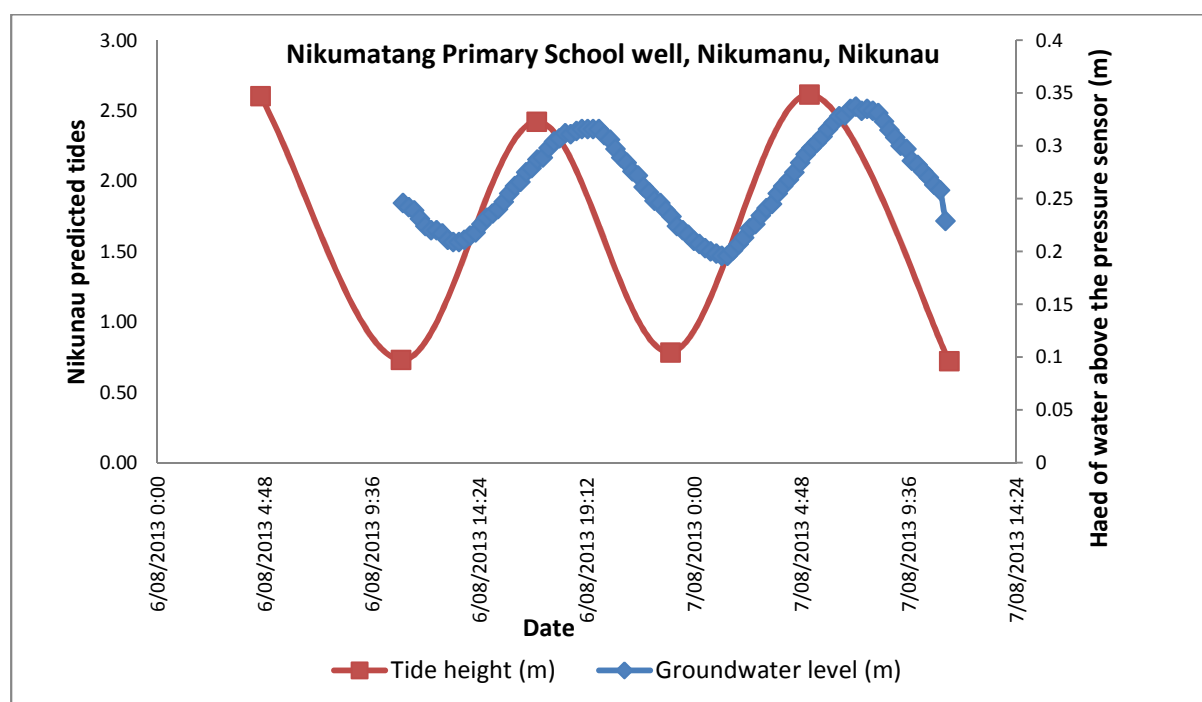
# Annex 8

## Village CTD Diver Data, Nikunau

This annex presents the salinity and water level records and graphs obtained during the real-time monitoring conducted at selected wells in certain target villages of Nikunau.

**Table A8-1. A summary of the logger data records and calculated tidal lags and efficiencies for Nikunau.**

Village	Well Owner	Diver number	Distance from closest water body, ocean or lagoon	Start Date and time	End date and time	Length of record (hrs)	Tidal lag	Tidal efficiency
Nikumanu	Nikumatang Primary School well	P5144	160	6/08/2013 11:00	7/08/2013 11:15	24.25	2.29	7%
	Awaki Head Teacher's well	K6813	110	6/08/2013 11:00	7/08/2013 12:15	25.25	2.25	7%
Rungata	Tione	K6813	105	8/08/2013 11:00	11/08/2013 8:15	69.25	1.59	15%
	Health Clinic	P5144	50	8/08/2013 11:00	11/08/2013 8:30	69.5	2.37	10%
Tabutoa	Tittu	K6813	70	12/08/2013 11:00	13/08/2013 16:30	29.5	3	10%
	Rubataake	P5144	105	12/08/2013 11:00	13/08/2013 11:30	24.5	2.45	12%
Murubenua	KPC Pastor's house	P5144	110	14/08/2013 11:00	15/08/2013 14:30	27.5	3.53	17%
	Rewii	K6813	44	14/08/2013 10:00	15/08/2013 14:15	26.25	3.25	12%
<b>Average</b>						37	2.59	11%



**Figure A8-1. Groundwater level measured at Nikumatang Primary School well in Nikumanu Village.**

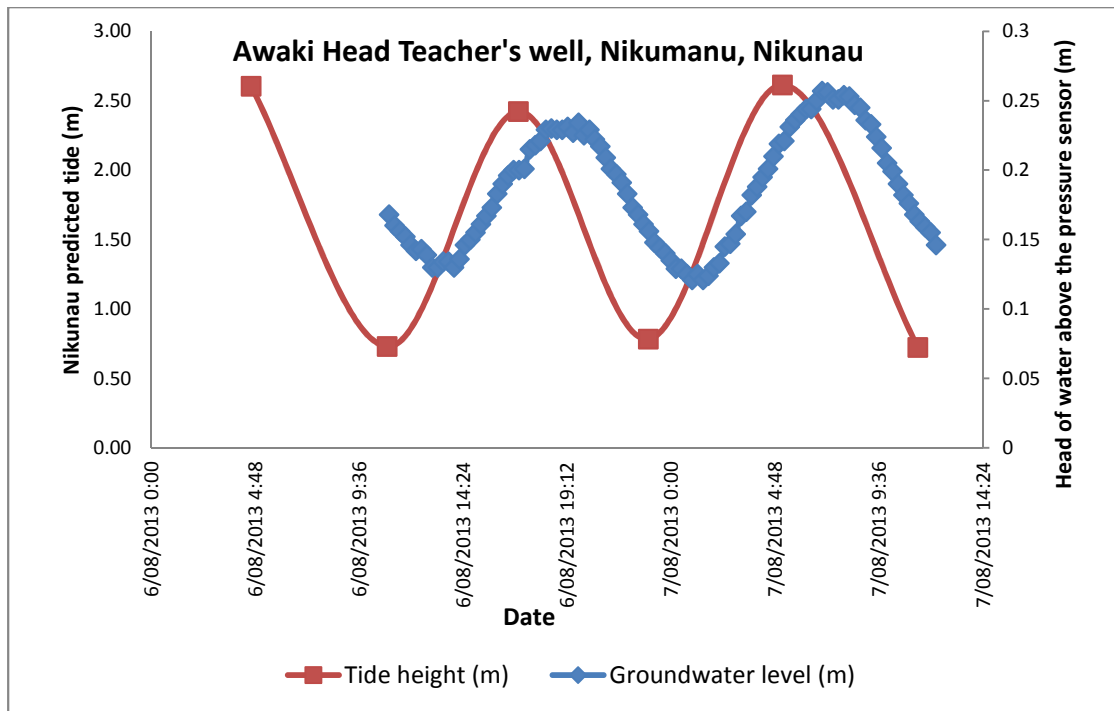


Figure A8-2. Groundwater level measured at head teacher's well in Nikumatang Primary School in Nikumanu Village.

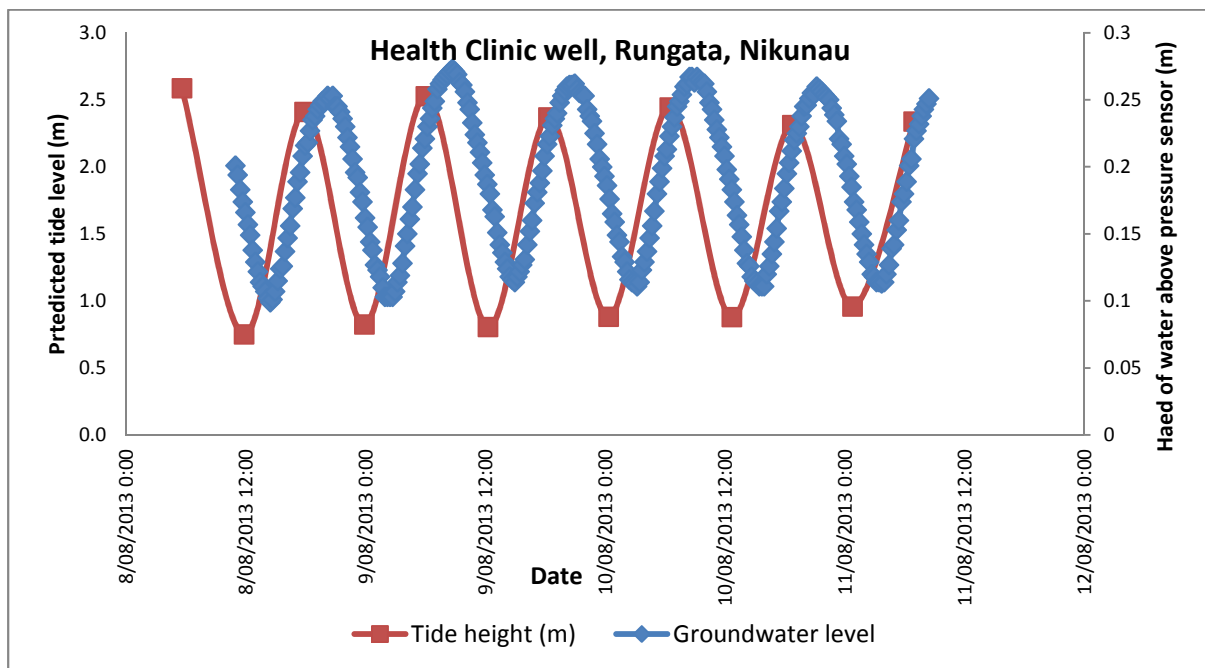


Figure A8-3. Groundwater level measured at the Health Clinic well in Rungata Village.

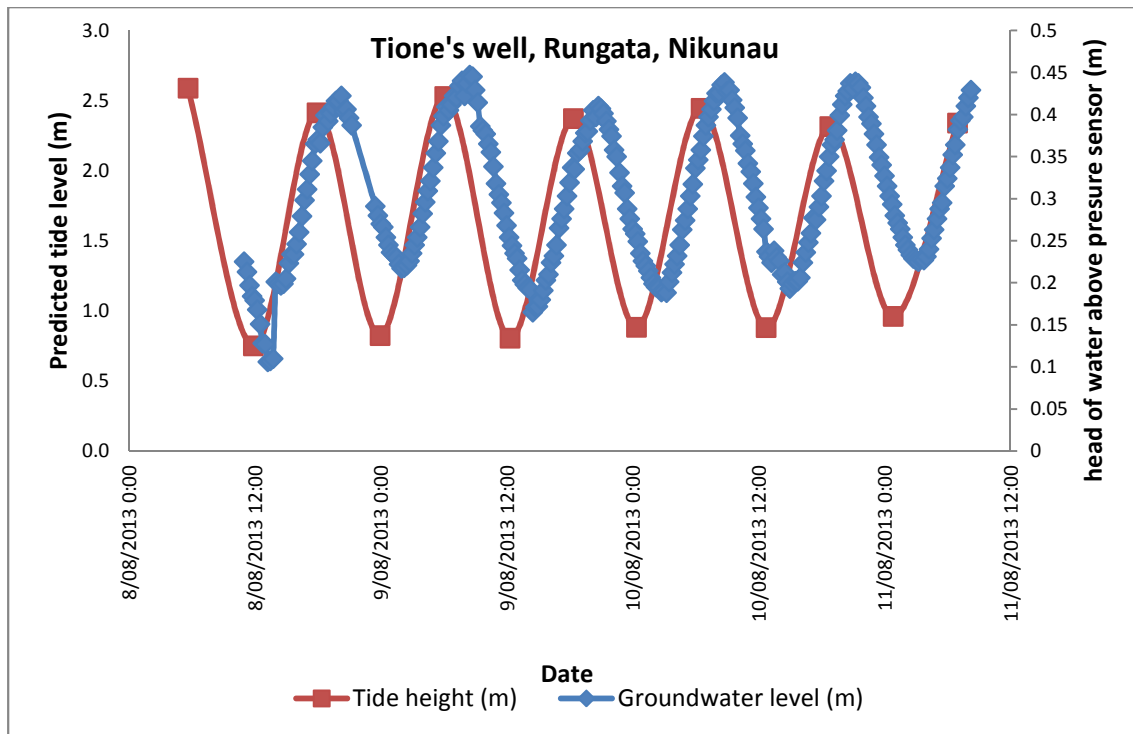


Figure A8-4. Groundwater level measured at Tione's well in Rungata Village.

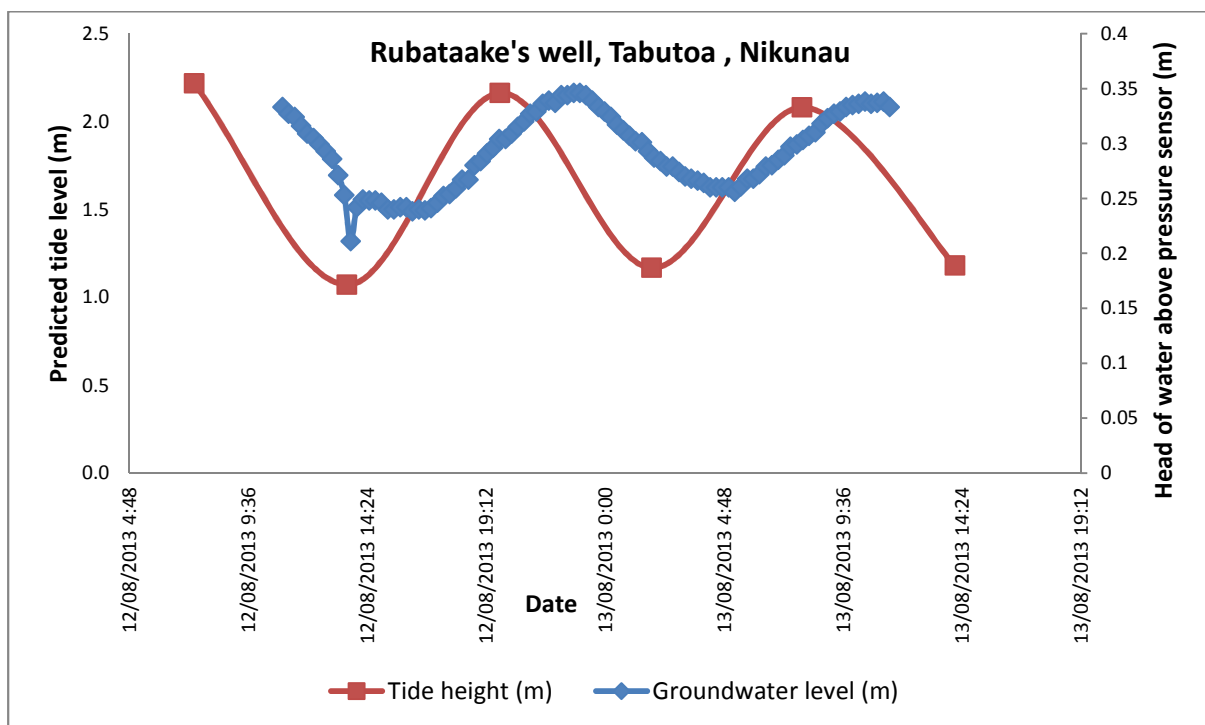


Figure A8-5. Groundwater level measured at Rubataake's well, Tabutoa Village.

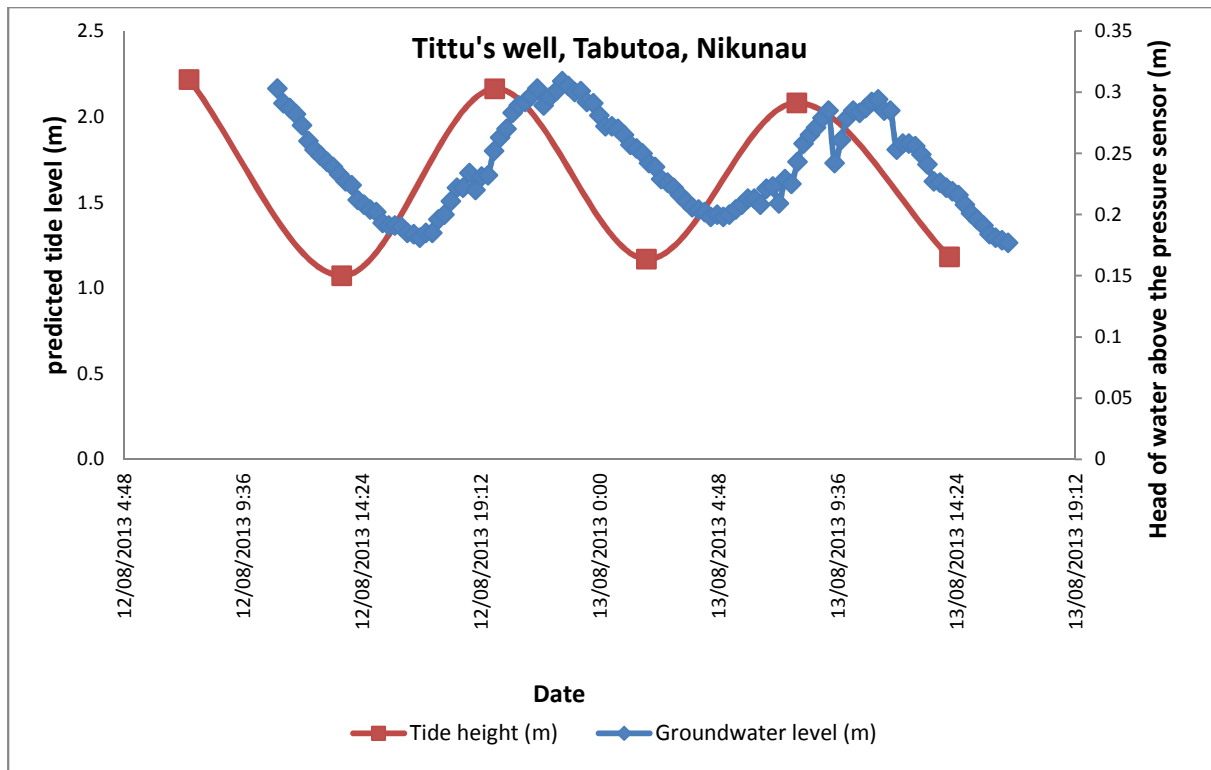


Figure A8-6. Groundwater level measured at Tittu's well, Tabutoa Village.

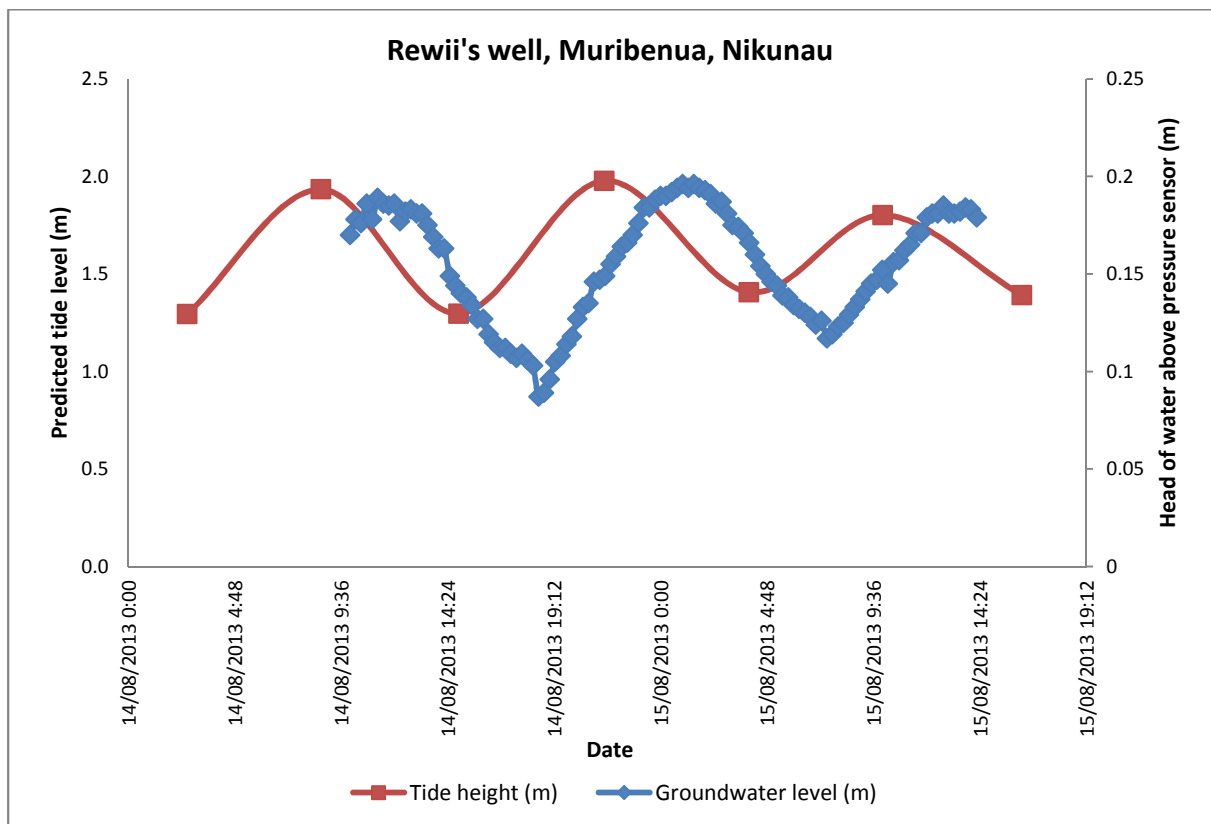


Figure A8-7. Groundwater level measured at Rewii's well, Muribenua Village.

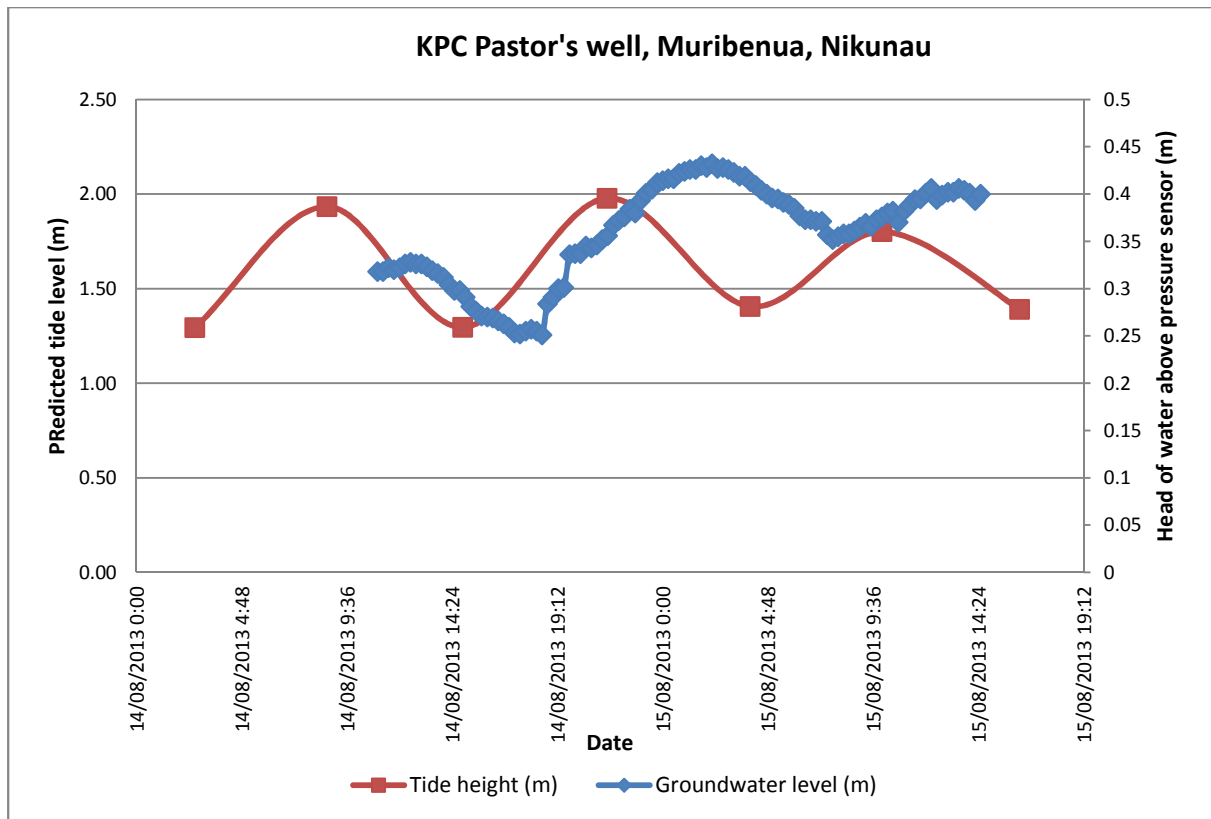


Figure A8-8. Groundwater level measured at KPC Pastor's well, Muribenua Village.

# Rainwater Harvesting Analysis Calculator & Nikunau Results

This annex presents the analysis of potential rainwater harvesting centres in all target villages in Nikunau.

The analysis relies on White’s (2010) rainfall calculator as presented in spreadsheet (Table A9-2) using the available historical monthly rainfall for Nikunau from January 1953 to December 2012.

Data on roof areas, guttering coverage and condition, and existing storage volumes of all target communal buildings were collected during the KIRIWATSAN field survey.

An effective roof area for each target communal building was calculated based on the approach by White (2010) see Table A9-1, which considers the collecting roof area and guttering condition to determine the capture efficiency for each building.

**Table A9-1. Rainwater-harvesting parameters suggested by White (2010).**

Attribute	Explanation
Building ID Number	Unique number identifying building
Type of building	Commercial, Community, Government, Other, Residential
Rain Tank Capacity (L)	$S = \text{Tank Capacity}/1000$ (L)
Roof Area (m <sup>2</sup> )	A
% Guttering	Percentage of roof edge bordered by guttering
Collecting Roof Area (m <sup>2</sup> )	$A_{col} = (\% \text{Guttering}) \times A/100$
Guttering Condition (Capture Efficiency, C, where $0 \leq C \leq 1$ )	Good (C = 0.75) Adequate (C = 0.55) Repair (C = 0.35) Replace (C = 0.15)
Effective Roof Area (m <sup>2</sup> )	$A_{eff} = C \times A_{col}$

The rainfall calculator (White, 2010) was used to determine the available water for each selected building with the following assumptions:

- No change to current roof area.
- Available water per person per day for each scenario considers an equal distribution of calculated available water amongst the entire current and predicted 2030 population.
- Effective roof area calculated incorporates guttering losses and runoff coefficient, allowing input runoff parameter C to be equal to 1 in rainwater calculator (White, 2010).
- A 84% satisfaction limit was assumed, where by the rainwater harvesting system would be able to provide the calculated volume of water per person per day for 10 out of 12 months, with a lesser amount available during the remaining two months.

The available water for each selected building was calculated for three scenarios:

1. Existing building under current catchment and storage condition with no improvements made.
2. Existing building with fully improved roof-catchment infrastructure, i.e. guttering and down pipes are in good condition with capture efficiency of 0.75 under existing roof area and existing storage volume.

3. Existing building with fully improved roof catchment infrastructure, i.e., gutters and downpipes are in good condition with a capture efficiency of 0.75 under existing roof area, and each building is supplied with an additional 20,000 L increase in storage volume)

For each scenario the combined available water that could be supplied for the identified population for all buildings was then aggregated to give an estimate of the total available water from existing suitable buildings identified for the village for both 2010 and 2030 projected populations.

It should be noted that in utilising these rainwater harvesting projections, one needs to be cautious about the in-built assumptions of the rainwater calculator (White 2010), summarised below:

1. Demand is constant irrespective of the remaining volume in the tank
2. All the interception, evaporation and leakage losses are constant irrespective of rainfall intensity
3. The capture efficiency is independent of rainfall intensity.
4. Monthly rainfall is used but the spread of rain over the months is not considered.

**Table A9-2. Rainwater calculator created by White (2010) and utilises Nikunau long-term and discontinuous monthly rainfalls from January 1953 to December 2012.**

INPUTS				RESULTS								
Catchment area	A	<input type="text" value="239"/>	m <sup>2</sup>	length of record	<input type="text" value="480"/>	months	<input type="text" value="480"/>	Overflow	<input type="text" value="#####"/>	average monthly overflow	<input type="text" value="#####"/>	litres
runoff C	C	<input type="text" value="1"/>	0.95-0.7	years	<input type="text" value="40"/>							
tank vol	S	<input type="text" value="20000"/>	litres	Reliability	<input type="text" value="0.0%"/>	(at end of month t)		Satisfaction	<input type="text" value="100%"/>	of monthly demand met on average		
Demand	D	<input type="text" value="0.022"/>	l/p/d	% (months) empty	<input type="text" value="100.0%"/>			longest	<input type="text" value="719"/>	months in a row where less than 100% demand is met		
Users	N	<input type="text" value="265"/>	0.01	% of months demand met	<input type="text" value="76.0%"/>			dry spell	<input type="text" value="719"/>	months in a row where less than 60% of demand is met		
month days	Dt	<input type="text" value="30.4333"/>		% tank full								
initial tank volume		<input type="text" value="0"/>										
NB Enter inputs into yellow boxes only. Results displayed depend on catchment area, runoff coefficient, tank volume, demand per person, and number of users												
Nikunau rainfall 1953-2012												
Month yr	Rain	Runoff (l)	I + Vt-1	Total D (O)	surplus/deficit	Storage	overflow	% of D	100%met	run	60%met	run
Jan-53	300	71700	71700	177	71523	20000	51523	100%	1	0	1	0
Feb-53	216	51624	71624	177	71447	20000	51447	100%	1	1	1	1
Mar-53	100	23900	43900	177	43723	20000	23723	100%	1	2	1	2
Apr-53	245	58555	78555	177	78378	20000	58378	100%	1	3	1	3
May-53	285	68115	88115	177	87938	20000	67938	100%	1	4	1	4
Jun-53	121	28919	48919	177	48742	20000	28742	100%	1	5	1	5
Jul-53	76	18164	38164	177	37987	20000	17987	100%	1	6	1	6
Aug-53	196	46844	66844	177	66667	20000	46667	100%	1	7	1	7
Sep-53	166	39674	59674	177	59497	20000	39497	100%	1	8	1	8

Oct-53	67	16013	36013	177	35836	20000	15836	100%	1	9	1	9
Nov-53	50	11950	31950	177	31773	20000	11773	100%	1	10	1	10
Dec-53	331	79109	99109	177	98932	20000	78932	100%	1	11	1	11
Jan-55	108	25812	45812	177	45635	20000	25635	100%	1	24	1	24
Feb-55	4	956	20956	177	20779	20000	779	100%	1	25	1	25
Mar-55	8	1912	21912	177	21735	20000	1735	100%	1	26	1	26
Apr-55	25	5975	25975	177	25798	20000	5798	100%	1	27	1	27
May-55	6	1434	21434	177	21257	20000	1257	100%	1	28	1	28
Jun-55	29	6931	26931	177	26754	20000	6754	100%	1	29	1	29
Jul-55	62	14818	34818	177	34641	20000	14641	100%	1	30	1	30
Aug-55	20	4780	24780	177	24603	20000	4603	100%	1	31	1	31
Sep-55	16	3824	23824	177	23647	20000	3647	100%	1	32	1	32
Oct-55	1	239	20239	177	20062	20000	62	100%	1	33	1	33
Nov-55	0	0	20000	177	19823	19823	0	100%	1	34	1	34
Dec-55	0	0	19823	177	19645	19645	0	100%	1	35	1	35
Jan-56	1	239	19884	177	19707	19707	0	100%	1	36	1	36
Feb-56	2	478	20185	177	20007	20000	7	100%	1	37	1	37
Mar-56	0	0	20000	177	19823	19823	0	100%	1	38	1	38
Apr-56	29	6931	26754	177	26576	20000	6576	100%	1	39	1	39
May-56	32	7648	27648	177	27471	20000	7471	100%	1	40	1	40
Jun-56	0	0	20000	177	19823	19823	0	100%	1	41	1	41
Jul-56	63	15057	34880	177	34702	20000	14702	100%	1	42	1	42
Aug-56	33	7887	27887	177	27710	20000	7710	100%	1	43	1	43
Sep-56	54	12906	32906	177	32729	20000	12729	100%	1	44	1	44
Oct-56	0	0	20000	177	19823	19823	0	100%	1	45	1	45
Nov-56	0	0	19823	177	19645	19645	0	100%	1	46	1	46
Dec-56	51	12189	31834	177	31657	20000	11657	100%	1	47	1	47
Jan-57	58	13862	33862	177	33685	20000	13685	100%	1	48	1	48
Feb-57	53	12667	32667	177	32490	20000	12490	100%	1	49	1	49
Mar-57	100	23900	43900	177	43723	20000	23723	100%	1	50	1	50
Apr-57	63	15057	35057	177	34880	20000	14880	100%	1	51	1	51
May-57	126	30114	50114	177	49937	20000	29937	100%	1	52	1	52
Jun-57	160	38240	58240	177	58063	20000	38063	100%	1	53	1	53
Jul-57	309	73851	93851	177	93674	20000	73674	100%	1	54	1	54

Aug-57	27	6453	26453	177	26276	20000	6276	100%	1	55	1	55
Sep-57	77	18403	38403	177	38226	20000	18226	100%	1	56	1	56
Oct-57	239	57121	77121	177	76944	20000	56944	100%	1	57	1	57
Nov-57	478	114242	134242	177	134065	20000	114065	100%	1	58	1	58
Dec-57	262	62618	82618	177	82441	20000	62441	100%	1	59	1	59
Jan-58	180	43020	63020	177	62843	20000	42843	100%	1	60	1	60
Feb-58	567	135513	155513	177	155336	20000	135336	100%	1	61	1	61
Mar-58	592	141488	161488	177	161311	20000	141311	100%	1	62	1	62
Apr-58	363	86757	106757	177	106580	20000	86580	100%	1	63	1	63
May-58	182	43498	63498	177	63321	20000	43321	100%	1	64	1	64
Jun-58	85	20315	40315	177	40138	20000	20138	100%	1	65	1	65
Jul-58	178	42542	62542	177	62365	20000	42365	100%	1	66	1	66
Aug-58	77	18403	38403	177	38226	20000	18226	100%	1	67	1	67
Sep-58	0	0	20000	177	19823	19823	0	100%	1	68	1	68
Oct-58	0	0	19823	177	19645	19645	0	100%	1	69	1	69
Nov-58	313	74807	94452	177	94275	20000	74275	100%	1	70	1	70
Dec-58	467	111613	131613	177	131436	20000	111436	100%	1	71	1	71
Jan-59	338	80782	100782	177	100605	20000	80605	100%	1	72	1	72
Feb-59	385	92015	112015	177	111838	20000	91838	100%	1	73	1	73
Mar-59	232	55448	75448	177	75271	20000	55271	100%	1	74	1	74
Apr-59	77	18403	38403	177	38226	20000	18226	100%	1	75	1	75
May-59	81	19359	39359	177	39182	20000	19182	100%	1	76	1	76
Jun-59	101	24139	44139	177	43962	20000	23962	100%	1	77	1	77
Jul-59	27	6453	26453	177	26276	20000	6276	100%	1	78	1	78
Aug-59	47	11233	31233	177	31056	20000	11056	100%	1	79	1	79
Sep-59	63	15057	35057	177	34880	20000	14880	100%	1	80	1	80
Oct-59	0	0	20000	177	19823	19823	0	100%	1	81	1	81
Nov-59	104	24856	44679	177	44501	20000	24501	100%	1	82	1	82
Dec-59	0	0	20000	177	19823	19823	0	100%	1	83	1	83
Jan-60	188	44932	64755	177	64577	20000	44577	100%	1	84	1	84
Feb-60	149	35611	55611	177	55434	20000	35434	100%	1	85	1	85
Mar-60	26	6214	26214	177	26037	20000	6037	100%	1	86	1	86
Apr-60	93	22227	42227	177	42050	20000	22050	100%	1	87	1	87
May-60	0	0	20000	177	19823	19823	0	100%	1	88	1	88

Jun-60	5	1195	21018	177	20840	20000	840	100%	1	89	1	89
Jul-60	37	8843	28843	177	28666	20000	8666	100%	1	90	1	90
Aug-60	0	0	20000	177	19823	19823	0	100%	1	91	1	91
Sep-60	13	3107	22930	177	22752	20000	2752	100%	1	92	1	92
Oct-60	56	13384	33384	177	33207	20000	13207	100%	1	93	1	93
Nov-60	31	7409	27409	177	27232	20000	7232	100%	1	94	1	94
Dec-60	177	42303	62303	177	62126	20000	42126	100%	1	95	1	95
Jan-61	149	35611	55611	177	55434	20000	35434	100%	1	96	1	96
Feb-61	18	4302	24302	177	24125	20000	4125	100%	1	97	1	97
Mar-61	168	40152	60152	177	59975	20000	39975	100%	1	98	1	98
Apr-61	78	18642	38642	177	38465	20000	18465	100%	1	99	1	99
May-61	48	11472	31472	177	31295	20000	11295	100%	1	100	1	100
Jun-61	83	19837	39837	177	39660	20000	19660	100%	1	101	1	101
Jul-61	84	20076	40076	177	39899	20000	19899	100%	1	102	1	102
Aug-61	74	17686	37686	177	37509	20000	17509	100%	1	103	1	103
Sep-61	24	5736	25736	177	25559	20000	5559	100%	1	104	1	104
Oct-61	20	4780	24780	177	24603	20000	4603	100%	1	105	1	105
Nov-61	8	1912	21912	177	21735	20000	1735	100%	1	106	1	106
Dec-61	0	0	20000	177	19823	19823	0	100%	1	107	1	107
Jan-62	0	0	19823	177	19645	19645	0	100%	1	108	1	108
Feb-62	0	0	19645	177	19468	19468	0	100%	1	109	1	109
Mar-62	57	13623	33091	177	32913	20000	12913	100%	1	110	1	110
Apr-62	9	2151	22151	177	21974	20000	1974	100%	1	111	1	111
May-62	0	0	20000	177	19823	19823	0	100%	1	112	1	112
Jun-62	12	2868	22691	177	22513	20000	2513	100%	1	113	1	113
Jul-62	132	31548	51548	177	51371	20000	31371	100%	1	114	1	114
Aug-62	115	27485	47485	177	47308	20000	27308	100%	1	115	1	115
Sep-62	6	1434	21434	177	21257	20000	1257	100%	1	116	1	116
Oct-62	0	0	20000	177	19823	19823	0	100%	1	117	1	117
Nov-62	16	3824	23647	177	23469	20000	3469	100%	1	118	1	118
Dec-62	24	5736	25736	177	25559	20000	5559	100%	1	119	1	119
Jan-63	43	10277	30277	177	30100	20000	10100	100%	1	120	1	120
Feb-63	9	2151	22151	177	21974	20000	1974	100%	1	121	1	121
Mar-63	83	19837	39837	177	39660	20000	19660	100%	1	122	1	122

Apr-63	14	3346	23346	177	23169	20000	3169	100%	1	123	1	123
May-63	0	0	20000	177	19823	19823	0	100%	1	124	1	124
Jun-63	31	7409	27232	177	27054	20000	7054	100%	1	125	1	125
Jul-63	33	7887	27887	177	27710	20000	7710	100%	1	126	1	126
Aug-63	114	27246	47246	177	47069	20000	27069	100%	1	127	1	127
Sep-63	29	6931	26931	177	26754	20000	6754	100%	1	128	1	128
Oct-63	312	74568	94568	177	94391	20000	74391	100%	1	129	1	129
Nov-63	211	50429	70429	177	70252	20000	50252	100%	1	130	1	130
Dec-63	496	118544	138544	177	138367	20000	118367	100%	1	131	1	131
Jan-64	278	66442	86442	177	86265	20000	66265	100%	1	132	1	132
Feb-64	402	96078	116078	177	115901	20000	95901	100%	1	133	1	133
Mar-64	28	6692	26692	177	26515	20000	6515	100%	1	134	1	134
Apr-64	0	0	20000	177	19823	19823	0	100%	1	135	1	135
May-64	27	6453	26276	177	26098	20000	6098	100%	1	136	1	136
Jun-64	52	12428	32428	177	32251	20000	12251	100%	1	137	1	137
Jul-64	13	3107	23107	177	22930	20000	2930	100%	1	138	1	138
Aug-64	128	30592	50592	177	50415	20000	30415	100%	1	139	1	139
Sep-64	24	5736	25736	177	25559	20000	5559	100%	1	140	1	140
Oct-64	0	0	20000	177	19823	19823	0	100%	1	141	1	141
Nov-64	39	9321	29144	177	28966	20000	8966	100%	1	142	1	142
Dec-64	162	38718	58718	177	58541	20000	38541	100%	1	143	1	143
Jan-65	346	82694	102694	177	102517	20000	82517	100%	1	144	1	144
Feb-65	289	69071	89071	177	88894	20000	68894	100%	1	145	1	145
Mar-65	128	30592	50592	177	50415	20000	30415	100%	1	146	1	146
Apr-65	239	57121	77121	177	76944	20000	56944	100%	1	147	1	147
May-65	199	47561	67561	177	67384	20000	47384	100%	1	148	1	148
Jun-65	90	21510	41510	177	41333	20000	21333	100%	1	149	1	149
Jul-65	481	114959	134959	177	134782	20000	114782	100%	1	150	1	150
Aug-65	198	47322	67322	177	67145	20000	47145	100%	1	151	1	151
Sep-65	240	57360	77360	177	77183	20000	57183	100%	1	152	1	152
Oct-65	467	111613	131613	177	131436	20000	111436	100%	1	153	1	153
Nov-65	220	52580	72580	177	72403	20000	52403	100%	1	154	1	154
Dec-65	225	53775	73775	177	73598	20000	53598	100%	1	155	1	155
Jan-66	534	127626	147626	177	147449	20000	127449	100%	1	156	1	156

Feb-66	363	86757	106757	177	106580	20000	86580	100%	1	157	1	157
Mar-66	248	59272	79272	177	79095	20000	59095	100%	1	158	1	158
Apr-66	93	22227	42227	177	42050	20000	22050	100%	1	159	1	159
May-66	85	20315	40315	177	40138	20000	20138	100%	1	160	1	160
Jun-66	6	1434	21434	177	21257	20000	1257	100%	1	161	1	161
Jul-66	195	46605	66605	177	66428	20000	46428	100%	1	162	1	162
Aug-66	32	7648	27648	177	27471	20000	7471	100%	1	163	1	163
Sep-66	28	6692	26692	177	26515	20000	6515	100%	1	164	1	164
Oct-66	51	12189	32189	177	32012	20000	12012	100%	1	165	1	165
Nov-66	48	11472	31472	177	31295	20000	11295	100%	1	166	1	166
Dec-66	37	8843	28843	177	28666	20000	8666	100%	1	167	1	167
Jan-67	20	4780	24780	177	24603	20000	4603	100%	1	168	1	168
Feb-67	3	717	20717	177	20540	20000	540	100%	1	169	1	169
Mar-67	31	7409	27409	177	27232	20000	7232	100%	1	170	1	170
Apr-67	77	18403	38403	177	38226	20000	18226	100%	1	171	1	171
May-67	4	956	20956	177	20779	20000	779	100%	1	172	1	172
Jun-67	43	10277	30277	177	30100	20000	10100	100%	1	173	1	173
Jul-67	4	956	20956	177	20779	20000	779	100%	1	174	1	174
Aug-67	67	16013	36013	177	35836	20000	15836	100%	1	175	1	175
Sep-67	0	0	20000	177	19823	19823	0	100%	1	176	1	176
Oct-67	9	2151	21974	177	21796	20000	1796	100%	1	177	1	177
Nov-67	50	11950	31950	177	31773	20000	11773	100%	1	178	1	178
Dec-67	341	81499	101499	177	101322	20000	81322	100%	1	179	1	179
Jan-68	245	58555	78555	177	78378	20000	58378	100%	1	180	1	180
Feb-68	147	35133	55133	177	54956	20000	34956	100%	1	181	1	181
Mar-68	11	2629	22629	177	22452	20000	2452	100%	1	182	1	182
Apr-68	58	13862	33862	177	33685	20000	13685	100%	1	183	1	183
May-68	0	0	20000	177	19823	19823	0	100%	1	184	1	184
Jun-68	0	0	19823	177	19645	19645	0	100%	1	185	1	185
Jul-68	20	4780	24425	177	24248	20000	4248	100%	1	186	1	186
Aug-68	6	1434	21434	177	21257	20000	1257	100%	1	187	1	187
Sep-68	0	0	20000	177	19823	19823	0	100%	1	188	1	188
Oct-68	0	0	19823	177	19645	19645	0	100%	1	189	1	189
Nov-68	41	9799	29444	177	29267	20000	9267	100%	1	190	1	190

Dec-68	234	55926	75926	177	75749	20000	55749	100%	1	191	1	191
Jan-69	380	90820	110820	177	110643	20000	90643	100%	1	192	1	192
Feb-69	264	63096	83096	177	82919	20000	62919	100%	1	193	1	193
Mar-69	212	50668	70668	177	70491	20000	50491	100%	1	194	1	194
Apr-69	52	12428	32428	177	32251	20000	12251	100%	1	195	1	195
May-69	25	5975	25975	177	25798	20000	5798	100%	1	196	1	196
Jun-69	207	49473	69473	177	69296	20000	49296	100%	1	197	1	197
Jul-69	10	2390	22390	177	22213	20000	2213	100%	1	198	1	198
Aug-69	72	17208	37208	177	37031	20000	17031	100%	1	199	1	199
Sep-69	46	10994	30994	177	30817	20000	10817	100%	1	200	1	200
Oct-69	22	5258	25258	177	25081	20000	5081	100%	1	201	1	201
Nov-69	6	1434	21434	177	21257	20000	1257	100%	1	202	1	202
Dec-69	104	24856	44856	177	44679	20000	24679	100%	1	203	1	203
Jan-70	321	76719	96719	177	96542	20000	76542	100%	1	204	1	204
Feb-70	128	30592	50592	177	50415	20000	30415	100%	1	205	1	205
Mar-70	175	41825	61825	177	61648	20000	41648	100%	1	206	1	206
Apr-70	171	40869	60869	177	60692	20000	40692	100%	1	207	1	207
May-70	0	0	20000	177	19823	19823	0	100%	1	208	1	208
Jun-70	13	3107	22930	177	22752	20000	2752	100%	1	209	1	209
Jul-70	83	19837	39837	177	39660	20000	19660	100%	1	210	1	210
Aug-70	178	42542	62542	177	62365	20000	42365	100%	1	211	1	211
Sep-70	0	0	20000	177	19823	19823	0	100%	1	212	1	212
Oct-70	0	0	19823	177	19645	19645	0	100%	1	213	1	213
Nov-70	0	0	19645	177	19468	19468	0	100%	1	214	1	214
Dec-70	0	0	19468	177	19290	19290	0	100%	1	215	1	215
Jan-71	0	0	19290	177	19113	19113	0	100%	1	216	1	216
Feb-71	0	0	19113	177	18935	18935	0	100%	1	217	1	217
Mar-71	0	0	18935	177	18758	18758	0	100%	1	218	1	218
Apr-71	2	478	19236	177	19059	19059	0	100%	1	219	1	219
May-71	47	11233	30292	177	30114	20000	10114	100%	1	220	1	220
Jun-71	56	13384	33384	177	33207	20000	13207	100%	1	221	1	221
Jul-71	56	13384	33384	177	33207	20000	13207	100%	1	222	1	222
Aug-71	3	717	20717	177	20540	20000	540	100%	1	223	1	223
Sep-71	8	1912	21912	177	21735	20000	1735	100%	1	224	1	224

Oct-71	27	6453	26453	177	26276	20000	6276	100%	1	225	1	225
Nov-71	144	34416	54416	177	54239	20000	34239	100%	1	226	1	226
Dec-71	26	6214	26214	177	26037	20000	6037	100%	1	227	1	227
Jan-72	275	65725	85725	177	85548	20000	65548	100%	1	228	1	228
Feb-72	117	27963	47963	177	47786	20000	27786	100%	1	229	1	229
Mar-72	30	7170	27170	177	26993	20000	6993	100%	1	230	1	230
Apr-72	138	32982	52982	177	52805	20000	32805	100%	1	231	1	231
May-72	514	122846	142846	177	142669	20000	122669	100%	1	232	1	232
Jun-72	256	61184	81184	177	81007	20000	61007	100%	1	233	1	233
Jul-72	424	101336	121336	177	121159	20000	101159	100%	1	234	1	234
Aug-72	390	93210	113210	177	113033	20000	93033	100%	1	235	1	235
Sep-72	439	104921	124921	177	124744	20000	104744	100%	1	236	1	236
Oct-72	409	97751	117751	177	117574	20000	97574	100%	1	237	1	237
Nov-72	327	78153	98153	177	97976	20000	77976	100%	1	238	1	238
Dec-72	242	57838	77838	177	77661	20000	57661	100%	1	239	1	239
Jan-73	343	81977	101977	177	101800	20000	81800	100%	1	240	1	240
Feb-73	268	64052	84052	177	83875	20000	63875	100%	1	241	1	241
Mar-73	311	74329	94329	177	94152	20000	74152	100%	1	242	1	242
Apr-73	46	10994	30994	177	30817	20000	10817	100%	1	243	1	243
May-73	30	7170	27170	177	26993	20000	6993	100%	1	244	1	244
Jun-73	14	3346	23346	177	23169	20000	3169	100%	1	245	1	245
Jul-73	15	3585	23585	177	23408	20000	3408	100%	1	246	1	246
Aug-73	18	4302	24302	177	24125	20000	4125	100%	1	247	1	247
Sep-73	18	4302	24302	177	24125	20000	4125	100%	1	248	1	248
Oct-73	1	239	20239	177	20062	20000	62	100%	1	249	1	249
Nov-73	0	0	20000	177	19823	19823	0	100%	1	250	1	250
Dec-73	0	0	19823	177	19645	19645	0	100%	1	251	1	251
Jan-74	0	0	19645	177	19468	19468	0	100%	1	252	1	252
Feb-74	11	2629	22097	177	21919	20000	1919	100%	1	253	1	253
Mar-74	0	0	20000	177	19823	19823	0	100%	1	254	1	254
Apr-74	0	0	19823	177	19645	19645	0	100%	1	255	1	255
May-74	390	93210	112855	177	112678	20000	92678	100%	1	256	1	256
Jun-74	354	84606	104606	177	104429	20000	84429	100%	1	257	1	257
Jul-74	61	14579	34579	177	34402	20000	14402	100%	1	258	1	258

Aug-74	99	23661	43661	177	43484	20000	23484	100%	1	259	1	259
Sep-74	13	3107	23107	177	22930	20000	2930	100%	1	260	1	260
Oct-74	52	12428	32428	177	32251	20000	12251	100%	1	261	1	261
Nov-74	12	2868	22868	177	22691	20000	2691	100%	1	262	1	262
Dec-74	426	101814	121814	177	121637	20000	101637	100%	1	263	1	263
Jan-75	265	63335	83335	177	83158	20000	63158	100%	1	264	1	264
Feb-75	30	7170	27170	177	26993	20000	6993	100%	1	265	1	265
Mar-75	50	11950	31950	177	31773	20000	11773	100%	1	266	1	266
Apr-75	121	28919	48919	177	48742	20000	28742	100%	1	267	1	267
May-75	26	6214	26214	177	26037	20000	6037	100%	1	268	1	268
Jun-75	191	45649	65649	177	65472	20000	45472	100%	1	269	1	269
Jul-75	29	6931	26931	177	26754	20000	6754	100%	1	270	1	270
Aug-75		0	20000	177	19823	19823	0	100%	1	271	1	271
Sep-75	0	0	19823	177	19645	19645	0	100%	1	272	1	272
Oct-75	0	0	19645	177	19468	19468	0	100%	1	273	1	273
Nov-75	0	0	19468	177	19290	19290	0	100%	1	274	1	274
Dec-75	0	0	19290	177	19113	19113	0	100%	1	275	1	275
Jan-76	8	1912	21025	177	20847	20000	847	100%	1	276	1	276
Feb-76	16	3824	23824	177	23647	20000	3647	100%	1	277	1	277
Mar-76	122	29158	49158	177	48981	20000	28981	100%	1	278	1	278
Apr-76	112	26768	46768	177	46591	20000	26591	100%	1	279	1	279
May-76	228	54492	74492	177	74315	20000	54315	100%	1	280	1	280
Jun-76	224	53536	73536	177	73359	20000	53359	100%	1	281	1	281
Jul-76	247	59033	79033	177	78856	20000	58856	100%	1	282	1	282
Aug-76	395	94405	114405	177	114228	20000	94228	100%	1	283	1	283
Sep-76	373	89147	109147	177	108970	20000	88970	100%	1	284	1	284
Oct-76	218	52102	72102	177	71925	20000	51925	100%	1	285	1	285
Nov-76	46	10994	30994	177	30817	20000	10817	100%	1	286	1	286
Dec-76	175	41825	61825	177	61648	20000	41648	100%	1	287	1	287
Jan-77	391	93449	113449	177	113272	20000	93272	100%	1	288	1	288
Feb-77	133	31787	51787	177	51610	20000	31610	100%	1	289	1	289
Mar-77	463	110657	130657	177	130480	20000	110480	100%	1	290	1	290
Apr-77	205	48995	68995	177	68818	20000	48818	100%	1	291	1	291
May-77	49	11711	31711	177	31534	20000	11534	100%	1	292	1	292

Jun-77	49	11711	31711	177	31534	20000	11534	100%	1	293	1	293
Jul-77	86	20554	40554	177	40377	20000	20377	100%	1	294	1	294
Aug-77	116	27724	47724	177	47547	20000	27547	100%	1	295	1	295
Sep-77	151	36089	56089	177	55912	20000	35912	100%	1	296	1	296
Oct-77	98	23422	43422	177	43245	20000	23245	100%	1	297	1	297
Nov-77	255	60945	80945	177	80768	20000	60768	100%	1	298	1	298
Dec-77	440	105160	125160	177	124983	20000	104983	100%	1	299	1	299
Jan-78	509	121651	141651	177	141474	20000	121474	100%	1	300	1	300
Feb-78	345	82455	102455	177	102278	20000	82278	100%	1	301	1	301
Mar-78		0	20000	177	19823	19823	0	100%	1	302	1	302
Apr-78	42	10038	29861	177	29683	20000	9683	100%	1	303	1	303
May-78		0	20000	177	19823	19823	0	100%	1	304	1	304
Jun-78		0	19823	177	19645	19645	0	100%	1	305	1	305
Jul-78		0	19645	177	19468	19468	0	100%	1	306	1	306
Aug-78		0	19468	177	19290	19290	0	100%	1	307	1	307
Sep-78	27	6453	25743	177	25566	20000	5566	100%	1	308	1	308
Oct-78	9	2151	22151	177	21974	20000	1974	100%	1	309	1	309
Nov-78	0	0	20000	177	19823	19823	0	100%	1	310	1	310
Dec-78	134	32026	51849	177	51671	20000	31671	100%	1	311	1	311
Jan-79	674	161086	181086	177	180909	20000	160909	100%	1	312	1	312
Feb-79	337	80543	100543	177	100366	20000	80366	100%	1	313	1	313
Mar-79	406	97034	117034	177	116857	20000	96857	100%	1	314	1	314
Apr-79	18	4302	24302	177	24125	20000	4125	100%	1	315	1	315
May-79	226	54014	74014	177	73837	20000	53837	100%	1	316	1	316
Jun-79	223	53297	73297	177	73120	20000	53120	100%	1	317	1	317
Jul-79	94	22466	42466	177	42289	20000	22289	100%	1	318	1	318
Aug-79	65	15535	35535	177	35358	20000	15358	100%	1	319	1	319
Sep-79	31	7409	27409	177	27232	20000	7232	100%	1	320	1	320
Oct-79	199	47561	67561	177	67384	20000	47384	100%	1	321	1	321
Nov-79	246	58794	78794	177	78617	20000	58617	100%	1	322	1	322
Dec-79	723	172797	192797	177	192620	20000	172620	100%	1	323	1	323
Jan-80	155	37045	57045	177	56868	20000	36868	100%	1	324	1	324
Feb-80	222	53058	73058	177	72881	20000	52881	100%	1	325	1	325
Mar-80	366	87474	107474	177	107297	20000	87297	100%	1	326	1	326

Apr-80	468	111852	131852	177	131675	20000	111675	100%	1	327	1	327
May-80	241	57599	77599	177	77422	20000	57422	100%	1	328	1	328
Jun-80	254	60706	80706	177	80529	20000	60529	100%	1	329	1	329
Jul-80	660	157740	177740	177	177563	20000	157563	100%	1	330	1	330
Aug-80	321	76719	96719	177	96542	20000	76542	100%	1	331	1	331
Sep-80		0	20000	177	19823	19823	0	100%	1	332	1	332
Oct-80	0	0	19823	177	19645	19645	0	100%	1	333	1	333
Nov-80		0	19645	177	19468	19468	0	100%	1	334	1	334
Dec-80		0	19468	177	19290	19290	0	100%	1	335	1	335
Jan-81	63	15057	34347	177	34170	20000	14170	100%	1	336	1	336
Feb-81	80	19120	39120	177	38943	20000	18943	100%	1	337	1	337
Mar-81	410	97990	117990	177	117813	20000	97813	100%	1	338	1	338
Apr-81	397	94883	114883	177	114706	20000	94706	100%	1	339	1	339
May-81	64	15296	35296	177	35119	20000	15119	100%	1	340	1	340
Jun-81	54	12906	32906	177	32729	20000	12729	100%	1	341	1	341
Jul-81		0	20000	177	19823	19823	0	100%	1	342	1	342
Aug-81		0	19823	177	19645	19645	0	100%	1	343	1	343
Sep-81	79	18881	38526	177	38349	20000	18349	100%	1	344	1	344
Oct-81		0	20000	177	19823	19823	0	100%	1	345	1	345
Nov-81		0	19823	177	19645	19645	0	100%	1	346	1	346
Dec-81		0	19645	177	19468	19468	0	100%	1	347	1	347
Jan-82	0	0	19468	177	19290	19290	0	100%	1	348	1	348
Feb-82	18	4302	23592	177	23415	20000	3415	100%	1	349	1	349
Mar-82	0	0	20000	177	19823	19823	0	100%	1	350	1	350
Apr-82	97	23183	43006	177	42828	20000	22828	100%	1	351	1	351
May-82	128	30592	50592	177	50415	20000	30415	100%	1	352	1	352
Jun-82		0	20000	177	19823	19823	0	100%	1	353	1	353
Jul-82		0	19823	177	19645	19645	0	100%	1	354	1	354
Aug-82		0	19645	177	19468	19468	0	100%	1	355	1	355
Sep-82		0	19468	177	19290	19290	0	100%	1	356	1	356
Oct-82		0	19290	177	19113	19113	0	100%	1	357	1	357
Nov-82		0	19113	177	18935	18935	0	100%	1	358	1	358
Dec-82	77	18403	37338	177	37161	20000	17161	100%	1	359	1	359
Jan-83	154	36806	56806	177	56629	20000	36629	100%	1	360	1	360

Feb-83	101	24139	44139	177	43962	20000	23962	100%	1	361	1	361
Mar-83	25	5975	25975	177	25798	20000	5798	100%	1	362	1	362
Apr-83	64	15296	35296	177	35119	20000	15119	100%	1	363	1	363
May-83	214	51146	71146	177	70969	20000	50969	100%	1	364	1	364
Jun-83	378	90342	110342	177	110165	20000	90165	100%	1	365	1	365
Jul-83	120	28680	48680	177	48503	20000	28503	100%	1	366	1	366
Aug-83	55	13145	33145	177	32968	20000	12968	100%	1	367	1	367
Sep-83	8	1912	21912	177	21735	20000	1735	100%	1	368	1	368
Oct-83	0	0	20000	177	19823	19823	0	100%	1	369	1	369
Nov-83	2	478	20301	177	20123	20000	123	100%	1	370	1	370
Dec-83	31	7409	27409	177	27232	20000	7232	100%	1	371	1	371
Jan-84	20	4780	24780	177	24603	20000	4603	100%	1	372	1	372
Feb-84	15	3585	23585	177	23408	20000	3408	100%	1	373	1	373
Mar-84	0	0	20000	177	19823	19823	0	100%	1	374	1	374
Apr-84	72	17208	37031	177	36853	20000	16853	100%	1	375	1	375
May-84	19	4541	24541	177	24364	20000	4364	100%	1	376	1	376
Jun-84	24	5736	25736	177	25559	20000	5559	100%	1	377	1	377
Jul-84	75	17925	37925	177	37748	20000	17748	100%	1	378	1	378
Aug-84	29	6931	26931	177	26754	20000	6754	100%	1	379	1	379
Sep-84	38	9082	29082	177	28905	20000	8905	100%	1	380	1	380
Oct-84		0	20000	177	19823	19823	0	100%	1	381	1	381
Nov-84	10	2390	22213	177	22035	20000	2035	100%	1	382	1	382
Dec-84		0	20000	177	19823	19823	0	100%	1	383	1	383
Jan-85		0	19823	177	19645	19645	0	100%	1	384	1	384
Feb-85		0	19645	177	19468	19468	0	100%	1	385	1	385
Mar-85		0	19468	177	19290	19290	0	100%	1	386	1	386
Apr-85		0	19290	177	19113	19113	0	100%	1	387	1	387
May-85		0	19113	177	18935	18935	0	100%	1	388	1	388
Jun-85		0	18935	177	18758	18758	0	100%	1	389	1	389
Jul-85		0	18758	177	18581	18581	0	100%	1	390	1	390
Aug-85		0	18581	177	18403	18403	0	100%	1	391	1	391
Sep-85		0	18403	177	18226	18226	0	100%	1	392	1	392
Oct-85		0	18226	177	18048	18048	0	100%	1	393	1	393
Nov-85		0	18048	177	17871	17871	0	100%	1	394	1	394

Dec-85		0	17871	177	17693	17693	0	100%	1	395	1	395
Jan-86	20	4780	22473	177	22296	20000	2296	100%	1	396	1	396
Feb-86		0	20000	177	19823	19823	0	100%	1	397	1	397
Mar-86		0	19823	177	19645	19645	0	100%	1	398	1	398
Apr-86	0	0	19645	177	19468	19468	0	100%	1	399	1	399
May-86	21	5019	24487	177	24309	20000	4309	100%	1	400	1	400
Jun-86		0	20000	177	19823	19823	0	100%	1	401	1	401
Jul-86		0	19823	177	19645	19645	0	100%	1	402	1	402
Aug-86		0	19645	177	19468	19468	0	100%	1	403	1	403
Sep-86		0	19468	177	19290	19290	0	100%	1	404	1	404
Oct-86	163	38957	58247	177	58070	20000	38070	100%	1	405	1	405
Nov-86	362	86518	106518	177	106341	20000	86341	100%	1	406	1	406
Dec-86	350	83650	103650	177	103473	20000	83473	100%	1	407	1	407
Jan-87		0	20000	177	19823	19823	0	100%	1	408	1	408
Feb-87	308	73612	93435	177	93257	20000	73257	100%	1	409	1	409
Mar-87		0	20000	177	19823	19823	0	100%	1	410	1	410
Apr-87	126	30114	49937	177	49759	20000	29759	100%	1	411	1	411
May-87	136	32504	52504	177	52327	20000	32327	100%	1	412	1	412
Jun-87	402	96078	116078	177	115901	20000	95901	100%	1	413	1	413
Jul-87	372	88908	108908	177	108731	20000	88731	100%	1	414	1	414
Aug-87	226	54014	74014	177	73837	20000	53837	100%	1	415	1	415
Sep-87	120	28680	48680	177	48503	20000	28503	100%	1	416	1	416
Oct-87	153	36567	56567	177	56390	20000	36390	100%	1	417	1	417
Nov-87	141	33699	53699	177	53522	20000	33522	100%	1	418	1	418
Dec-87	404	96556	116556	177	116379	20000	96379	100%	1	419	1	419
Jan-88	326	77914	97914	177	97737	20000	77737	100%	1	420	1	420
Feb-88	206	49234	69234	177	69057	20000	49057	100%	1	421	1	421
Mar-88	84	20076	40076	177	39899	20000	19899	100%	1	422	1	422
Apr-88	116	27724	47724	177	47547	20000	27547	100%	1	423	1	423
May-88	156	37284	57284	177	57107	20000	37107	100%	1	424	1	424
Jun-88	56	13384	33384	177	33207	20000	13207	100%	1	425	1	425
Jul-88	22	5258	25258	177	25081	20000	5081	100%	1	426	1	426
Aug-88		0	20000	177	19823	19823	0	100%	1	427	1	427
Sep-88		0	19823	177	19645	19645	0	100%	1	428	1	428

Oct-88		0	19645	177	19468	19468	0	100%	1	429	1	429
Nov-88		0	19468	177	19290	19290	0	100%	1	430	1	430
Dec-88		0	19290	177	19113	19113	0	100%	1	431	1	431
Jan-89		0	19113	177	18935	18935	0	100%	1	432	1	432
Feb-89		0	18935	177	18758	18758	0	100%	1	433	1	433
Mar-89	4	956	19714	177	19537	19537	0	100%	1	434	1	434
Apr-89		0	19537	177	19359	19359	0	100%	1	435	1	435
May-89	3	717	20076	177	19899	19899	0	100%	1	436	1	436
Jun-89		0	19899	177	19721	19721	0	100%	1	437	1	437
Jul-89	7	1673	21394	177	21217	20000	1217	100%	1	438	1	438
Aug-89	20	4780	24780	177	24603	20000	4603	100%	1	439	1	439
Sep-89	86	20554	40554	177	40377	20000	20377	100%	1	440	1	440
Oct-89	24	5736	25736	177	25559	20000	5559	100%	1	441	1	441
Nov-89		0	20000	177	19823	19823	0	100%	1	442	1	442
Dec-89		0	19823	177	19645	19645	0	100%	1	443	1	443
Jan-90	148	35372	55017	177	54840	20000	34840	100%	1	444	1	444
Feb-90	168	40152	60152	177	59975	20000	39975	100%	1	445	1	445
Mar-90		0	20000	177	19823	19823	0	100%	1	446	1	446
Apr-90		0	19823	177	19645	19645	0	100%	1	447	1	447
May-90		0	19645	177	19468	19468	0	100%	1	448	1	448
Jun-90		0	19468	177	19290	19290	0	100%	1	449	1	449
Jul-90	117	27963	47253	177	47076	20000	27076	100%	1	450	1	450
Aug-90	180	43020	63020	177	62843	20000	42843	100%	1	451	1	451
Sep-90	212	50668	70668	177	70491	20000	50491	100%	1	452	1	452
Oct-90	73	17447	37447	177	37270	20000	17270	100%	1	453	1	453
Nov-90	82	19598	39598	177	39421	20000	19421	100%	1	454	1	454
Dec-90	351	83889	103889	177	103712	20000	83712	100%	1	455	1	455
Jan-10	261.0	62379	82379	177	82202	20000	62202	100%	1	684	1	684
Feb-10	211.0	50429	70429	177	70252	20000	50252	100%	1	685	1	685
Mar-10	273.3	65319	85319	177	85141	20000	65141	100%	1	686	1	686
Apr-10	211.1	50453	70453	177	70275	20000	50275	100%	1	687	1	687
May-10	95.1	22729	42729	177	42551	20000	22551	100%	1	688	1	688
Jun-10	18.8	4493	24493	177	24316	20000	4316	100%	1	689	1	689
Jul-10	19.9	4756	24756	177	24579	20000	4579	100%	1	690	1	690

Aug-10	17.0	4063	24063	177	23886	20000	3886	100%	1	691	1	691
Sep-10	6.9	1649	21649	177	21472	20000	1472	100%	1	692	1	692
Oct-10	18.9	4517	24517	177	24340	20000	4340	100%	1	693	1	693
Nov-10	0.0	0	20000	177	19823	19823	0	100%	1	694	1	694
Dec-10	68.4	16348	36170	177	35993	20000	15993	100%	1	695	1	695
Jan-11	3.1	741	20741	177	20563	20000	563	100%	1	696	1	696
Feb-11	2.2	526	20526	177	20348	20000	348	100%	1	697	1	697
Mar-11	19.0	4541	24541	177	24364	20000	4364	100%	1	698	1	698
Apr-11	54.6	13049	33049	177	32872	20000	12872	100%	1	699	1	699
May-11	65.6	15678	35678	177	35501	20000	15501	100%	1	700	1	700
Jun-11	75.5	18045	38045	177	37867	20000	17867	100%	1	701	1	701
Jul-11	92.7	22155	42155	177	41978	20000	21978	100%	1	702	1	702
Aug-11	133.7	31954	51954	177	51777	20000	31777	100%	1	703	1	703
Sep-11	0.0	0	20000	177	19823	19823	0	100%	1	704	1	704
Oct-11	0.0	0	19823	177	19645	19645	0	100%	1	705	1	705
Nov-11	0.0	0	19645	177	19468	19468	0	100%	1	706	1	706
Dec-11	0.0	0	19468	177	19290	19290	0	100%	1	707	1	707
Jan-12	6.4	1530	20820	177	20642	20000	642	100%	1	708	1	708
Feb-12	10.0	2390	22390	177	22213	20000	2213	100%	1	709	1	709
Mar-12	55.3	13217	33217	177	33039	20000	13039	100%	1	710	1	710
Apr-12	111.0	26529	46529	177	46352	20000	26352	100%	1	711	1	711
May-12	215.8	51576	71576	177	71399	20000	51399	100%	1	712	1	712
Jun-12	82.9	19813	39813	177	39636	20000	19636	100%	1	713	1	713
Jul-12	400.0	95600	115600	177	115423	20000	95423	100%	1	714	1	714
Aug-12	57.4	13719	33719	177	33541	20000	13541	100%	1	715	1	715
Sep-12	47.4	11329	31329	177	31151	20000	11151	100%	1	716	1	716
Oct-12	69.0	16491	36491	177	36314	20000	16314	100%	1	717	1	717
Nov-12	57.2	13671	33671	177	33493	20000	13493	100%	1	718	1	718
Dec-12	115.1	27509	47509	177	47331	20000	27331	100%	1	719	1	719

**Table A9-3. RWH potential of surveyed communal buildings in relation to meeting current and future village drinking water demands.**

Building Type	Owner	<sup>1</sup> Roof area (m <sup>2</sup> )	Building ID	Percentage of roof margin covered by guttering	<sup>2</sup> Collecting Roof Area (m <sup>2</sup> )	<sup>3</sup> Guttering Condition	<sup>4</sup> Guttering Efficiency	<sup>5</sup> Effective Roof Area (m <sup>2</sup> )	<sup>6</sup> Improved Roof Area (m <sup>2</sup> )	<sup>7</sup> Rain Tank Capacity (L)	Population	<sup>1</sup> RWH capacity under current catchment conditions (L/p/d)	<sup>2</sup> RWH capacity with roof improvements (L/p/d)	<sup>3</sup> RWH capacity with roof improvements and increased storage 20,000L (L/p/d)
<b>Maneaba</b>	KPC	318	Ni1	0%	0	None	0	0	239	0	2010 (265)	0	0	0.9
											2030 (188)	0	0	1.3
<b>Copra Shed</b>	KPC	132	Ni2	50%	66	Adequate	0.55	36	99	0	2010 (265)	0	0	0.55
											2030 (188)	0	0	0.8
<b>Church House</b>	KPC	185	Ni3	0%	0	None	0	0	139	0	2010 (265)	0	0	0.7
											2030 (188)	0	0	0.95
<b>Church</b>	Rungata Church	312	Ni4	75%	234	Repair	0.35	82	234	0	2010 (265)	0	0	0.9
											2030 (188)	0	0	1.3
<b>Church</b>	Catholic	192	Ni4	75%	144	Repair	0.35	50	144	0	2010 (265)	0	0	1
											2030 (188)	0	0	0.7
<b>Village Total</b>								<b>168</b>	<b>855</b>	<b>0</b>	<b>2010 (265)</b>	<b>0</b>	<b>0</b>	<b>3.8</b>
											<b>2030 (188)</b>	<b>0</b>	<b>0</b>	<b>5.4</b>
<b>Church</b>	Catholic	126	Mu1	0	0	None	0	0	95	10 000	2010 (240)	0	0.45	0.62
											2030 (249)	0	0.43	0.6
<b>Church House</b>	Catholic	50	Mu2	0	0	None	0	0	38	0	2010 (240)	0	0	0.38
											2030 (249)	0	0	0.37
<b>Maneaba</b>	KPC	502	Mu3	100%	502	Adequate	0.55	276	377	0	2010 (240)	0	0	1.25
											2030 (249)	0	0	1.25
<b>Church</b>	KPC	386	Mu4	25%	97	Repair	0.35	34	290	0	2010 (240)	0	0	1.15
											2030 (249)	0	0	1.1
<b>Church</b>	KPC	219	Mu5	50%	110	Repair	0.35	38	164	10 000	2010 (240)	0.27	0.6	0.83
											2030 (249)	0.26	0.58	0.8
<b>Church</b>	KPC	80	Mu6	50%	40	Adequate	0.55	22	60	0	2010 (240)	0	0	0.48
											2030 (249)	0	0	0.46
<b>Village Total</b>								<b>370</b>	<b>1024</b>	<b>20 000</b>	<b>2010 (240)</b>	<b>1.3</b>	<b>1.9</b>	<b>5</b>
											<b>2030 (249)</b>	<b>1.25</b>	<b>1.9</b>	<b>4.9</b>
<b>Maneaba</b>	JSS	291	Ru1	50%	146	Repair	0.35	51	218	5000	2010 (976)	0.06	0.11	0.24
											2030 (1253)	0.045	0.09	0.185
<b>Church</b>	KPC	430	Ru2	0%	0	None	0	0	323	5000	2010 (976)	0	0.13	0.29
											2030 (1253)	0	0.1	0.23
<b>Church</b>	KPC	243	Ru3	100%	243	Good	0.75	182	182	5000	2010 (976)	0.11	0.11	0.215
											2030 (1253)	0.085	0.085	0.17
<b>Church</b>	Catholic	97	Ru4	50%	49	Repair	0.35	17	73	5000	2010 (976)	0.031	0.07	0.13

											2030 (1253)	0.025	0.05	0.1
<b>Church</b>	School	198	Ru5	25%	50	Repair	0.35	17	149	5000	2010 (976)	0.031	0.1	0.19
											2030 (1253)	0.025	0.085	0.15
<b>Church</b>	Catholic	24	Ru6	0%	0	None	0	0	18	5000	2010 (976)	0	0.035	0.059
											2030 (1253)	0	0.025	0.046
<b>Village Total</b>								<b>267</b>	<b>963</b>	<b>30 000</b>	<b>2010 (976)</b>	<b>0.32</b>	<b>0.59</b>	<b>1.2</b>
											<b>2030 (1253)</b>	<b>0.25</b>	<b>0.49</b>	<b>0.92</b>
<b>Church</b>	KPC	103	Ta1	50%	52	Repair	0.35	18	77	5000	2010 (154)	0.205	0.46	0.85
											2030 (117)	0.27	0.58	1.16
<b>Church</b>	KPC	42	Ta2	0%	0	None	0	0	32	5000	2010 (154)	0	0.28	0.53
											2030 (117)	0	0.37	0.7
<b>Village Total</b>								<b>18</b>	<b>109</b>	<b>10 000</b>	<b>2010 (154)</b>	<b>0.275</b>	<b>0.75</b>	<b>1.4</b>
											2030 (117)	0.38	0.98	1.85

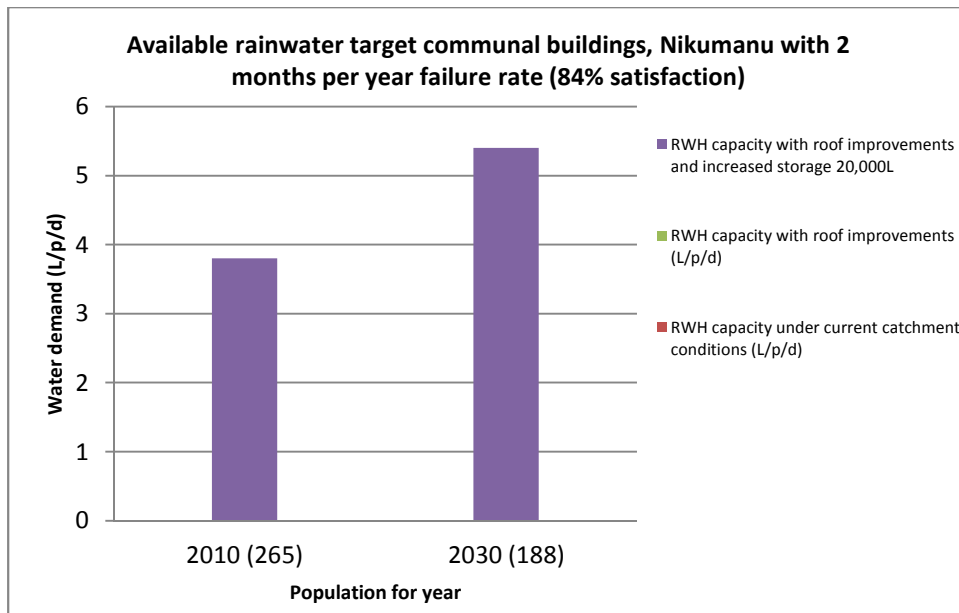


Figure A9-1. Per-capita water demand of all target communal buildings in Nikumanu Village.

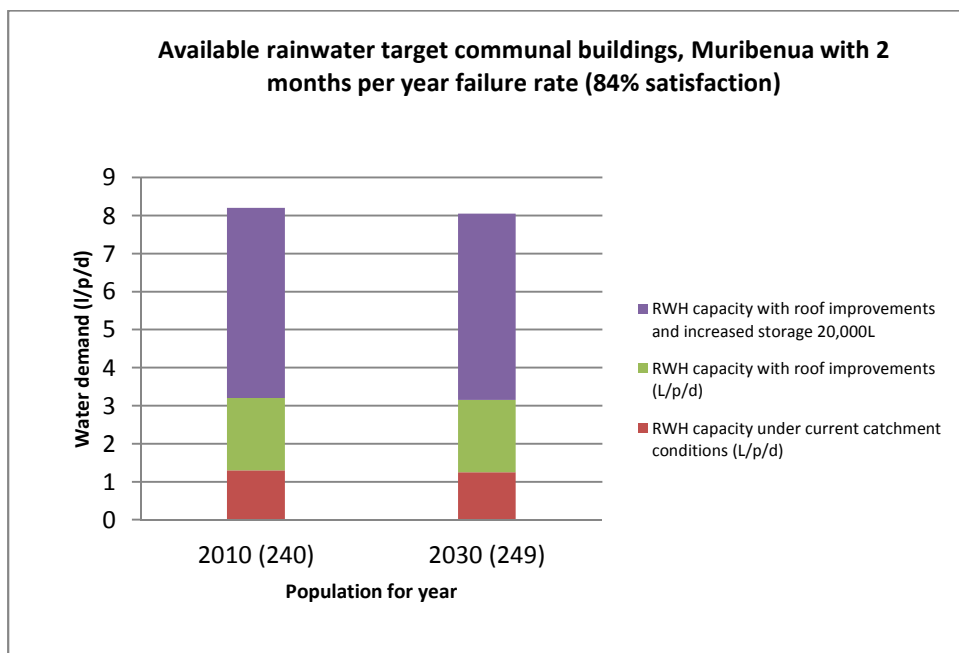
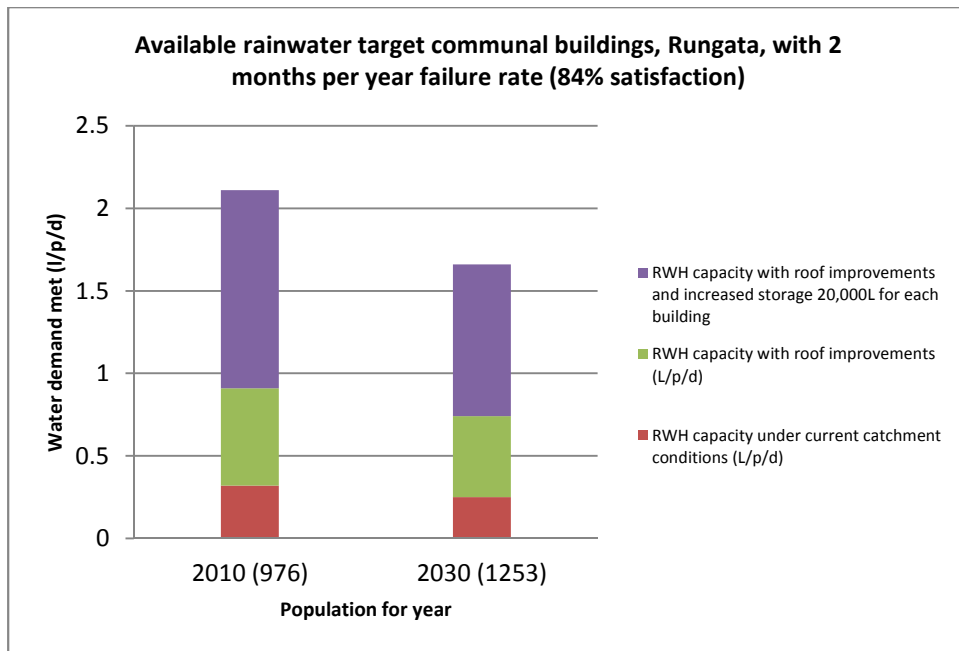
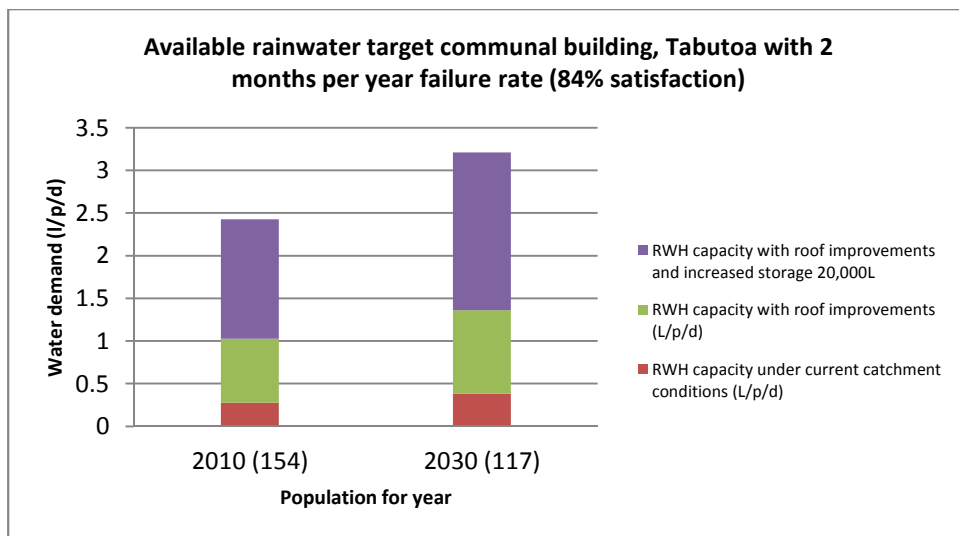


Figure A9-2. Per-capita water demand of all target communal buildings in Muribenua Village.



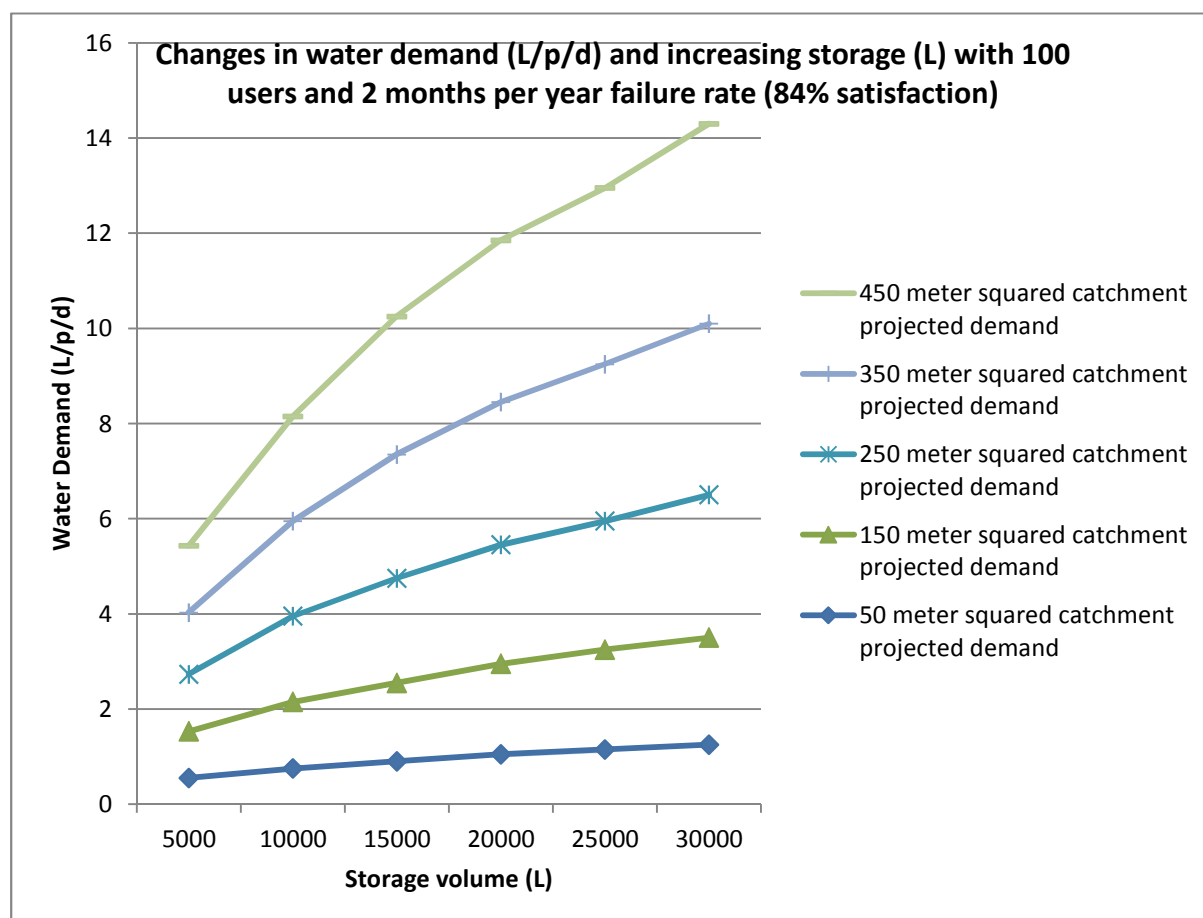
**Figure A9-3. Per-capita water demand of all communal buildings in Rungata Village.**



**Figure A9-4. Per-capita water demand of all communal buildings in Tabutoa Village.**

**Table A9-4. Summary of water available L/p/d for 100 people assuming 84% satisfaction or 2 months per year failure rate under varying roof area and storage.**

Roof Catchment	5000	10 000	15 000	20 000	25 000	30 000
50 meter squared catchment projected demand	0.55	0.75	0.9	1.05	1.15	1.25
100 meter squared catchment projected demand	0.8	1.1	1.35	1.5	1.7	1.8
150 meter squared catchment projected demand	0.98	1.4	1.65	1.9	2.1	2.25
200 meter squared catchment projected demand	1.1	1.6	1.9	2.2	2.4	2.7
250 meter squared catchment projected demand	1.2	1.8	2.2	2.5	2.7	3
300 meter squared catchment projected demand	1.2	1.9	2.4	2.8	3	3.3
350 meter squared catchment projected demand	1.3	2	2.6	3	3.3	3.6
400 meter squared catchment projected demand	1.4	2.1	2.8	3.2	3.5	3.9
450 meter squared catchment projected demand	1.4	2.2	2.9	3.4	3.7	4.2
500 meter squared catchment projected demand	1.5	2.3	3.1	3.6	3.9	4.4



**Figure A9-5. Analysis of changing water demand on varying roof catchment area based on a fixed number of users and 84% satisfaction.**

# Annex 10

## Village Meeting Notes from Nikunau

This annex presents the issues and challenges raised by various communities during village consultation meetings in Nikunau.

**Table A10-1. Summary of key discussion areas in the target villages. Meeting in Rungata was not held because of miscommunication with village elders resulting in the engagement of villagers in several community gatherings.**

Village	Summary of discussion points
<b>Nikumanu 16/08/2013</b>	<p>Village groups:</p> <ul style="list-style-type: none"> <li>• Showed great concerns with high E.coli contamination</li> <li>• Agreed with the need to have communally owned system to address long-term operation and maintenance issues</li> <li>• Gave assurance on village support, in terms of land access and labour, during future construction stage</li> <li>• Requested the rehabilitation of the old village system</li> <li>• Requested more distribution tanks and tap stands as village population is expected to increase</li> </ul>
<b>Tabutoa 16/08/2013</b>	<p>Village groups:</p> <ul style="list-style-type: none"> <li>• Showed concern with high E.coli contamination</li> <li>• Agreed with the need to have communally owned system to address long-term operation and maintenance issues</li> <li>• The request to rehabilitate the old village system was made</li> <li>• Agreed to the importance of establishing mechanism for water supply governance and operation</li> <li>• Requested more distribution tanks and tap stands</li> </ul>
<b>Muribenua 16/08/2013</b>	<p>Village groups:</p> <ul style="list-style-type: none"> <li>• Showed concern with high E.coli contamination</li> <li>• Acknowledged the limited groundwater potential underlying the village</li> <li>• Agreed with the need to have communally owned system to address long-term operation and maintenance issues</li> <li>• Requested for the rehabilitation of the old village system, with more tap stands</li> <li>• Requested more rainwater harvesting facilities and storage tanks</li> </ul>

# Annex 11

## Selection of Nikunau Survey Photos

This annex presents selected photos captured during the water resources assessment and is intended to show the status and/or condition of water supply infrastructure in Nikunau Atoll at the time of the assessment, from 5<sup>th</sup> to 19<sup>th</sup> August 2013.



**Figure A11-1.** *A household well using coral rock as casing material right down to bedrock.*



**Figure A11-2. Water- table and well- dimension measurement done by village workers.**



**Figure A11-3. Tamana pump used in a household well in Muribenua.**



**Figure A11-4.** Survey team assessing the Muribenua Village well; water is abstracted by solar pump.



**Figure A11-5.** Rainwater harvesting assessment conducted at the Island Council Maneaba in Rungata Village.



*Figure A11-6. Tamana distribution line from a poorly protected household well.*



*Figure A11-7. Village workers assessing water salinity level using an EC meter.*



**Figure A11-8.** Salinity measurement of the saline lake located inland from Rungata Village with 15.6 mS/cm suggesting some mixing with adjacent freshwater bodies.



**Figure A11-9.** EM34 survey team working around Nikumanu Village.



*Figure A11-10. KPC Church in Nikumanu, a potential rainwater harvesting site for the village.*



*Figure A11-11. Catholic Church in Nikumanu, a potential rainwater harvesting site for the village.*



*Figure A11-12. Survey team measuring the roof height of a private building in Rungata Village.*



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