KIRIWATSAN Water Resources Assessment
Beru Island, Kiribati

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EUROPEAN UNION

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KIRIWATSAN

Water Resources Assessment

BERU ISLAND, KIRIBATI

Secretariat of the Pacific Community, Suva

March 2015

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IMPORTANT NOTICE

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Abbreviations and symbols

ADB	Asian Development Bank
AUD	Australian dollars
BIVA	Bonriki Inundation Vulnerability Assessment (Project)
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
FW	freshwater
GoK	Government of Kiribati
HBHS	Hiram Beigham High School
HYCOS	Hydrological Cycle Observation System
IC	Island Council
JSS	Junior Secondary School
KIRIWATSAN I	Kiribati Water and Sanitation Phase 1 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^2	Square metres
m^3	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.

We acknowledge the support from the UNICEF staff in Tarawa and Suva in the logistics and their input into the review of the document. Finally, we would like to thank the people of Beru for allowing us access to their land and for their generous hospitality during our stay.

1.0 EXECUTIVE SUMMARY

As part of the EDF 10 KIRIWATSAN I project, Beru Island was visited between 18th November and 2nd December 2013 for water resources assessment. The survey was conducted at Autukia, Tabiang, Aoniman, Nuka, Teteirio and Taubukiniberu, 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 lens beneath the villages.

Forty (40) permanently roofed buildings were surveyed for rainwater harvesting potential and improvements. Of these, twenty (20) were communal buildings, namely churches and *maneaba*. These communal buildings are considered suitable for rainwater harvesting improvements, due to 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 down pipes, 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 forty five (245) wells were assessed for infrastructural status and groundwater quality. The assessment of water table depth and salinity showed an average of 1.4 mbgl and 3.1 mS/cm. 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 and membrane filtration procedure, indicated the presence of E. coli bacteria in more than 80% 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 a 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 bailers stand 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.

EM34 geophysical surveys identified the extent and thickness of the freshwater lens underlying the area around the villages.

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. In Autukia, where groundwater potential is poor and vulnerable to saline intrusion, the household wells could be improved for non-potable purposes whilst the construction of more rainwater tanks and cisterns is essential to improve storage capacity and ensure the sufficiency of drinking water throughout the year.

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 regime. 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 10th 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 thirty-five (35) target villages across eight (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 carried out in Beru Island, under component 1 of the KIRIWATSAN Phase I Project.

- Field investigations for Beru Island were undertaken from 18th November to 2nd December 2013. The assessment was conducted in six (6) target villages: Autukia, Tabiang, Aoniman, Nuka, Teteirio and Taubukiniberu and included a survey of forty (40) buildings to assess the existing and potential rainwater harvesting systems.
- A survey of two hundred and forty-five (245) 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 its 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 Beru Island.

2.2 Survey team and schedule

The survey team for Beru included Aminisitai Loco from the Geoscience Division of the Secretariat of the Pacific Community (SPC), Martin Mataio, Laavaneta Juliano and Mouia Aroito from the Water Engineering Unit (WEU) of the Ministry of Public Works and Utilities (MPWU); and the Beru Island Water Technician, Bokauea Mitiraim. 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

Beru Island, one of the southern islands of the Gilbert Islands group, is located between longitudes 175°57'E and 176°01'E and latitudes 1°16'S and 1°22'S. The NW-SE trending island atoll has a land area of 17.6 km^2 (National Statistics Office, 2012), with the island's widest point measured at Tabiang Village to be 1.1 km and its narrowest, 0.16 km, at Wenete (Office of te Beretitenti and T'Makei Services, 2012).

The villages are scattered in a linear pattern along the lagoon shoreline. Land use practices include small-scale commercial and subsistence agriculture, which are concentrated toward the middle of the island. Vegetation on the island includes coastal strand plants like pandanus, coconut palms and scrub. Extensive saline lakes are located near Taboiaki (in the south) and Autukia (in the north). The Tabuariki Lake, adjacent to Taboiaki, is where edible algae known as "*bokaboka*" is found; whilst the "*te nein i man*" or the 'lake of fauna', near Autukia, is usually full of fish during rainy seasons and becomes a salt reservoir during drought period (Office of te Beretitenti and T'Makei Services, 2012).

The Island Council is located at Taubukiniberu Village, with the medical centre next to it, along with the rest of the government facilities for agriculture, fisheries, climate station and post office. The summary of the locations and additional descriptions of the target villages are presented in the Table 1.

There are nine (9) villages on Beru, six (6) of which were identified by the Government of Kiribati (GoK) as target villages for the KIRIWATSAN Project: Autukia, Tabiang, Aoniman, Nuka, Teteirio and Taubukiniberu. Note that Rongorongo Village was partly surveyed due to its very close proximity to

Nuka Village as well as the misunderstanding by village elders regarding the Nuka Village land boundary.

Table 1. Summary of locations and descriptions of the six target villages. (Source: National Statistics Office)

Village	Population	Population density pers/km^2	Land Area (m^2)	Description
Autukia	188	203	928,272	Village is located towards the north-eastern tip of the Beru atoll, with the lagoon shoreline covered with extensive mangrove swamps and residential areas concentrated around the centre of the island. The village has a medical clinic. The island maximum width around the village is ~900 m.
Tabiang	399	178	2,244,242	This village is located at the north-western tip of the Beru atoll and north of Aoniman Village, with the residential areas concentrated in a linear pattern along the lagoon shoreline. The village has a medical clinic and accommodates Namon Primary School, with a maximum island width of ~1100 m measured around the village centre.
Aoniman	123	98	1,249,053	The village is located between Tabiang and Rongorongo villages, with the houses sparsely located along the lagoon shoreline. The maximum island width around the village is ~550 m.
Nuka	443	260	1,703,067	This is the biggest target village, located very close to Rongorongo Village. The densely populated village accommodates Beru Junior Secondary School and Teibubutei Primary School, with the residential area concentrated along the lagoon shoreline. Note that the survey around this village extended into Rongorongo Village, particularly around Hiram Beigham High School. The maximum island width around the village is ~900 m.
Teteirio	79	135	585,983	The village is located on the south-eastern end of the atoll and is connected to Nuka Village by a causeway. The houses are concentrated along the lagoon shoreline with a maximum island of ~ 700 m measured around the village.
Taubukiniberu	64	223	287,606	This village is closely located to Teteirio Village, where the Island Council buildings and government offices are located. The maximum island width around the village is ~650 m.

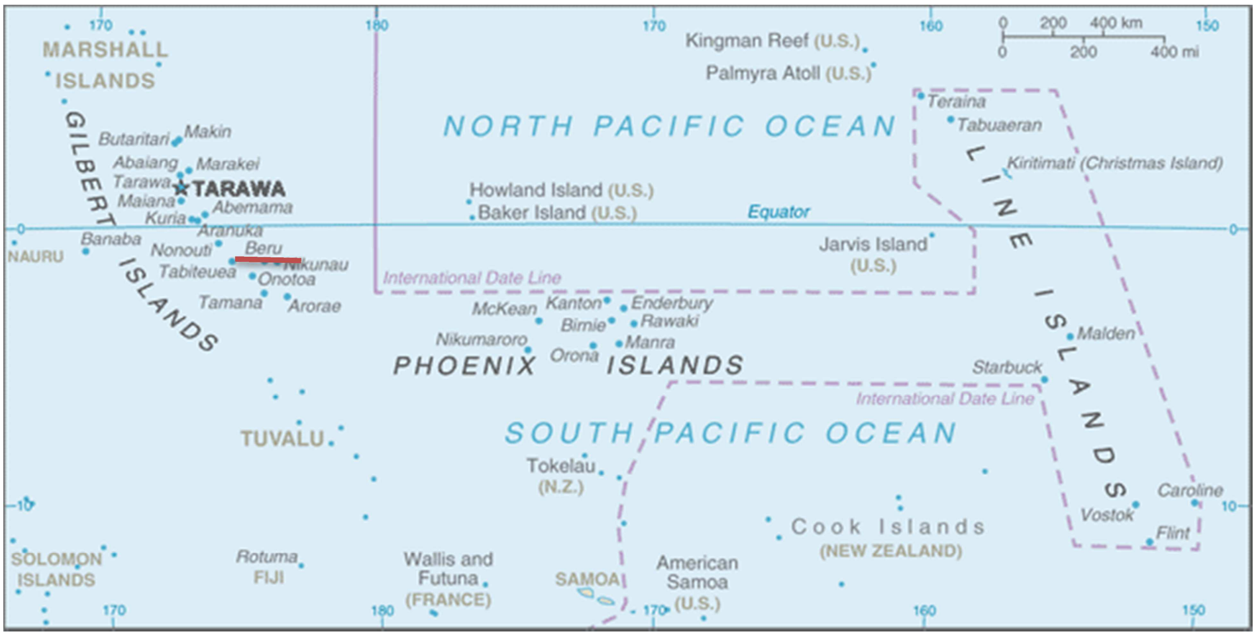

Figure 1. Location map of Beru Island in the Gilbert Islands group.
Source: https://www.cia.gov/library/publications/the-world-factbook/geos/kr.html

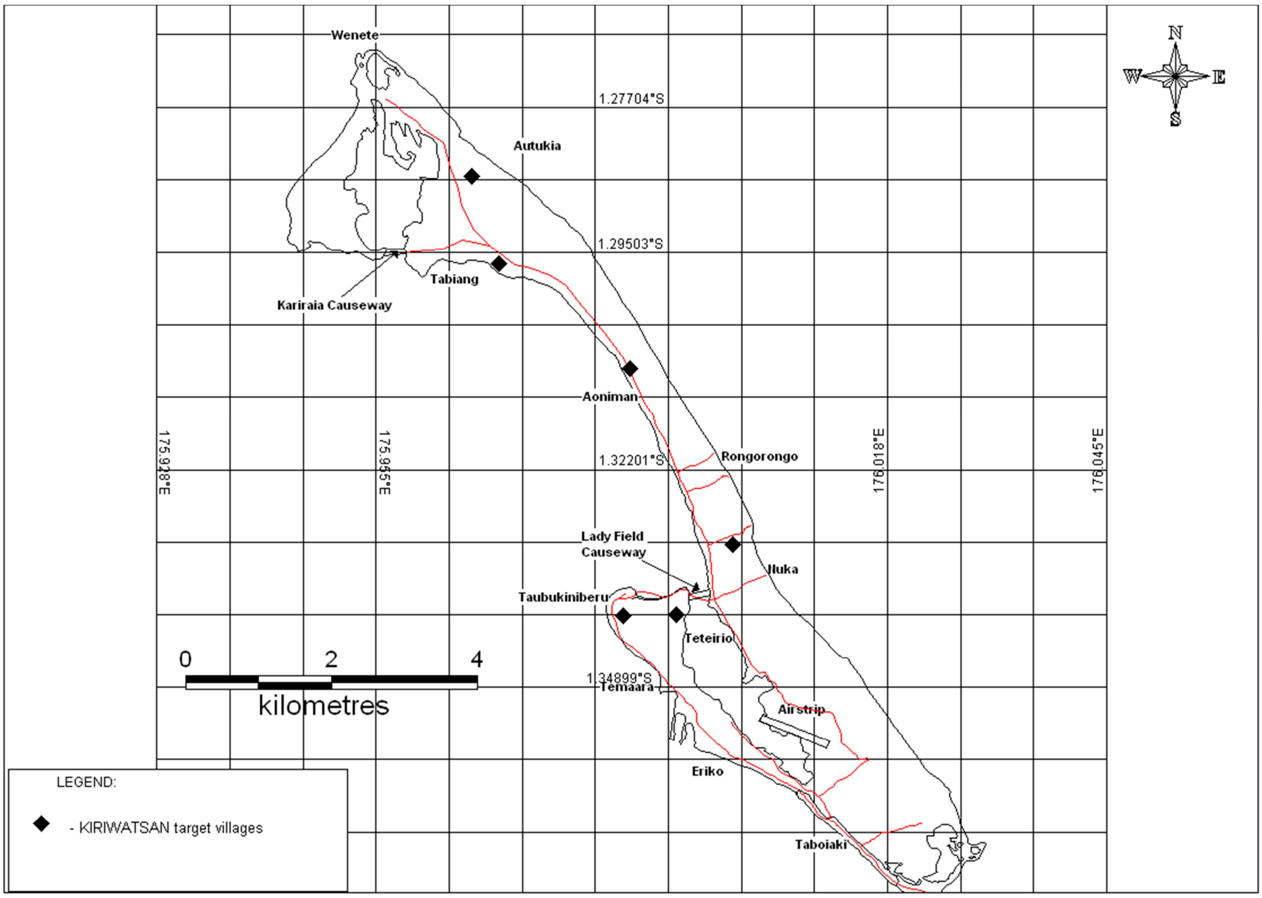

Figure 2. Locations of KIRIWATSAN 1 water resources assessment (WRA) target villages. (Map Source: Beru Island profile, UNICEF 2012 profiling report).

3.2 Population

Population on the island over the last two decades, according to census data, has decreased sporadically between villages and over time. Significant population decrease was recorded from 2000 to 2005, with a 4.1% negative growth registered. Minor declines were recorded in 1995, 2000 and 2010, with 0.9%, 0.4% and 0.6% negative growth rates, respectively. Table 2 shows the annual growth rates between each census 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 Beru 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	2030
Autukia	279	252	226	204	188	-1.9%	-2.1%	-1.9%	-1.6%	-1.9%	**117**
Tabiang	518	461	477	416	399	-2.2%	0.7%	-2.6%	-0.8%	-0.9%	**328**
Aoniman	179	151	149	101	123	-3.1%	-0.3%	-6.4%	4.4%	-1.4%	89
Rongorongo	420	487	498	315	190	3.2%	0.5%	-7.3%	-7.9%	-2.9%	79
Nuka	519	537	568	348	443	0.7%	1.2%	-7.7%	5.5%	-0.1%	**433**
Teteirio	66	62	91	74	79	-1.2%	9.4%	-3.7%	1.4%	1.4%	102
Taubukiniberu	130	157	86	97	64	4.2%	-9.0%	2.6%	-6.8%	-2.3%	**35**
Eriko	280	268	258	265	259	-0.9%	-0.7%	0.5%	-0.5%	-0.4%	**239**
Taboiaki	518	409	379	349	354	-4.2%	-1.5%	-1.6%	0.3%	-1.7%	231
Total	**2909**	**2784**	**2732**	**2169**	**2099**	**-0.9%**	**-0.4%**	**-4.1%**	**-0.6%**	**-1.5%**	**1469**

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

The population trend from 1931 to 2010 (Figure 3) shows the following trends:

1. a relatively stable growth rate recorded from 1931 to 1978;
2. a significant increase recorded from 1978 to 1990; and
3. continued, yet varied, decline registered from 1990 to 2010.

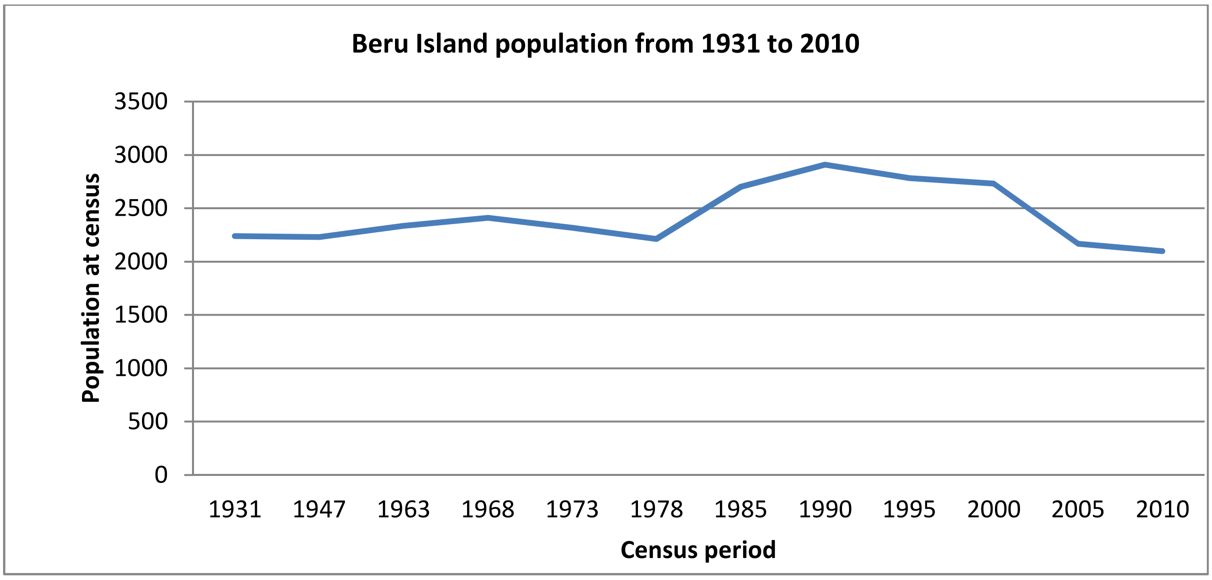

Figure 3. Population growth on Beru Island, 1931 - 2010 (Source: National Statistics Office).

The different growth rates in each target village will impact 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

Beru Island has a climate station situated in Taubukiniberu Village, which is currently being maintained by the Kiribati Meteorological Service – this contributes to the availability of longer term rainfall records, compared to other islands. Also, the climate station measures other parameters besides rainfall. Other climate stations for the Gilbert Islands are:

- Betio, South Tarawa
- Butaritari

Monthly rainfall data for Beru are available from January 1945 to June 2014, with gaps (Annex 2). The dataset shows 81% of monthly records with the bulk of the complete rainfall data (48 years) falling within the period from 1945 to 1992. Major data gaps in the rainfall record occurred from 1995 to 2000; and from 2004 to 2009.

The climate data are summarised in Table 3 and the monthly records are attached as Annex 2. The maximum monthly rainfall of 850 mm recorded during this period occurred in January 1948. Zero monthly rainfall was recorded at least once for every month except for June, July and August. Beru, as with other islands within the Gilbert Islands group, has on average a 5 month 'wetter' (December to April) period, followed by a 7 month 'drier' (May to November) period. Comparison between the monthly mean 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 rainfall than surrounding 'drier' months, possibly due to some high rainfall events in 1946, 1951, 1965, 1976, 1982, 1983, 1987 and 2012 (see Annex 2).

A comparison between mean annual rainfall and latitude for the Gilbert Islands was undertaken. There is a discernible trend indicating that the further away from the equator the island is, the more rainfall can expected; and the further an island is situated north of the equator the more likely it is to have more 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).

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

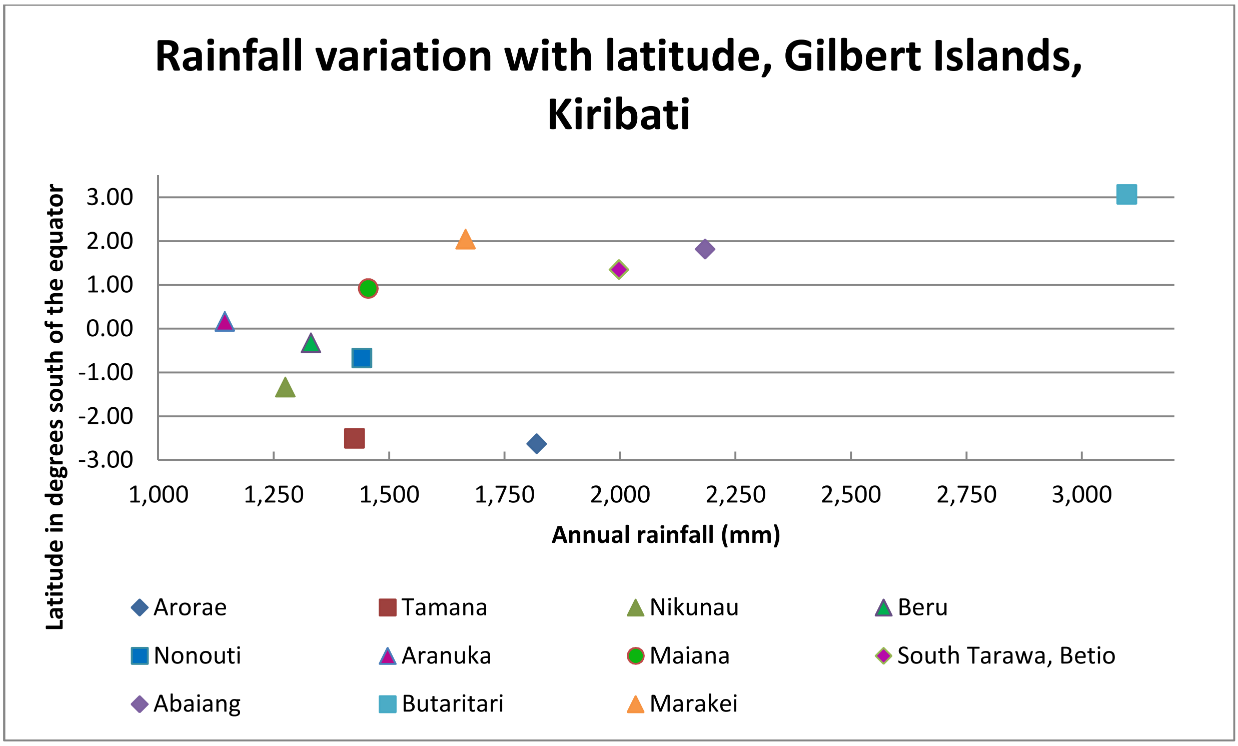

Figure 4. Mean annual rainfall (1950- 2014) variation with latitude for the Gilbert Islands group.

Table 3. Statistics of monthly rainfall in Beru for the period 1945-2014 (with gaps).

Months	January	February	March	April	May	June	July	August	September	October	November	December	Total
Mean (mm)	203	116	110	106	102	92	121	104	80	68	89	170	**1331**
Standard deviation (mm)	210	144	123	113	93	75	114	107	87	83	119	153	**751**
CV*	1.04	1.24	1.12	1.06	0.92	0.82	0.94	1.03	1.08	1.22	1.34	0.90	**0.56**
Maximum (mm)	850	535	517	582	366	346	400	460	436	384	570	571	**3104**
Minimum (mm)	0	0	0	0	0	2	7	8	0	0	0	0	**247**
Median (mm)	117	44	60	67	67	76	76	67	47	39	43	125	**1228**
No. of years	58	58	57	56	57	57	54	56	57	56	57	57	**54**

***CV – Coefficient of variation = standard deviation/mean**

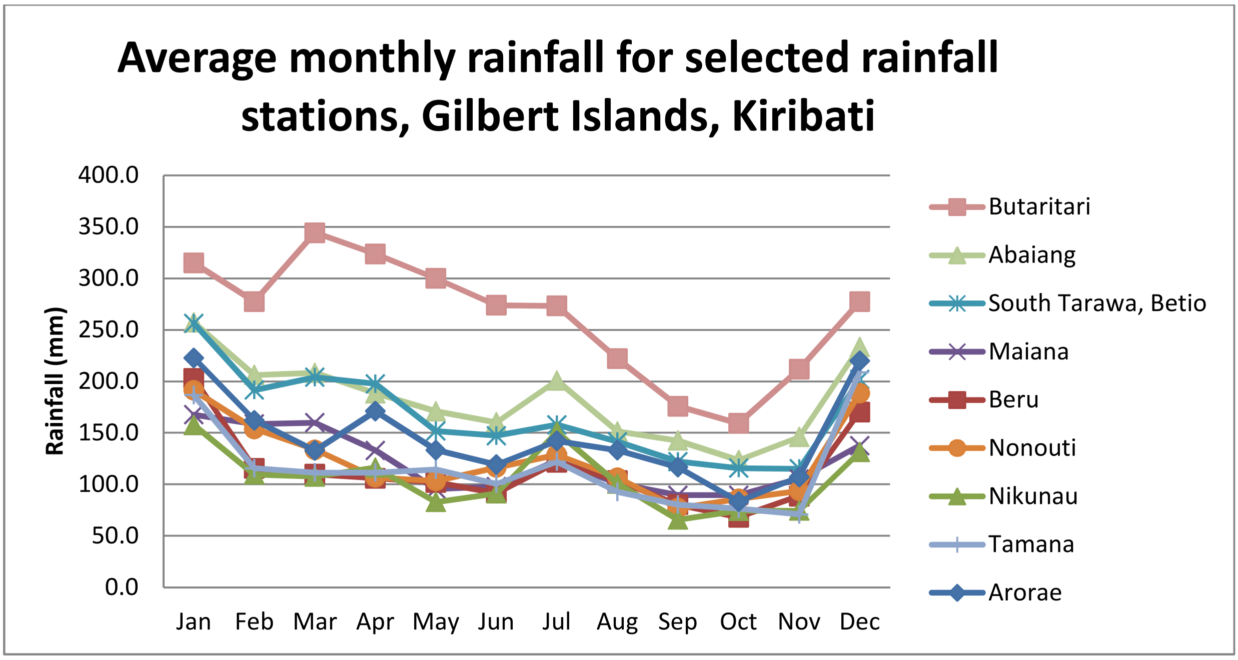

Figure 5. Variation in monthly rainfall for selected islands in the period 1945 – 2014 (available records). Generally, the months from May to November are considered the driest months whilst the months from December to April, the wetter months, for Gilbert Islands.

Table 4. Annual seasonal rainfall statistics for Beru 1945 to 2014, 'drier' May to November (7 months) and 'wetter' December to April (5 months).

Statistic	Annual	May-November	December-April
Mean (mm)	1331	648	717
Standard deviation (mm)	751	500	494
CV	0.56	0.77	0.69
Maximum (mm)	3104	2192	1832
Minimum (mm)	247	143	46
Median (mm)	1228	496	631
No. Years	54	56	56

It is noted that the 'drier' 7 months from May to November for Beru received only less rainfall than the 5 months from December to April for the period 1945-2014.

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 Coefficient of Variation (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 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 Coefficient of Variation for Beru is 0.56 indicating that rainfall in any one year, for about 68% of the time, can be expected to vary ± 56% from the long-term annual average rainfall of 1331 mm.

The CV of 0.56 indicates a relatively high temporal variability of rainfall. It is also noted that the seasonality of the rainfall also shows a high CV suggesting greater variability of rainfall away from the long-term seasonal average of rainfall, indicating that rainfall is even less reliable with consideration to any particular season. This is an important water security consideration especially with regard to assessing the reliability of rainwater harvesting to supplement or supply freshwater in the future.

The relatively large gaps in the Beru rainfall dataset precludes further analysis of the rainfall data. The Tarawa climate station, (~450 km from the Beru rainfall station) with good quality long-term data and a comparison between the two datasets indicates that the Beru historical rainfall is on average 40% lower than that of 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 Beru.

It is a recommendation that daily rainfall recording to be continued in Beru and supported by GoK into the future as it provides a critically important dataset for water resources management providing an indication of climate variability both temporally and spatially.

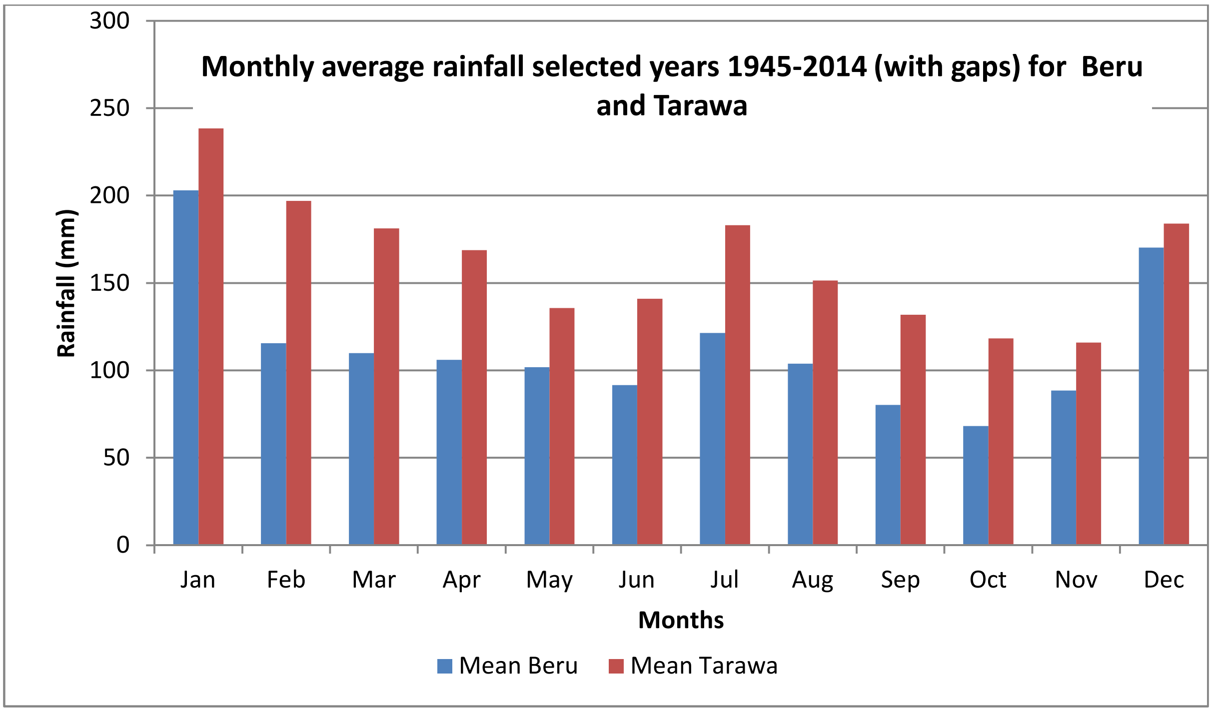

Figure 6. Historical and discontinuous average monthly rainfall for common years between Beru and Tarawa for the period 1945-2014.

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 temperatures 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).

3.4 Geology and Hydrogeology

No detailed geology of Beru 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 Beru is similar to that in Tarawa, with unconsolidated Holocene sediments unconformably overlying the more-permeable Pleistocene limestone.

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

The occurrence of freshwater underlying atoll islands like Beru 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.

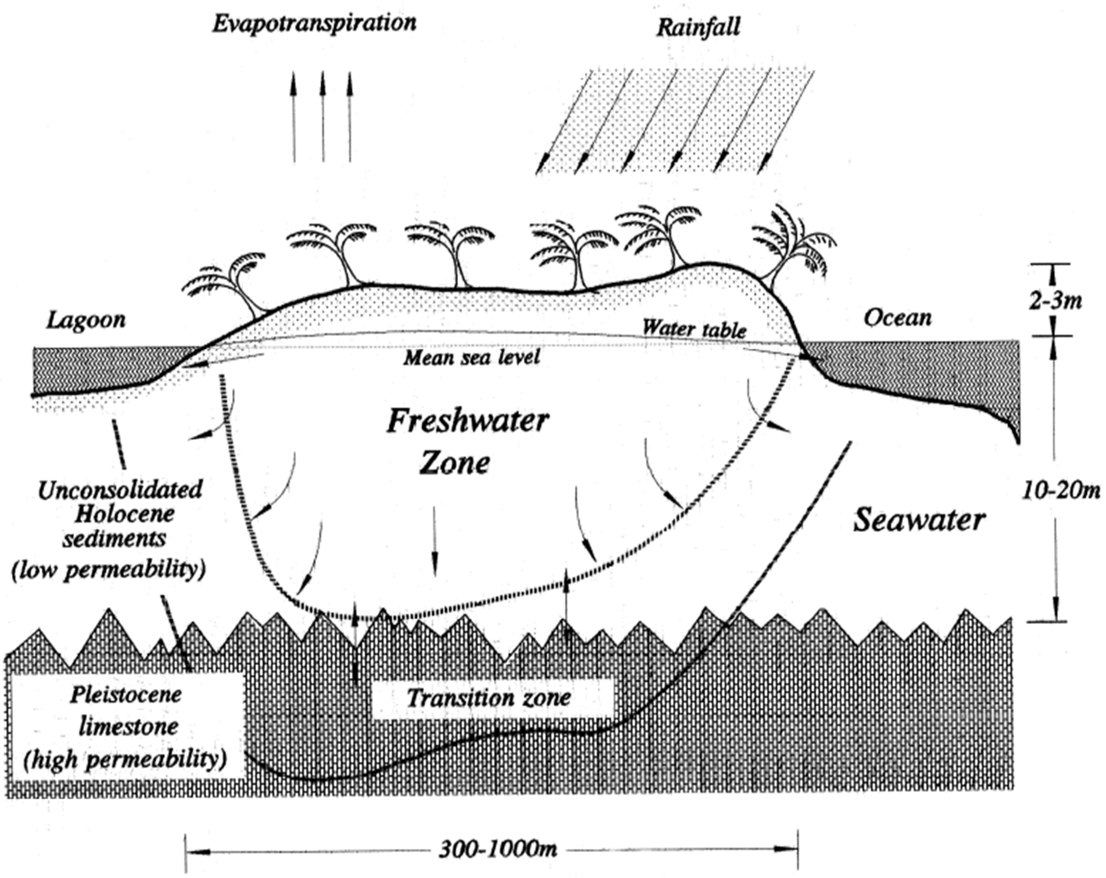

Figure 7. Freshwater lens configuration typical in atoll environments like Beru Island (Falkland, 2003).

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 Beru (1331 mm), the estimated mean annual recharge for Beru was 319 mm, which accounted for an estimated 24% of annual rainfall.

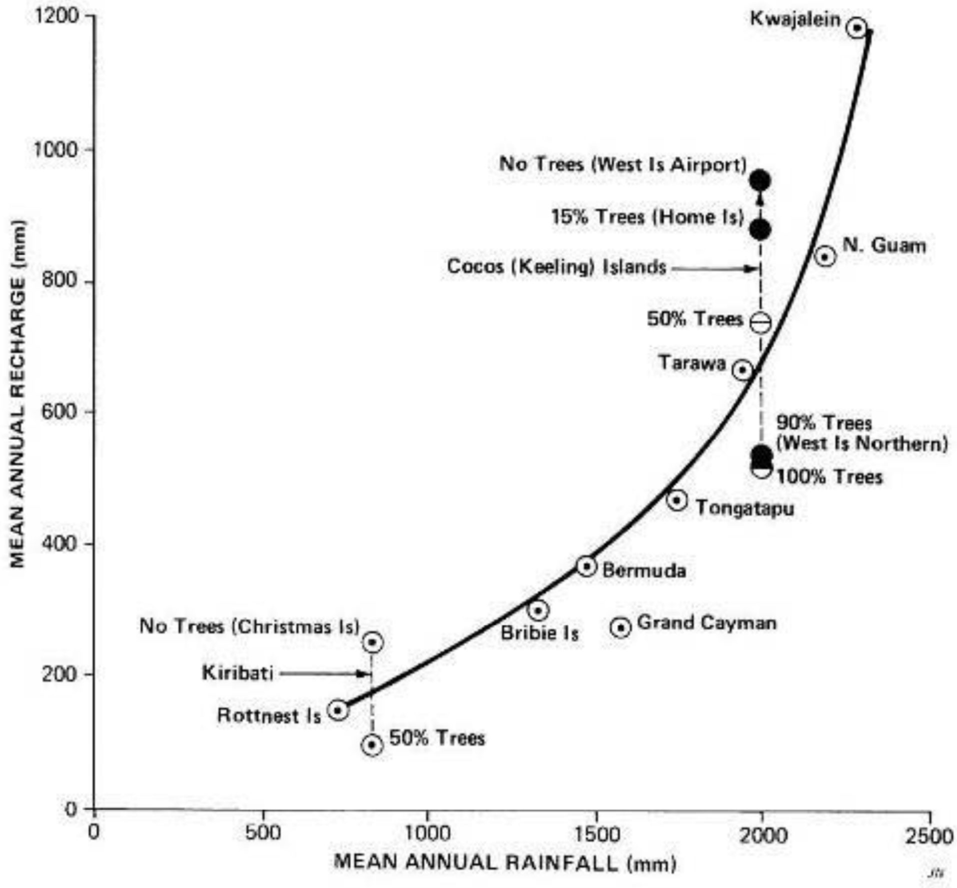

Figure 8. Annual rainfall – recharge relationship for a few studied small islands (UNESCO, 1991).

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 Beru with a mean annual rainfall of approximately 1331 mm and an estimated mean annual recharge of 319 mm with 24% of rainfall; a conservative preliminary sustainable yield of 14% of annual recharge is determined which correlates with the estimated sustainable yield for Beru by Falkland (2003), of 14% and equivalent to 3% of rainfall.

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

3.5 Water supply and sanitation

Groundwater is the primary water source for drinking and domestic purposes on Beru (92%), whilst rainwater is used as the primary drinking water source for less than 2% of households (Table 5) (National Statistics Office, 2012).

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

Main Source of Drinking Water						
Village	**Rain water tank**	**Pipe System (PUB)**	**Open well water**	**Protected well water**	**Other**	**Total**
Autukia	1	0	24	9	5	**39**
Tabiang	1	0	14	72	0	**87**
Aoniman	0	0	0	27	1	**28**
Rongorongo	0	0	0	3	19	**22**
Nuka	2	0	4	93	0	**99**
Teteirio	1	0	2	15	0	**18**
Taubukiniberu	0	0	0	16	0	**16**
Eriko	2	0	30	34	0	**66**
Taboiaki	0	0	23	50	1	**74**
Total	7	0	97	319	26	449

Previous inspection of the water supply systems in the outer islands, including Beru Island, was documented by Falkland (2003). As part of this water resources assessment, the status of the water supply systems for each target village was updated and compared with the 2003 records, refer to Table 6.

Table 6. Update of water supply systems summary table (after Falkland 2003).

Village	Population (2000 Census)	2003 Water Supply Status	Population (2010 Census)	2013 Water Supply Status (KIRIWATSAN survey)
Autukia	226	2 wells with 9 Southern Cross hand pumps – wells are in good source areas	188	28 household wells surveyed, with 6 hand pumps (1 not working, 1 electrical pump (damaged) and a few shared wells and 1 communal well with water abstracted by multiple hand pumps, 3 × 5000-L rainwater tanks connected to the church
Tabiang	477	2 wells with 29 Southern Cross hand pumps, 11 working and 18 not working	399	78 household wells surveyed (including Namon Primary School) with 1 solar pump (not working), 1 electrical pump (damaged), 42 hand pumps (a few shared wells), 4 rainwater tanks
Aoniman	149	4 wells with 10 Southern Cross hand pumps	123	23 household wells (2 church-owned community wells used for drinking), with 5 hand pumps and 5 rainwater tanks connected to KPC and Catholic Church
Rongorongo	498	Gallery with two solar pumps 1 hp, 1/3 hp at Hiram Beigham High School	190	Village was surveyed under Nuka Village due to its proximity and obscure village boundary
Nuka	568	8 wells and 17 *Tamana* pumps. Hand pumps (1 working and 16 not installed)	443	87 household wells (including Hiram Beigham High School, Beru Junior Secondary School, and Teibubutei Primary School), with 22 hand pumps, 8 electrical pumps (3 not working) 2 solar pumps (1 not working) 14 × 5000-L rainwater tanks connected to a number of communal buildings
Teteirio	91	1 well, 4 Southern Cross hand pumps. Working.	79	22 household wells surveyed (including 1 village well with water abstracted by multiple hand pumps), 6 hand pumps 1 electrical pump (not working), and 2 × 5000-L rainwater tanks
Taubukiniberu	86	2 wells, 2 Southern Cross hand pumps and 4 *Tamana* pumps.	64	7 household wells surveyed (including 2 village wells with water abstracted by multiple hand pumps, 4 hand pumps, 3 electrical pumps and 2 × 5000-L rainwater tanks connected to the Ministry of Women office
Eriko	258	6 wells and 16 *Tamana* pumps (8 working and 8 not working)	259	Not surveyed
Temaara		1 well, 6 *Tamana* pumps. 1 handpump working and 5 not working		Not surveyed
Tebikeriki		2 wells, 3 Southern Cross hand pumps and 1 *Tamana* pumps. 2 hand pumps working and 2 not working.		Not surveyed
Taboiaki	379	5 wells and 15 *Tamana* pumps and 1 gallery with solar pump 1 hp, 10 solar panels	354	Not surveyed

The 2010 census also indicates that 41% of households practise open defecation – beach (162) and bush (21). Flush toilets (147), including pour-flush, are increasingly being used and account for 33% of households, whilst the sea (105), pit latrines (2) and Atolette (8) account for 26% of the sanitation practices for households (Table 7).

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

Census year	Flush PUB	Flush Own	Latrine	Atolette	Beach	Bush	Sea	No. Households
2005	0	9	121	17	348	258	235	462
2010	0	147	2	8	162	21	105	449

A comparison of the sanitation systems indicated in the census data over time suggests that there is an increase of improved sanitation practices 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.

3.6 Previous work

The first of the previous studies undertaken in Beru was under the United Nations Capital Development Fund for Outer Islands Community Water Supply project in the 1990s. This entailed the installation of one (1) solar-powered village well system at the Hiram Beigham High School (HBHS), located in Rongorongo Village and operated by the Kiribati Protestant Church (KPC). Details of the water supply assistance are presented in Table 8:

Table 8. Water supply system assistance on Beru Island (Water Unit, 2002)

Village	Well excavated (count)	Well rings (count)	Hand pump (count)	Solar Pump	Tanks (9 kL)	Length of distribution PE pipes (m)
Rongorongo	1	6	–	2	2	1150

The coverage of this project suggested that a small fraction of Beru Island will have previous experience and some awareness of water supply improvement, together with its associated socio-economic impacts.

A summary of the project's challenges and conclusions is tabulated below (Table 9).

Table 9. Summary of the UNCD Project 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 the 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, testing positive for E. coli

It is worth noting that many of these observations were also observed 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:

- 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 include:
    - 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 include:
    - 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 electromagnetics to determine the lateral variability in bulk ground conductivity as a guide to fresh groundwater thickness estimation.
4. Conduct community awareness 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 was 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.[1]

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

4.2 Rainwater harvesting survey assessment

A total of forty (40) buildings were surveyed in the target villages on Beru atoll, to assess their suitability and potential for rainwater harvesting and recommend improvements (Table 10). The following were assessed:

- 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

- Namon Primary School (Tabiang Village);
- Hiram Beigham High School (Rongorongo Village); and
- Teibubutei Primary School & Beru Junior Secondary School (Nuka Village).

All the schools have considerable potential for increasing RWH water supply with good roofing materials and substantial catchment areas, but will need significant improvements in infrastructure, such as down pipes, fascia boards, guttering and additional storage.

[1] http://ict.sopac.org/kiriwatsan/login/index

2. Churches

Both Kiribati Protestant Church (KPC) and Catholic Church buildings were surveyed for their existing RWH status and potential. A total of nine (9) churches were surveyed. Most of these church buildings make good communal rainwater harvesting centres due to 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.

3. *Maneaba*

Three (3) *maneaba* (village-owned and church-owned) were surveyed for their existing rainwater harvesting status and potential. Similar to the churches, *maneaba* also make good communal rainwater harvesting centres due to their communal accessibility and substantial roof catchment but lack collection, transmission, storage and abstraction facilities as indicated above.

Added consideration should be made on *maneaba* roof heights, some of which were measured to be as low as 1.4 m, when designing and/or selecting appropriately sized rainwater storage tanks for rainwater harvesting.

4. Village clinics

The three (3) newly constructed village health clinics at Autukia, Tabiang and Taubukiniberu were surveyed and do not require any immediate infrastructural improvements.

5. Private buildings

Several privately owned buildings were also surveyed due to 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 owner.

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

Village	Autukia	Tabiang	Aoniman	Nuka	Teteirio	Taubukiniberu	Total
Number of buildings surveyed	3	16	4	13	3	5	44
Buildings with proper roofing materials	2	10	2	4	2	3	23
Buildings without fascia board	0	5	0	3	0	0	6
Buildings without guttering	0	10	0	4	0	0	14
Buildings without down pipes	0	13	1	9	1	4	28
Buildings with overhanging vegetation	1	10	3	4	2	2	22
Buildings with tanks	3	4	3	5	2	2	19

It was assessed that:

- 52% of the buildings have good roof conditions – with the remaining 48% requiring minor repairs to total replacement of roofs.
- 14% of the suitably roofed buildings do not have fascia boards, 32% do not have guttering, and 64% do not have down pipes, demonstrating that the buildings are inadequately equipped for optimum rainwater collection and transmission.
- 50% appear to be partially covered with vegetation raising the potential of rainwater contamination, and guttering blockages and overflow.
- 43% of the buildings have storage tanks, suggesting that more than half of the buildings will require suitably sized rainwater tanks to be installed for secure and adequate storage/conservation.

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

Suggested upgrades to improve rainwater harvesting potential include the following:

- Repair or replacement of roofing materials with corrugated zinc-aluminium coated steel, preferably.
- 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 to (1) store rainwater for low-roof *maneaba* and abstracted via *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 Beru, 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[2] with an estimated 57% of households abstracting the groundwater with the use of bailers (Figure 9). Most wells are poorly sited and constructed. Many wells are with inadequate casing or

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

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 two hundred and forty-five (245) wells across six (6) villages in Beru (Table 11). Standard water resource assessment techniques for the groundwater survey were used. These included surveying all wells in the target villages to help determine:

Figure 9. A communal well in Taubukiniberu Village, sited away from the residential areas and abstracted by multiple* Tamana *pumps.

- well location;
- construction type;
- general condition;
- contamination risk;
- salinity; and
- 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 95% of all households in the target villages on Beru rely on groundwater for their potable and domestic water needs. This is reflected in the high percentage of well ownership for households – between 44% to 122%[3] – depending on the village. Well ownership data indicates that:

[3] More wells surveyed than households indicate some households have more than one well, and/or there are communal wells providing water supply.

- 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 due to 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 10. Multiple* Tamana *pumps installed in a communal well for Taubukiniberu Village.

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

Village	Autukia	Tabiang	Aoniman	Nuka	Teteirio	Taubukiniberu	Total
Number of wells surveyed	28	78	23	87	22	7	245
Number of households (2010 census)	39	87	28	99	18	16	287
% of households with access to individual wells	72	90	82	88	122	44	
% of households relying on groundwater for water needs (Census 2010)	85	99	96	98	94	100	
INFRASTRUCTURE							
Unlined wells	2	4	2	6	0	0	14
Wells with coral-rock casing	18	37	12	30	8	1	106
Wells with cement-ring casing	8	26	9	47	13	6	109
Wells with cement-block casing	0	5	0	4	0	0	9
Wells with PE/PVC casing	0	5	0	0	0	0	5
Wells with timber casing	0	0	0	0	1	0	1
Wells with parapet	23	66	20	50	14	4	177
Wells without cover	22	35	19	68	15	2	161
Wells without apron	13	67	18	68	22	7	195
Wells without fence	27	67	22	85	20	7	228
ABSTRACTION							
Wells using *Tamana* pumps	6	44	5	22	6	4	87
Wells using solar pumps	0	1	0	1	0	0	2
Wells using electrical pumps	1	1	0	0	1	3	6
Wells using bailers	20	28	17	60	14	0	139
Well not used	1	4	1	4	0	0	10
CONTAMINATION							
Wells located ≤ 20 m from contaminant sources	15	59	19	69	0	4	166
WATER QUALITY – PHYSICAL PROPERTIES							
Average total depth (mbgl)	2.1	1.1	2.2	1.9	1.7	1.2	1.7
Average depth to water table (mbgl)	1.8	0.9	1.9	1.7	1.4	0.9	1.4
Maximum salinity (mS/cm)	4.4	12.4	18.9	15.4	6.2	3.6	18.9
Minimum salinity (mS/cm)	0.6	0.5	0.5	0.5	1	1.3	0.50
Average salinity (mS/cm)	1.4	3.3	7.1	4.4	2.6	2.0	3.5
Median salinity (mS/cm)	1.2	2.2	6.2	4.2	2.1	1.7	2.9
Number of wells exceeding salinity limit	3	29	16	53	0	1	102
WATER QUALITY – BACTERIOLOGICAL TESTS							
Number of E.coli samples taken	10	19	5	17	10	6	67
Number of samples showing E.coli presence	9	13	4	15	9	4	54
% of samples indicating contamination	90	68	80	88	90	67	

The well survey suggests that most wells (> 65%) 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 on construction, condition and maintenance of surveyed wells, from households, community, church, clinic and schools is summarised below:

- For accessible wells surveyed, 6% were unlined, 43% use coral rocks, 44% use locally made cement rings, 4% use cement blocks and 2% use other materials, such as polyethylene (PE) drums, tins and timber. The remaining 1% is completely covered with no information recorded on construction details.
- 72% 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.
- 66% of the wells do not have proper covers and 93% 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 water from groundwater wells is carried out by:

- 36% of wells using locally-made *Tamana* or hand pump (Figures 10 & 11);
- 1% of wells using solar pumps;
- 2% of wells using electric submersible pumps;
- 57% of wells using bailers, namely buckets, tins and containers – most bailers were found unprotected, lying on the ground, with increased potential for contamination; and
- 4% 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 to the groundwater. Unused wells should be covered, and abandoned wells backfilled with clean sediments to help minimise contamination risk.

Figure 11. A* Tamana *pump connected to a completely covered well in Aoniman Village.

Figure 12. Aoniman KPC* maneaba *– a target communal building for RWH.

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 µS/cm. This limit is used in many parts of the Pacific, as 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 individual. That is, some individuals and communities will be used to slightly more brackish water than others based on what they are accustomed to. 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.[4]

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 µS/cm (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 Beru and to provide guidance for management purposes.

Salinity µS/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%	Salinity taste in the water will be perceptible to all and unacceptable to many Upper limit of freshwater
50,000	100%	Seawater

[4] http://www.who.int/water_sanitation_health/dwq/guidelines/en/

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

- The median EC value of the 245 wells at the time of the survey was 2940 µS/cm suggesting the overall dominance of brackish wells.
- The average depth to the water table is 1.45 mbgl for all wells; and the maximum and minimum depths for the water table based on all sites are 3.14 – 0.55 mbgl, respectively.

One hundred and two wells (102), 42% of the surveyed wells, exhibited salinity levels in excess of the 2500 µS/cm adopted limit for freshwater resources. The higher salinity of these wells is likely to be due to well 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.

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 lagoon shoreline.

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 procedure 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 E. coli results of tested groundwater wells and rainwater tanks, is provided in Annex 5, with village contamination maps shown in Annex 6.

A summary of the sampled wells and rainwater tanks is presented in Table 13 below.

Table 13. Summary of tested groundwater wells and rainwater tanks around the target villages.

Village	Guideline compliant (0 E.coli count/100 ml)	Tolerable (1-10 E.coli/100 ml)	Requires Treatment (11-100 E.coli count/100 ml)	Unsuitable without proper treatment (>100 E.coli count/100 ml)	Total
Autukia	1	1	1	7	10
Tabiang	6	10	1	2	19
Aoniman	1	1	3	0	5
Nuka	2	4	8	3	17
Teteirio	1	3	1	5	10
Taubukiniberu	2	2	1	1	6
Total	13	21	15	18	67
	19%	31%	23%	27%	100%

Table 13 shows that water from approximately 80% of the sampled wells and rain tanks indicated the presence of E.coli bacteria. This can be attributed to:

- 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 prevent the entry of contaminated water or contaminant sources;
- poor storage and handling of bailers used for abstracting groundwater and rainwater; and
- ingress of contaminated surface-runoff during heavy rainfall events.

The results from the well water sampling represents the bacteriological status of the tested wells or rainwater tanks at the time of the survey, and is 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 be placed 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, 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 algal 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.
- Hand pumps such as the *Tamana* pump, which
    - is relatively easy to operate and maintain;
    - uses materials readily available (locally) for repairs;
    - allows access to better quality water whereby the well can be located at distant more secure and better yielding sources away from contamination sources;

    - permits low-yield abstraction that minimises up-coning and saline intrusion; and
    - reduces the need for activities to be centred very close to the well, thereby reducing the potential for 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 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 Beru Island between the 19th and the 27th of November 2013, using the Geonics EM34 unit owned by the Ministry of Public Works and Utility.

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

4.4.2 Survey location

Thirty-four (34) EM34 survey lines were completed across the target villages. The focus for geophysical investigations was the area within the immediate vicinity of the each target village, as these were the areas of most interest for the villages. It was considered that undertaking investigations within 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 location of EM surveys at 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 due to the presence of *bwabwai* pits, dense vegetation and areas of flooding.

4.4.3 Interpretation of results

The relationship derived from the EM34 calibrations of EM34 readings and known freshwater thicknesses from monitoring bores, undertaken during the KIRIWATSAN and SAPHE projects was used to convert all EM34 field measurements in the villages (Table 14, Annex 7). Based on the estimated freshwater thicknesses, contours were hand drawn into MapInfo GIS using 2.5 m contour intervals and presented in Annex 6.

Table 14. EM34 conductivity readings applied for selected freshwater zones are based on the combined KIRIWATSAN and SAPHE field calibration data.

Freshwater zone thickness (m)	EM Conductivity (mS/cm)	
	10 m	20 m
1	44	79
2	36	66
3	31	58
4	28	52
5	26	48
6	24	44
7	22	41
8	20	39
9	19	36
10	18	34

The extent of the freshwater lens underneath the surveyed villages were defined as the area of freshwater with an EC reading of less than 2500 µS/cm and estimated thickness of greater than or equal to 2.5 m. This definition follows from the recent groundwater investigations of GWP under KAPII, 2010. Any estimated thickness less than 2.5 m is classified as of limited groundwater potential, being more likely to be brackish during prolonged dry periods (Falkland, 2004). The extent of the lens underneath each village is presented in Table 15.

Table 15. Estimated freshwater lens area beneath the target village areas.

Village	Autukia	Tabiang	Aoniman	Nuka	Teteirio	Taubukiniberu
Total land area (m^2)[1]	928,270	2,244,240	1,380,320	1,825,500	585,980	287,600
Freshwater lens area (m^2)[2]	12,041	1,297,950	525,600	1,180,900	293,600	114,000
Lens/Total land ratio (%)	1%	58%	38%	65%	50%	40%
Fresh groundwater potential	Limited	Good	Moderate	Good	Good	Moderate

Note:

[1]the EM34 survey area, in some cases, does not cover the entire village.

[2]Freshwater lens area has an estimated thickness of greater than or equal to 2.5 m, in line with previous groundwater assessments under KAPII.

Apart from Autukia, which showed poor groundwater potential, the fresh groundwater potential for the other surveyed villages in Beru is moderate to good. The poor groundwater potential in Autukia is likely to be caused by the dominant influence of adjacent and extensive mangrove swamps, allowing the flow of saline water and limiting fresh groundwater storage.

The villages (as illustrated in Annex 6), where households are predominantly located, have an estimated freshwater lens of typically less than 1 m thick. The household wells, located in these areas are poorly sited with regards to the fresh groundwater potential of the island. During dry seasons, wells located in these peripheral areas of fresh groundwater potential can be expected to become brackish.

Note that the EM34 survey does not provide any indication of potability of the groundwater with respect to pathogens nor to identify its risk to contamination. Water quality testing for E. coli bacteria is used in combination with the assessment of contamination source threats to help identify the risk of contamination of the groundwater. Groundwater quality sampling was undertaken for selected wells with the results provided in Section 4.3.3.

Caution is required when applying freshwater lens thickness estimates for calculations of water demand and water resource potential as the lens thickness estimates are relevant to the climatic conditions at the time of the survey and will vary over time in response to recent rainfall events.

Freshwater lenses are dynamic, contracting and expanding in response to climatic variations. El Niño and La Niña conditions have a significant impact on the rainfall in equatorial regions and therefore the freshwater lens. During La Niña, drier conditions are experienced in Kiribati which will have the effect of reducing the freshwater lens thickness whilst during El Niño, high rainfall conditions will increase the freshwater lens thickness. It is necessary to monitor the freshwater lens thickness over time, with salinity measurements in selected wells and where possible with repeated EM34 survey under different climatic conditions. The monitoring and reporting of rainfall and salinity variations in wells over time will be important for developing the sustainability of abstraction and drought management plans and actions that village communities can consider.

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 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 impact and tidal lag observed. 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 16.

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;
- permeability on the ocean side of the island is 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 – 25 m.

Tidal measurements are not available for Beru. In the absence of actual measurements, a tidal prediction calculator was used to calculate tides. The spreadsheet was developed by Doug Ramsey (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 ± 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 monitoring wells at the Bonriki water reserve (collected during the Bonriki Inundation Vulnerability Assessment (BIVA) project) is provided in Table 17 for comparison with the data collected from Beru, as well as the results from other KIRIWATSAN 1 survey islands, namely Abaiang, Nonouti, and Maiana.

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

Figures 13 and 14 graph the monitoring wells at Rongorongo and Teteirio villages (~8 km apart).

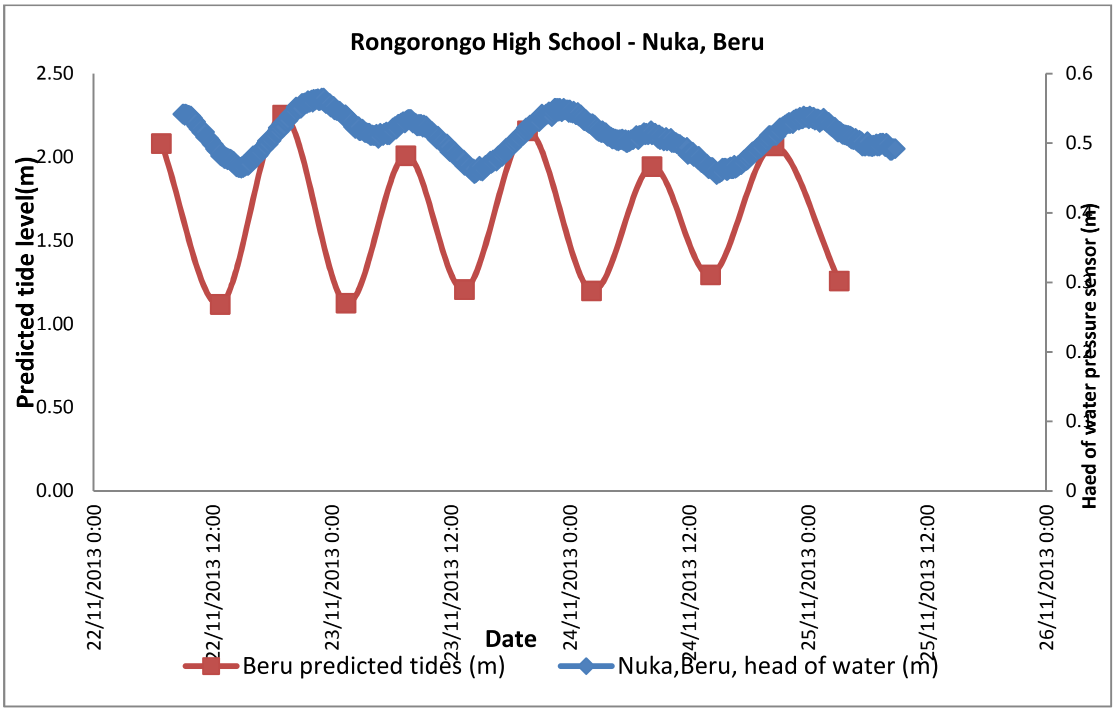

Figure 13. Predicted tidal height and measured groundwater level at Hiram Beigham High School community well in Rongorongo Village, abstracted by solar pump system, with groundwater monitoring commencing at 9 am (22nd November 2013) and terminated after 71.8 hours.

Table 16. A summary of the logger data records and calculated tidal lags and efficiencies for selected wells on Beru Island. (See also Annex 8)

Village	Well Owner	Diver number	Distance from closest water body, ocean or lagoon (m)	Start Date and time	End date and time	Length of record (hrs)	Tidal lag	Tidal efficiency
Autukia	Rouben Nikora	K6813	130	19/11/2013 10:00	20/11/2013 8:12	22.2	2.1	8%
Tabiang	Kaireiti	K6813	40	20/11/2013 9:06	21/11/2013 8:18	23.2	3.1	7%
	Ubwanteman	P5144	60	20/11/2013 10:00	21/11/2013 12:42	26.7	2.4	4%
Nuka	Catholic Church	K6813	150	22/11/2013 8:30	25/11/2013 9:06	72.6	2.4	4%
Rongorongo	Hiram Beigham High School	P5144	170	22/11/2013 9:00	25/11/2013 8:48	71.8	2	7%
Teteirio	Village	K6813	90	25/11/2013 10:00	28/11/2013 14:30	76.5	2.1	7%
Taubukiniberu	Agriculture Station	P5144	90	26/11/2013 10:00	28/11/2013 14:48	76.8	2.2	6%
Average						52.8	2.3	6%

Table 17. Summary of tidal lag and tidal efficiency of monitoring bores at the Bonriki Water Reserve during the BIVA Project.

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	1.8	7.9%	-17.7
Bonriki , Tarawa	BN2B	270	2.2	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	1.2	14.3%	-11.9
Bonriki , Tarawa	BN32	450	0.6	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	2-2.2	6.6%	-11.6
Bonriki , Tarawa	PS18	365	2.7	5.0%	-10.9

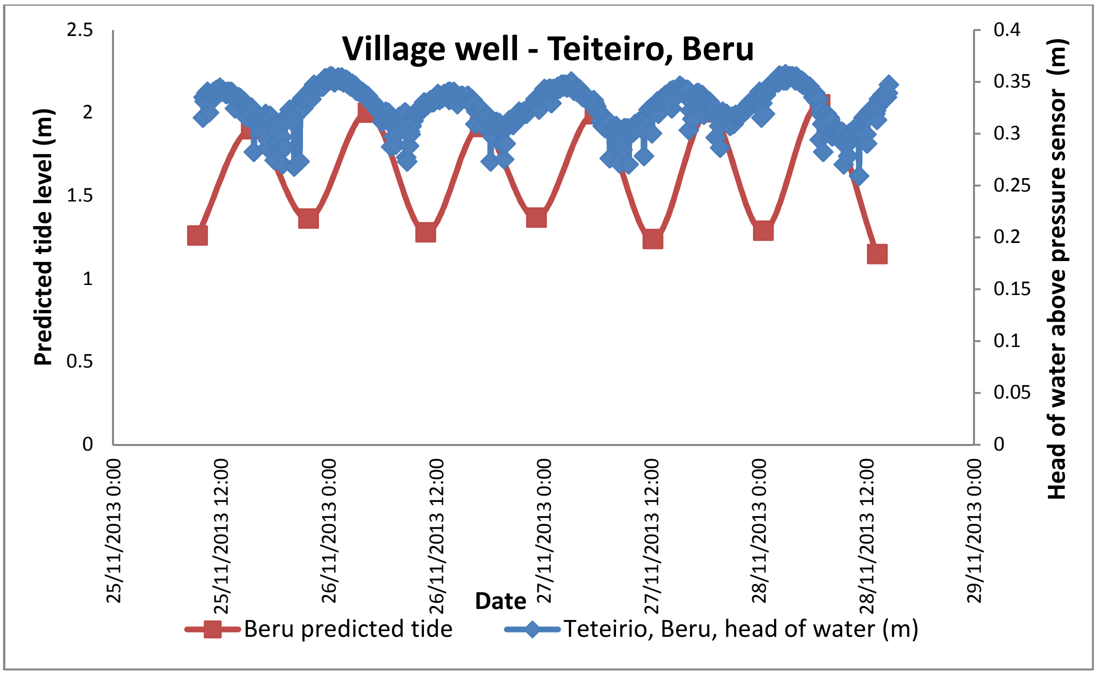

Figure 14. Predicted tidal height and measured groundwater level at communal well at Teteirio Village, abstracted by multiple hand pumps, with groundwater monitoring commencing at 10 am (25th November 2013) and terminated after 76.5 hours. Note the length and frequency of groundwater abstraction is shown through the occasional abrupt decreases in water level.

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, Beru's groundwater response is similar although there is stronger correlation with Abaiang, Nonouti and Maiana islands (Figure 15). This suggests a similarity in geology of the islands, although sediments are likely to be more permeable for Beru than found in Bonriki, hence 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 is required to assess this suggested variation between the islands.

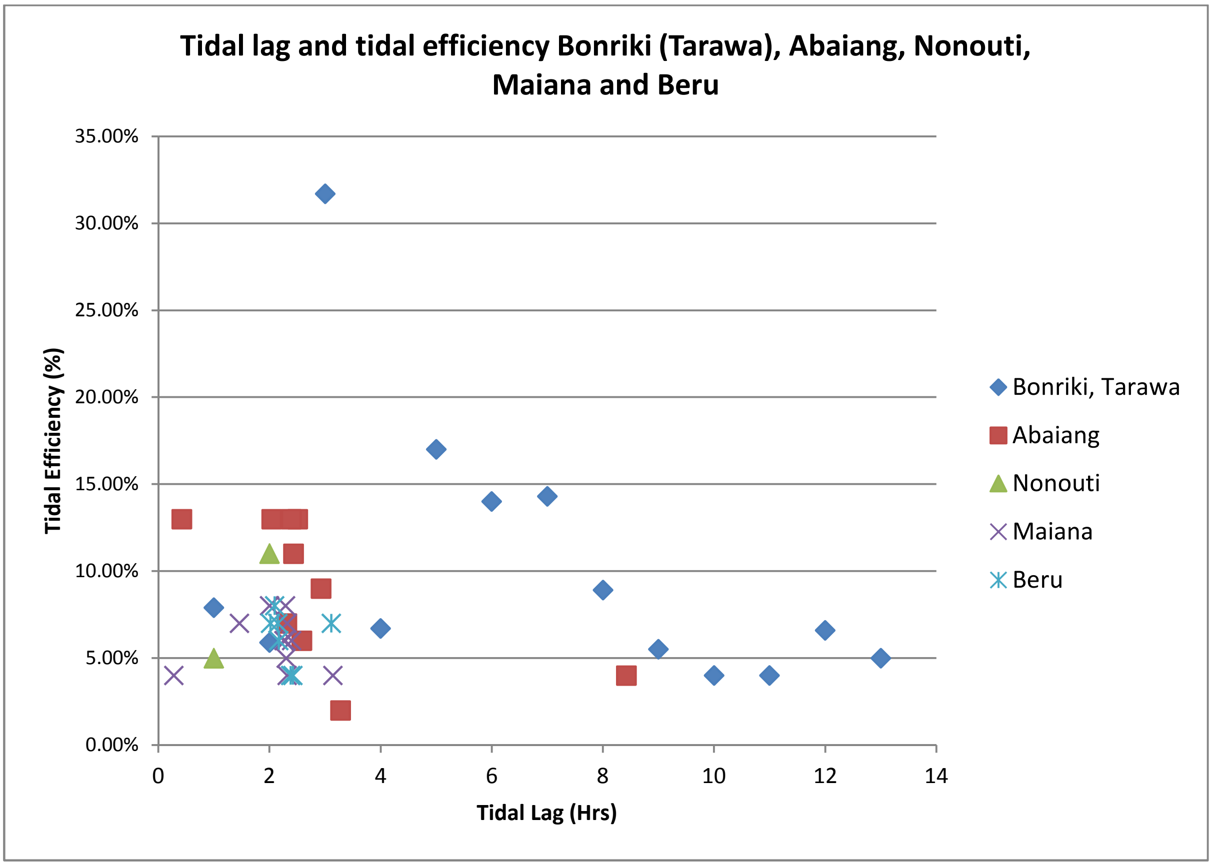

Figure 15. Tidal lag and tidal efficiency for Bonriki, Tarawa and KIRIWATSAN monitoring data from Abaiang, Nonouti, Maiana and Beru, with anomalous values removed.

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 Beru monthly rainfall record (from January 1945 to June 2014), the rainwater harvesting potential in the communal buildings was assessed through a rainwater calculator developed and utilised by the KAP II Project (see also Annex 9).

A summary of all the communal buildings and subsequent analyses are presented in Table 18, assuming that all roofs are equipped with proper facilities.

From Tables 18 and 19, 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 an appropriate storage volume 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 providing an increase in water supply as demanded by a fixed population will gradually decrease once the maximum roof area is reached. An analysis was conducted using White's (2010) rainfall calculator to determine the ideal storage for a range of roof catchment areas in Beru (see Figure 16). This was conducted using:

- a roof area range of 50 – 450 m^2;
- 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 18. Summary of potential communal RWH centers. (See also Annex 9)

Village	Building Type	Owner	[1]Roof area (m^2)	Building ID	Percentage of roof bordered by guttering	[2]Collecting Roof Area (m^2)	[3]Gutter Condition	[4]Guttering Efficiency	[5]Effective Roof Area (m^2)	[6]Improved Roof Area (m^2)	[7]Rain Tank Capacity (L)
Aoniman	Church	KPC Church	170	Ao1	50%	85	Replace	0.15	13	127	5000
	Maneaba	KPC Church	260	Ao2	0%	0	None	0	0	195	5000
	Church	LDS Elders	59	Ao3	50%	29	Replace	0.15	4	44	5000
	Church	Catholic Church	93	Ao4	25%	23	Replace	0.15	3	70	5000
				Villager total[8]					21	436	20000
Autukia	Church	Catholic Church	158	Au1	50%	79	Replace	0.15	12	119	6000
	Church	KPC Church	83	Au2	50%	41	Replace	0.15	6	62	6000
				Village total					18	180	12000
Nuka	Church	Catholic priest	71	Nu1	50%	35	Replace	0.15	5	53	5000
	Church	Catholic	237	Nu2	100%	237	Replace	0.15	36	178	5000
	Church	KPC Church	405	Nu3	50%	203	Replace	0.15	30	304	5000
	Church	KPC minister's house	142	Nu4	50%	71	Replace	0.15	11	107	5000
				Village total					82	641	20000
Tabiang	Church	KPC Church	287	Ta1	50%	143	Replace	0.15	22	215	5000
	Church	KPC Minister	165	Ta2	25%	41	Replace	0.15	6	124	5000
	Church	Catholic Church	175	Ta3	25%	44	None	0	0	131	6000
				Tabiang total					28	470	16000
Teteirio	Church	KPC Church	110	Te1	50%	55	Adequate	0.55	30	82	5000
Rongorongo[9]	Church	KPC Church	564	Ro3	0	0	None	0	0	423	0

Notes:

[1] the product of the measured roof length and width
[2] the product of the roof catchment area and the current guttering coverage
[3] observed on-site guttering condition
[4] guttering efficiency values are derived from White (2010) shown in Table 19 below. This assigns 0.75 efficiency to a "good" guttering – this also considers the run-off coefficient as specified in the White (2010) rainfall calculator spreadsheet
[5] the product of collecting roof area and guttering efficiency
[6] assumes 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 × 0.75
[7] existing rainwater storage volume
[8] represents the aggregate roof capacity for all the buildings in each village in relation to meeting the villages' current and future drinking water demands
[9] confusion regarding the land boundary between Rongorongo and Nuka resulted in the extension of the field survey into Rongorongo Village

Table 19. 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 = Tank Capacity/1000 (L)
Roof Area (m^2)	A
% Guttering	Percentage of roof edge bordered by guttering
Collecting Roof Area (m^2)	A_{col} = (%Guttering) x 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^2)	A_{eff} = C x A_{col}

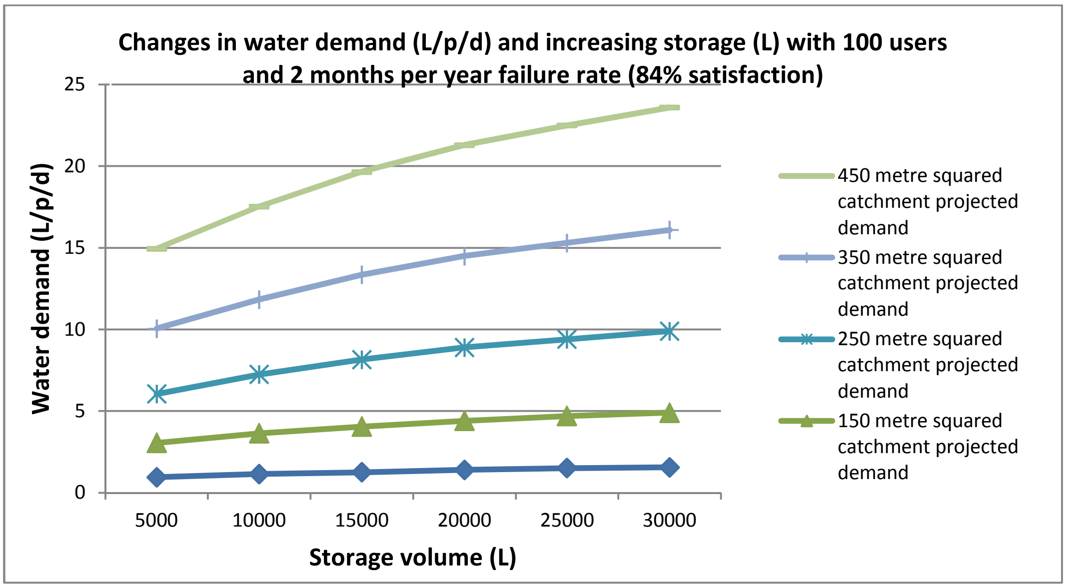

Figure 16. Changes in water demand (L/p/d) in relation to changing roof catchment and increasing storage volume based on 2 months failure rate in any one year (84% satisfaction).

Table 20. Analysis of building potential by village to serve the current and future populations (after White, 2010). (See also Annex 9)

Village	Population	[1]RWH capacity under current catchment conditions (L/p/d)	[2]RWH capacity with roof improvements (L/p/d)	[3]RWH with roof improvements with improved storage of 20,000 L at each building (L/p/d)
Aoniman	2010 (123)	0.6	5.3	8.4
	2030 (89)	0.84	7.5	11.5
Autukia	2010 (188)	0.31	1.85	3.4
	2030 (117)	0.57	3	3.8
Nuka	2010 (443)	0.44	2	2.9
	2030 (433)	0.45	2	3
Tabiang	2010 (399)	0.23	1.75	2.5
	2030 (328)	0.28	2.1	3.2
Teteirio	2010 (79)	0.81	1.7	2.5
	2030 (102)	0.63	1.3	1.9
Rongorongo	2010 (190)	0	0	9
	2030 (79)	0	0	21

Note:

[1] Water demand under normal condition uses the current roof condition (effective roof area from Table 18) and the 2010 and 2030 populations

[2] Water demand under improved condition uses the improved roof catchment from Table 18 and the 2010 and 2030 populations

[3] Water demand under improved condition and storage assigns a 20,000-L storage increase to all buildings and uses Table 18 and the 2010 and 2030 populations

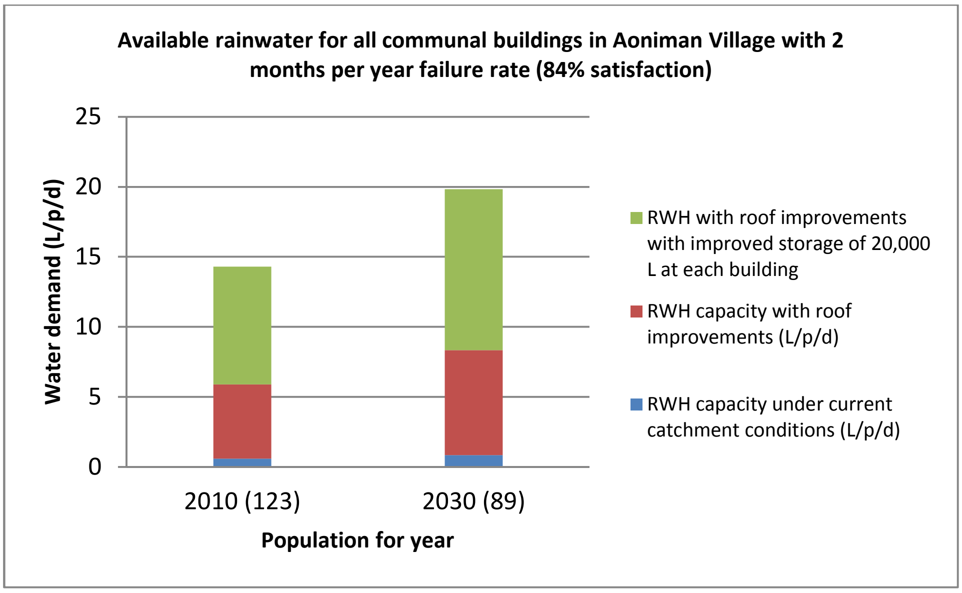

Figure 17. Analysis of per capita water demand on all target communal buildings in Aoniman Village with 2 months per year failure rate (84% satisfaction).

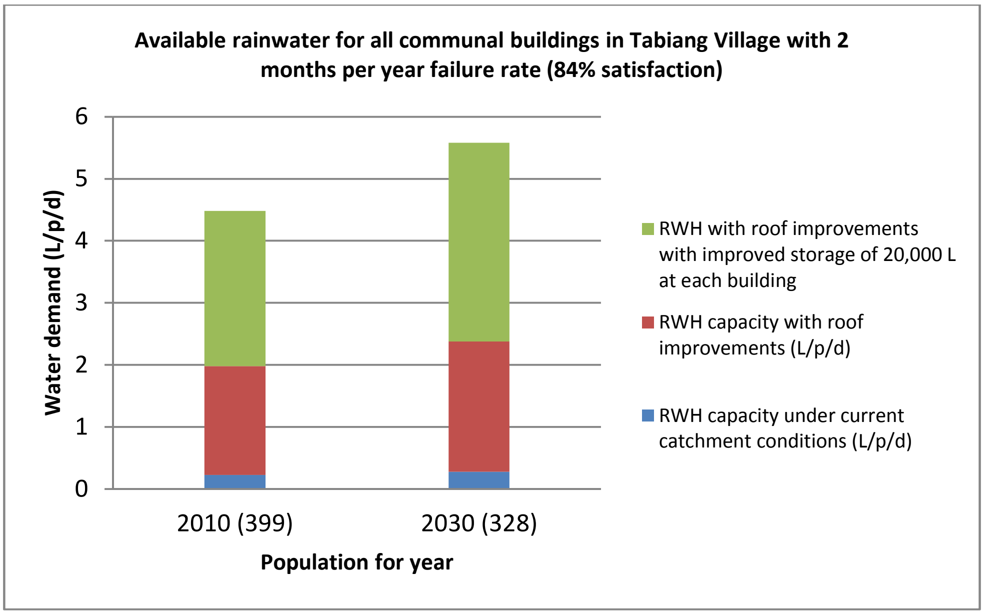

Figure 18. Analysis of per capita water demand on all target communal buildings in Tabiang Village with 2 months per year failure rate (84% satisfaction).

Table 20, and Figures 17 and 18 indicate that most of the communal buildings, namely church and *maneaba,* have the potential to adequately provide 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.

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 well maintained, is susceptible to contamination. The use of rainwater harvesting 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 rainwater harvesting 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 rainwater harvesting 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 EM34 geophysics principles and survey results as presented in Annex 7, indicate the ground conductivity readings for each survey point and the corresponding estimate of the freshwater lens thickness based on the reference data (refer to Section 4.4).

The estimated freshwater lens thicknesses based on the EM34 survey were hand-contoured using 2.5 m contour intervals to delineate the spatial extent of freshwater lens for each village (Annex 6).

An average of the freshwater lens thicknesses for the main groundwater resource determined from the EM34 survey was used to calculate the estimated freshwater lens volume. A specific yield of 0.3 for coral sand was assumed to calculate the available groundwater volume that could be abstracted. A summary of groundwater resources underlying each village is presented in the Table 21.

It appears that the variability in lens extent for villages is greatly influenced by island width at village locations. Note that Autukia has the least lens coverage, which is possibly due to its location around the narrow part of the island.

Some uncertainty should be noted in the estimated lens extent as determined from the EM34 survey in certain villages. The uncertainty is due to:

- limited access to some areas due to *bwabwai* pits and dense vegetation restricting the survey; and
- time constraints, resulting in the survey lines not being completed as planned.

Table 21. Summary of estimated groundwater resources underlying each village.

Village	Autukia	Tabiang	Aoniman	Nuka	Teteirio	Taubukiniberu
Surveyed area (m^2)[1]	928,270	2,244,240	1,380,320	1,825,500	585,980	287,600
Maximum width (m)[2]	900	1,100	550	900	700	650
RAINFALL RECHARGE[3]						
Average annual rainfall recharge (m/yr)	0.32	0.32	0.32	0.32	0.32	0.32
2030 predicted annual rainfall recharge (m/yr)	0.35	0.35	0.35	0.35	0.35	0.35
FRESHWATER LENS[4]						
Freshwater lens area (m^2)	12,041	1,297,950	525,600	1,180,900	293,600	114,000
Average freshwater lens thickness (m)	1.4	13.8	4.9	12.8	7.2	8.3
Lens/surveyed area ratio	1%	58%	38%	65%	50%	40%
Freshwater lens area > 6 m thick (m^2)	0	494,000	65,000	963,300	127,300	82,400
Average freshwater lens thickness (m)	0	12.9	13.3	16.8	16	9.1
Lens/surveyed area ratio freshwater lens > 6 m thick	0%	22%	5%	53%	22%	29%
AVAILABLE FRESHWATER ESTIMATION[5]						
Freshwater lens volume (m^3)	16,857	17,911,710	2,575,440	15,115,520	2,113,920	946,200
Available groundwater (m^3)	5,057	5,373,513	772,632	4,534,656	634,176	283,860
Freshwater lens volume > 6 m thick (m^3)	0	6,372,600	864,500	16,183,440	2,036,800	749,840
Available groundwater for lens > 6 m thick (m^3)	0	1,911,780	259,350	4,855,032	611,040	224,952

Notes: [1]the total land area covered by the EM34 survey, which, in some places, does not cover the entire village, [2]maximum island width estimated from the MapInfo (GIS) [3]rainfall recharge considers Falkland's rainfall/recharge ratio (Section 3.4) and takes into account the long-term annual average, minimum annual and the estimated 5% increasing rainfall proposed by the Australian Bureau of Meteorology & CSIRO (2011), [4]areas having lens thickness equal or greater than 2.5 m, after KAPII (GWP, 2011). The freshwater lens is delineated by selecting all estimated freshwater thickness greater than or equal to 2.5 m, whereas a proposed drought resilient zone is mapped around areas having the estimated freshwater thickness more than 6 m (Based on the 5 – 5.5 m drought-induced potential reduction in freshwater lens thickness, [5]freshwater lens volume = average freshwater lens thickness x lens area, groundwater volume represent the usable groundwater based on the assumed specific yield of 0.3 for coral sands (Falkland, 2003)

The freshwater lens thickness and areal extent and associated calculations in Table 21 are based on the survey and ground conditions present at the time of the investigation. The freshwater lens thickness will vary over time during wet and dry periods.

Unlike Tarawa, there are no dedicated monitoring wells on Beru, making it difficult to confirm the estimated freshwater lens thickness and extent, and to determine the variation in the freshwater lens over time. An indication of the changes to the lens over time can be obtained if regular salinity measurements are collected from selected wells around the island.

5.2.2 Residence time and sustainable yield estimation

Residence time is an expression of the time taken for water to move through the lens, and can be calculated by dividing the volume of groundwater in the lens by the total annual rainfall recharge (Vacher et al., 1990). The thickness of the freshwater lens influences the residence time of the groundwater, residence time is estimated to be from about 1 to 13 years for villages depending on the estimated freshwater thickness determined from the EM34 (Table 23).

The sustainable yield is a term often used for planning and management purposes to estimate the range or maximum limit that abstraction should be restricted to ensure water at sufficient quantity and quality for the social, environmental and economic considerations of the aquifer over the long term.

Sustainable yield in an atoll environment is often restricted to considering the needs of society with the greatest abstraction being for domestic needs, including drinking, washing, cooking, and household animals. Agriculture and irrigation is limited and little has been done on the needs and considerations of groundwater dependent environments in atolls. As a first estimate sustainable yield can be calculated as a percentage of the recharge for the lens area.

Falkland 2003 provides the following:

$y = x - 10$

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

For Beru, rainfall recharge is estimated using the approach of Falkland (2003) at 24% indicating that sustainable yield is estimated to be 14% of the average annual recharge, or 3.4% of the annual average rainfall. This approach would appear to be conservative.

A comparison was made between the estimated sustainable yield for Bonriki water reserve using the Falkland (2003) approach; and the modelled sustainable yield for Bonriki after Alam et al. (2002), see Table 22. (Note that Betio rainfall was used for both cases as this is what was used in the Alam et al. (2002) groundwater model).

Table 22. Analysis of previous sustainable yield work by Falkland (2003) and Alam et al. (2002).

	Estimated sustainable yield (after Falkland, 2003)	Modelled sustainable yield (after Alam et al., 2002)
Betio Annual rainfall (mm)	2021 (1984-2013)	1812 (1954-1991) 40% tree cover 1791 (1954-2001) 20% tree cover
Recharge mm/yr	712	926 (Using Watbal program) 980 (Using Watbal program)
Recharge as a % of rainfall	35%	47% (1954-1991) 40% tree cover 50% (1954-2001) 20% tree cover
Sustainable Yield as a % of recharge	SY = 35 – 10 = 25%	SY modelled = 1600 m^3/day = 56% (1954-2001) 20% tree cover
Sustainable Yield as a % of rainfall	9%	28%

Table 22 allows for a comparison between two approaches, estimated and modelled, for the same aquifer, the Bonriki water reserve. The recharge and corresponding estimated sustainable yield as a percentage of rainfall is determined using Falkland (2003) to be 9% of rainfall, while the calculated sustainable yield using the modelling results from Alam et al. (2002) is calculated to be 28% of rainfall – the modelled result being three times the result from the Falkland (2003) methodology.

The Bonriki water reserve in the ensuing 12 years after using the modelled sustainable yield from Alam et al. (2002) has operated successfully with abstraction (on average) slightly above the modelled sustainable yield at about 1700 m^3/day during the period 2002-2014. This suggests that the 'estimated' approach to sustainable yield is likely to be quite conservative and is suggested could be used as the lower estimate of a sustainable yield range.

It is recognised that the Bonriki freshwater lens is a relatively large freshwater lens compared with the other freshwater lenses in the Gilbert Islands. Taking into account the variable sizes of freshwater lenses it is considered prudent to also be conservative in suggesting an upper estimate of the sustainable yield to be twice the 'estimated' sustainable yield for each village water reserve using the Falkland (2003) approach. For larger freshwater lenses, similar in size to Bonriki, this upper estimate could be extended to 2.5 times the 'estimated' sustainable yield.

The resulting range of 'estimated' sustainable yield is useful for planning in the longer-term development of the groundwater resources.

The estimated sustainable yield (m^3/day) for each village and the theoretical sustainable yield per capita in 2010 are summarised in Table 23.

Based on the maximum water demand of 65 L/p/d (Falkland & White, 2009), it is clear that the mapped freshwater lenses in Tabiang, Aoniman, Nuka, Teteirio and Taubukiniberu are able to support the daily demand of the target villages' current populations.

5.2.3 Lens vulnerability to anthropogenic contamination, drought, population growth and climate change

a) Anthropogenic contamination

Intrinsically, freshwater lenses in atoll environments are susceptible to contamination due to the shallow depth to groundwater. The commonly observed contamination sources include pig pens, *bwabwai* pits, poorly sited and constructed sanitation systems, and general household activities such as washing and waste disposal. The E.coli sampling results indicate the prevalence of well water contamination. The sampling notes the extent of anthropogenic contamination observed in wells at the time of survey. The contamination of wells has the potential to increase as populations in the villages increase and well design and construction remain unchanged. Contamination of water sources such as groundwater environments that populations are located immediately above is inevitable. Measures to reduce the impact of contamination and awareness of the impact of the anthropogenic influences are required to help communities with self-management of the groundwater system. These include, but are not limited to, the relocation of contaminant sources to a nominal separation distance of at least 20 m from the wells.

b) Drought

Extended dry periods will result in stress to the freshwater resources in atoll environments in much reduced timeframes than seen in other aquifer systems, in part due to limited storage. The freshwater lens will “shrink” in response to reduced rainfall and recharge. Long-term monitoring of rainfall, abstraction and the lens thickness will assist in determining the impact on the lens and the capacity of the freshwater lens to provide groundwater of suitable salinity for domestic purposes. Monitoring and modelling of the impact of drought on the Bonriki water reserve and freshwater lens in Tarawa, based on observations during drought conditions from 1998 to 2000, predicted a reduction in lens thickness by between 5 m and 5.5 m (Falkland, 2003). These observations suggest that areas with a freshwater thickness of 6 m or more provide some drought resilience.

The drier season for rainfall is generally from May to November, with an average dry season rainfall of 648 mm for Beru, based on monthly rainfall from 1945 to2014. The lowest recorded annual rainfall was recorded in 1950, with 247 mm.

Using these dry-period parameters, the average recharge will reduce to 155 mm (24 % of rainfall) and 59 mm for the dry months and for the lowest annual rainfall, respectively.

The following observations can be made from Table 21 (above):

- Significant reduction to available groundwater is observed in all villages restricting available groundwater to those areas with a freshwater lens thickness of > 6 m.
- Autukia would yield negligible fresh groundwater during extreme dry periods because of its hydrogeological challenges.

Mapped freshwater lens of Tabiang, Aoniman, Nuka, Teteirio and Taubukiniberu villages is able to support the current water demand under extreme dry conditions. The above estimates are guides only and would require validation and monitoring of well water quality and rainfall to lessen effects on the lens during extended dry periods.

c) Population growth

Table 23 shows that all target villages will not be subject to the same pressures of population growth. The following are worth noting:

- Autukia, because of hydrogeological constraints, is expected to have salinity issues although a negative population growth is projected. Alternative water conservation strategies, such as the installation of additional rainwater harvesting systems and/or construction of underground cisterns, may be required to meet drinking water needs during extended dry periods.
- The other villages will have sufficient freshwater resource capacity to meet their estimated water demand of 65 L/p/d.

d) Climate change

The rainfall predictions for Kiribati under future climate models indicates that wet seasons, dry seasons and annual average rainfall will increase in the coming years (Australian Bureau of Meteorology and CSIRO, 2011). This would suggest that an increase in recharge for the groundwater systems can be expected overall. The distribution of this rainfall is not clear, and with increased temperatures, evapotranspiration may also increase.

Falkland & White (2009) have considered applying a 20% reduction in yield for Bonriki by 2030 due to the effects of rising sea level. Following on from this a conservative approach to future sustainable yield is applied to accommodate a 20% reduction in sustainable yield projected for the purposes of planning.

Using the same approach for sustainable yield for the mapped areas of drought resilience (> 6 m of freshwater lens thickness) the sustainable yield per capita estimates are provided in Table 23.

These indicate that in all but one village, water needs can be supported by their respective drought resilient zones. Again, Autukia is unable to support its water demand under the current and future scenarios. The other villages, with proper water resources management and protection strategies, should have adequate freshwater resources to cater for their current and future demands.

These climate calculations do not take into account:

- the variations in population density, land-use and water demand, in different parts of the island; and
- future development and associated population growth.

Table 23. Estimated sustainable yield considering the current and future populations and projected climatic conditions.

Village	Autukia	Tabiang	Aoniman	Nuka	Teteirio	Taubukiniberu
POPULATION DATA						
2010 population	188	399	123	443	79	64
2030 projected population	117	328	89	433	102	35
RAINFALL RECHARGE						
Average annual recharge (m/yr)	0.32	0.32	0.32	0.32	0.32	0.32
2030 predicted annual recharge (m/yr)	0.35	0.35	0.35	0.35	0.35	0.35
FRESHWATER LENS						
Freshwater lens area (m^2)	12,041	1,297,950	525,600	1,180,900	293,600	114,000
Average freshwater lens thickness (m)	1.4	13.8	4.9	12.8	7.2	8.3
[1]RESIDENCE TIME						
Average residence time for freshwater lens (yrs)	1.3	13	4.6	12	6.8	7.8
[2]SUSTAINABLE YIELD RANGE						
Sustainable yield range current (m^3/yr)	615–1230	66309–132618	26851–53703	60329–120658	14999–29998	5824–11648
Sustainable yield range 2030 (m^3/yr)	536–1072	57791–115582	23402–46804	52579–105158	13072–26145	5076–10152
Sustainable yield range current per capita L/p/d	9–18	966–1933	391–783	879–1758	219–437	85–170
Sustainable yield range 2030 per capita L/p/d	13–25	1353–2707	548–1096	1231–2462	306–612	119–238

Notes:

[1] residence time estimate = (average freshwater lens thickness x specific yield)/the annual rainfall recharge. Sustainable yield estimates m^3/day = estimated lens area x the calculated sustainable yield (after Falkland, 2003)/365 days x 0.27 (Section 3)

[2] sustainable yield = recharge as a % of rainfall – 10. Sustainable yield volumetric range considers the measured freshwater lens area, the long-term annual average rainfall recharge and the minimum annual rainfall recharge, and the calculated sustainable yield as a percentage of recharge. The projected 2030 sustainable volumetric yield uses the predicted 5% increase in rainfall (Australian Bureau of Meteorology & CSIRO, 2011) and the estimated 20% reduction in sustainable yield after (Falkland & White, 2009). The per capita sustainable yield in the current and 2030 periods uses the 2010 and 2030 populations, respectively. These estimates of sustainable yield are conservative by nature.

5.3 Community Awareness and Consultation

Community consultation and awareness meetings were held at all the target communities to share and discuss the preliminary WRA results, to establish the major water and sanitation problems and/or identify appropriate preferences from the perspectives of villagers.

Figure 19. Village consultation meeting at Aoniman Village.

Key issues raised during the meetings include the following:

- Requests for more rainwater storage tanks and tap stands in areas of low groundwater yield, such as Aoniman and Autukia.
- Concern shown by villagers on the high E. coli contamination results of sampled drinking water sources
- General preference for solar pumps and hand pumps because of their convenience and low breakdown frequency compared to electric pumps.
- Widespread support shown for the concept of village action plans to address the issues of communal ownership of water supply systems, with respect to the long-term operation and maintenance of water supply infrastructures.
- Assurance given by village elders in relation to allocation of, and permission to access, land for groundwater development; along with the provision of voluntary labour at future activities of water supply project assistance.
- Installation and improvements to rainwater harvesting facilities were requested.

The issues above illustrate:

- the communities' need for improved water supply systems based on the condition and associated challenges of existing systems.

- Moderate awareness of water quality issues and eagerness to address this through improved water supply infrastructure.
- The recognition that communities have the responsibility to select and manage the appropriate water supply option they prefer, be it solar- or hand-pumped systems.
- 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 former notion of government and/or island council being responsible for the maintenance of the villages' 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 documented by Falkland in 2003. This was reviewed at the time of the survey and an updated status for each water supply system is provided in Table 6.

As previously described (Section 3.5), the surveyed villages rely upon groundwater both for potable and non-potable water. Locally-made *Tamana* or hand pumps are commonly used and appear to be functional, during the survey. This is attributed to its low maintenance cost, ease of operation, and availability of spare parts. Solar pumps were observed in schools, but some of them appeared to be non-operational due to either pump failures or stolen solar panel. Electric pumps are installed mainly in medical clinics; some of them were not operating because of electrical faults.

Rainwater harvesting is not widely practised around the island. The reasons for poor rainwater harvesting include the following:

- Buildings with suitable permanent roofs are limited.
- Settlements are sparsely distributed, making access to centralised rainwater harvesting facilities difficult. Most villages are linear developments along the lagoon shoreline, with no natural centre where rainwater harvesting 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 rainwater harvesting centres. The proposed target communal buildings for rainwater harvesting are listed in Table 18 with suggested infrastructural improvements. Designs proposed for rainwater harvesting 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

6.3.1 Household well improvements

This option targets the improvement and protection of household wells. General features of improved groundwater abstraction systems are outlined in Section 4.3.4. Design features for a standard well used at the household level 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 potable purposes should first be boiled.

6.3.2 Communal wells

Communal wells allow a number of households to access and abstract their water needs from the same well – this can be is the preferred option for Aoniman, Teiteirio and Taubukiniberu where a suitable groundwater resource is available within the village residential area. This option can provide potable and non-potable domestic needs, 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 relevant for Tabiang, Aoniman, Nuka, Teteirio and Taubukiniberu. Village wells will be 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 for portable needs. 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 adequate freshwater lens. Nuka and Tabiang are communities with a large population for which an infiltration gallery would be suitable. 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 experiences 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 from 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 impacted by certain land-use practices including poor sanitation options. The survey of wells in the target villages in this study shows more than 67% of the wells are located within 20 m of an identified contamination source – and the majority of the wells (well over 80%) surveyed indicated the presence of E.coli in the water supply.

The 2010 census data indicates a growing preference by the community for pit and flush toilets. The census data also indicates a sizable portion of surveyed households (> 40%) still practice open defecation. It is appropriate to use this growing awareness for improved sanitation and the recent success of compost toilets in Tuvalu to recommend it for use in the outer islands of Kiribati, which shares similar coral atoll environment challenges as Tuvalu. 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:

- coarse textured surficial coral sand underlain by porous and moderately fractured limestone;
- shallow water table;
- relatively permeable unconfined aquifer; and
- 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 the installation of 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 utilise dry vegetation to assist decomposition, with adequate aeration vent and urine-separator, are suitable and can be successfully introduced as seen in Tuvalu (*"Falevatia: A toilet for our future"* http://www.pacific-iwrm.org/videos/Tuvalu-GEF-IWRM-Composting-Toilets.html).

Common factors contributing to the success of introducing an improved sanitation system includes:

- widespread community consultation, education and awareness will be needed 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 is promoted.

6.6 Water System Management

6.6.1 Village Water Action Plan (VWAP)

Due to 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 Beru 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 and 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 routinely conduct 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 rainwater harvesting 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 water supply damage 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 Beru, it is suggested that a specific phase of community consultation at all the villages should be undertaken 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 in (Loco et al., 2015) and outlines the essential steps pertinent to the monitoring of rainfall and selected wells for salinity and water level for freshwater resource development and management. A network of wells, selected across the island for periodical 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 impact to 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, preferable on six month to annual basis, 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) Standard well improvements are recommended for household wells.

2) Communal, village and infiltration galleries are recommended as the preferred option for abstraction of groundwater from suitable locations. The location of proposed shared, communal and gallery systems will have to be confirmed through thorough community consultation.

3) Rainwater harvesting improvements would complement the water diversification for Beru and meet the expectations and preferences of villagers for increased access to rainwater resources. Rainwater harvesting should be considered for communal buildings, where formal agreement between community members and property owners over access to stored rainwater is in place.

4) Periodical groundwater monitoring of wells at selected locations on Beru 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 resource abstraction areas. In addition, repeated EM34 geophysics surveys would be useful to indicate variations in the lens over time.

5) Introduction of appropriate sanitation options is essential to the long-term development and health of the communities. Composting toilets are the most appropriate sanitation. 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.

6) It is recommended that another round of community awareness and engagement meeting 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)

BERU ATOLL, KIRIBATI

Annex 1. Survey Schedule around Beru Island

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 and Filtration Membrane Procedures & Survey Results

Annex 6. Village Water Resources Assessment Maps

Annex 7. EM34 Principles & Survey Results

Annex 8. Village CTD Diver Data

Annex 9. Rainwater Harvesting Analysis Calculator & Results

Annex 10. Village Meeting Notes

Annex 11. Selected Survey Photos

Annex 1

Survey Schedule around Beru Island

This annex presents the water resources assessment (WRA) schedule around the target villages in Beru Island as per the discussion and agreement between the Island Council OIC and the SPC Team.

Table A1-1. Summary of survey schedule around Beru Island.

Date	Villages	Activities
18/11/2013		Team travels to Beru and met with the Island Council OIC to arrange for logistic needs and agree on the survey schedule
19/11/2013	Autukia	Conduct WRA survey in all the villages with EM34 survey conducted in Autukia
20/11/2013	Tabiang	Household well assessment and RWH survey; and EM34 survey were conducted at Tabiang northern and southern segments
21/11/2013	Tabiang & Aoniman	Household well assessment and RWH survey; and EM34 survey were conducted at Tabiang central segment and Aoniman
22/11/2013	Nuka	Household well assessment and RWH survey; and EM34 survey were conducted at Nuka (northern and central segments)
23/11/2013	Nuka	Household well assessment and RWH survey; and EM34 survey were conducted at Nuka (southern segment)
24/11/2013		Team rested at the guesthouse
25/11/2013	Teteirio	Complete household and RWH assessment at Teteirio
26/11/2013	Taubukiniberu	Complete household and RWH assessment at Taubukiniberu
27/11/2013	Taubukiniberu	Complete household and RWH assessment at Taubukiniberu
28/11/2013	Teteirio	Completed EM34 survey at unsurveyed areas and prepared for village meetings
29/11/2013	Autukia, Tabiang & Aoniman	Community awareness and consultation meeting with village groups
30/11/2013	Nuka, Teteirio & Taubukiniberu	Community awareness and consultation meeting with village groups
31/11/2013		Conducted training for Water Technician and visited Namod Primary School near Tabiang Village to assess solar panel and pump
1/12/2013		Team rested at the guesthouse
2/12/2013		Team returned to Tarawa

Annex 2

Historical Monthly Rainfall Data, Beru

This annex provides the historical monthly rainfall data for Beru Island, in the period from January 1945 to June 2014, together with a basic statistical summary.

Table A2-1. Historical monthly rainfall data on Beru Island from 1945 to 2014 (with gaps).

Monthly rainfall data (mm) for Beru, Kiribati													
Station J62300 Latitude 01 19 S Longitude 175 59 E													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
1945	48	7	9	62	54	99	57	60	63	72	22	108	**661**
1946	112	39	128	213	252	211	311	264	46	84	89	241	**1990**
1947	452	65	4	13	12	29	44	11	9	40	80	94	**853**
1948	850	262	60	184	193	109	130	20	38	20	80	270	**2216**
1949	729	139	136	11	62	43	31	32	12	25	3	3	**1226**
1950	1	0	2	2	0	8	28	68	34	31	32	41	**247**
1951	43	7	33	105	199	144	383	280	113	57	35	161	**1560**
1952	350	26	73	114	105	56	94	82	69	91	25	70	**1155**
1953	176	157	101	140	129	119	162	152	162	30	19	216	**1563**
1954	99	6	14	8	12	9	23	47	47	5	0	38	**308**
1955	122	0	45	35	15	12	24	65	36	9	4	27	**394**
1956	53	7	18	19	54	21	153	31	11	16	60	4	**447**
1957	28	46	44	22	151	161	255	85	179	216	383	291	**1861**
1958	338	197	315	582	246	66	117	28	22	33	281	273	**2498**
1959	314	405	194	65	100	52	72	30	10	19	30	9	**1300**
1960	216	31	19	86	53	7	93	33	57	19	11	126	**751**
1961	106	112	155	84	139	181	108	87	55	61	140	0	**1228**
1962	0	0	20	42	24	25	112	78	26	38	1	5	**371**
1963	15	3	27	21	6	113	76	192	48	77	352	360	**1290**
1964	519	535	24	0	6	23	42	93	7	2	27	81	**1359**
1965	27	188	89	105	119	141	287	370	293	384	307	49	**2359**
1966	648	333	152	231	60	30	234	58	57	54	63	65	**1985**
1967	98	0	48	0	92	53	32	41	22	8	53	169	**616**
1968	240	11	0	30	4	2	34	23	6	86	3	182	**621**
1969	342	299	426	276	10	46	40	29	66	61	40	302	**1937**
1970	278	58	137	201	43	132	76	43	13	2	5	5	**993**
1971	6	5	1	35	77	50	52	94	7	28	11	61	**427**
1972	132	42	16	132	366	277	245	231	436	292	345	571	**3085**
1973	651	474	242	22	35	13	7	83	33	2	1	19	**1582**
1974	0	0	0	22	229	31	20	85	25	18	15	276	**721**
1975	332	52	136	69	29	115	30	8	23	6	3	5	**808**
1976	91	16	23	50	191	346	357	344	144	118	30	170	**1880**
1977	207	121	165	352	49	29	155	131	95	58	90	411	**1863**
1978	358	324	320	50	35	75	43	48	1	11	16	153	**1434**
1979	267	259	66	11	93	104	42	28	29	122	84	153	**1258**
1980	100	96	132	63	72	76	15	104	54	108	65	157	**1042**
1981	62	30	150	295	62	132	36	30	81	16	0	125	**1019**
1982	4	10	12	84	64	168	351	460	176	337	182	546	**2394**
1983	78	168	108	146	284	244	385	105	101	0	43	61	**1723**
1984	6	8	11	92	87	40	140	28	47	37	35	24	**555**

1985	55	10	92	0	34	50	21	44	20	33	129	72	**560**
1986	30	7	8	8	16	65	148	101	194	229	132	368	**1306**
1987	356	248	517	362	340	182	279	160	151	84	76	349	**3104**
1988	267	138	185	71	206	28	49	65	20	11	13	6	**1059**
1989	0	0	2	62	33	92	18	11	24	14	30	87	**373**
1990	483	288	242	188	97	72		171	180	62	121	419	**2323**
1991	419	32	26	16	7	98	66	214	165	113	329	210	**1695**
1992	278	145	173	184	318	213	232	55	35	47	167	406	**2253**
1993	198	196	150		236	96			197	203	2	354	
1994	81	7	19	267	77		55	79	203		139	373	
1995													
1996													
1997													
1998													
1999													
2000													
2001	0.0	0.0	0.0	26.0	30.4	77.7	188.1	92.5	33.1	0.6	74.6	490.0	**1013**
2002	176.8	286.3	394.3	111.9	120.1	230.6	78.4	459.5	231.9	96.6	569.9	247.2	**3003.5**
2003	608.1	529.0	395.5	135.9	66.5	5.8		62.6	229.9	72.6	94.3	113.5	
2004													
2005													
2006													
2007													
2008													
2009													
2010	261.0	211.0	273.3	211.1	95.1	18.8	19.9	17.0	6.9	18.9	0.0	68.4	**1201.4**
2011	3.1	2.2	19.0	54.6	65.6	75.5	92.7	133.7	0.0	0.0	0.0	0.0	**446.4**
2012	6.4	10.0	55.3	111.0	215.8	82.9	400.0	57.4	47.4	69.0	57.2	115.1	**1227.5**
2013	40.5	50.1	52.5	51.4	36.7	148.8	17.3	9.0	83.7	66.2	47.3	107.3	**710.8**
2014	9.4	9.0				90.5							

Table A2-2. Basic statistical analysis of discontinuous 1945 – 2014 monthly rainfall.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean	203	116	110	106	102	92	121	104	80	68	89	170	**1331**
Std Dev	210	144	123	113	93	75	114	107	87	83	119	153	**751**
CV*	1.04	1.24	1.12	1.06	0.92	0.82	0.94	1.03	1.08	1.22	1.34	0.90	**0.56**
Max	850	535	517	582	366	346	400	460	436	384	570	571	**3104**
Min	0	0	0	0	0	2	7	8	0	0	0	0	**247**
Median	117	44	60	67	67	76	76	67	47	39	43	125	**1228**
No. of years	58	58	57	56	57	57	54	56	57	56	57	57	**54**

***CV – Coefficient of variation = standard deviation/mean, a measure or 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
5. Agriculture
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

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**

17 **Contamination source**
1. None
2. latrine
3. Pig Pen
4. Rubbish
5. Vegetation
5. Agriculture
6. Fuel depot
7. Other

18 **Contamination distance**

19 **Internal well diameter (m)**

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

21 **DTWT from parapet measuring point**

22 **TD from measuring point**

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**

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

No. Of photos taken

Photo nos.

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

eg Plastic, Cement, Steel, Fibreglass, Wood, Other

Storage Height Width Length

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
2. Drainage
3. Leaking tap
4. Spring loaded tap
5. Clean Gutters
6. Repair gutters
7. Connect downpipe
8. Connect tank
9. Other

18. **Comments**

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

No. Of photos taken ☐

Photo nos.

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
			eg Plastic, Cement, Steel, Fibreglass, Wood, Other

Storage	Height	Width	Length

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
2. Drainage
3. Leaking tap
4. Spring loaded tap
5. Clean Gutters
6. Repair gutters
7. Connect downpipe
8. Connect tank
9. Other

18. **Comments**

______

______

______

______

Annex 5

E.coli Compact Dry Plate and Filtration Membrane Sampling Procedures & Beru Survey Results

Standard Membrane Filtration Method

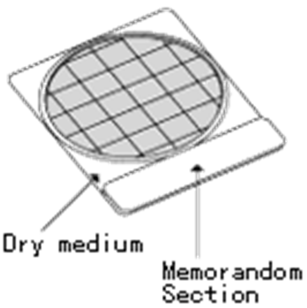
(Adapted from the US Environmental Protection Agency (EPA) and American Public Health Association (APHA) methods (EPA, 2000; APHA, 1995))

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.

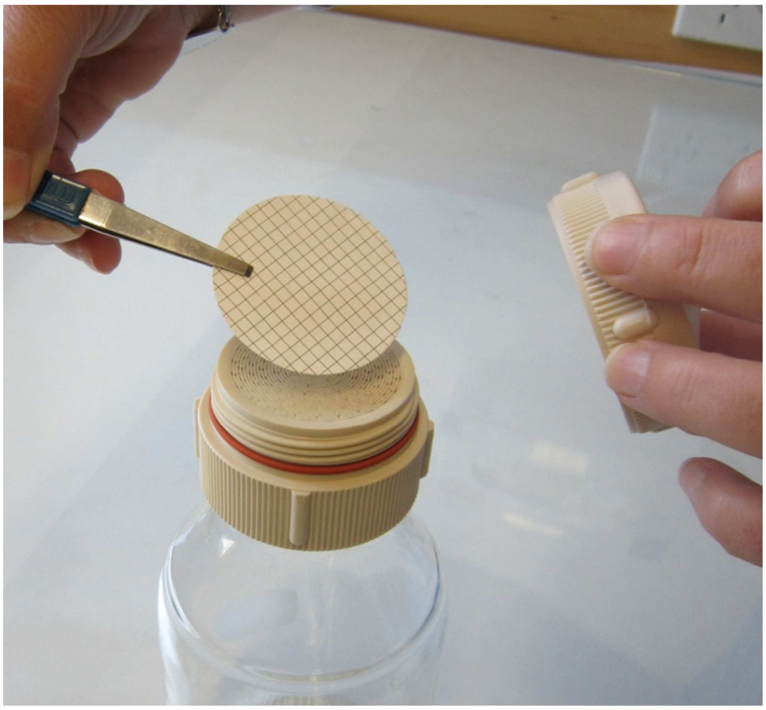
d. Fill the 1 ml syringe with sample water and then pour the sample into its labelled compact dry plate.
e. Repeat the above, until all samples have been prepared for 1 ml analysis.
f. Store all the rehydrated 1 ml plates in a cooler box and record the incubation start time.

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).

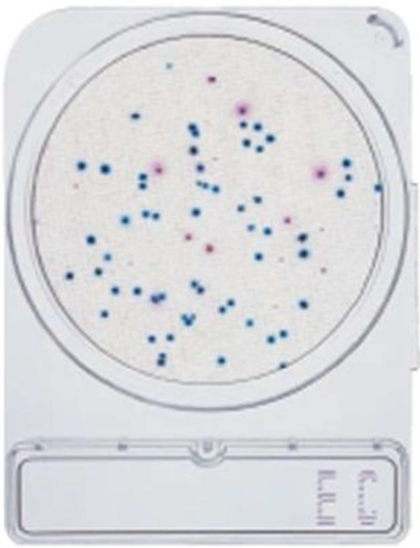
k. Use the sanitised tweezers to transfer the filter paper from the housing to the re-hydrated plate.
l. Repeat steps **d to e** until all samples have been prepared for 50 ml analysis.
m. For the CONTROL, use sterile water, instead of sample water, and subsequent to thoroughly rinsing the syringe and 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:

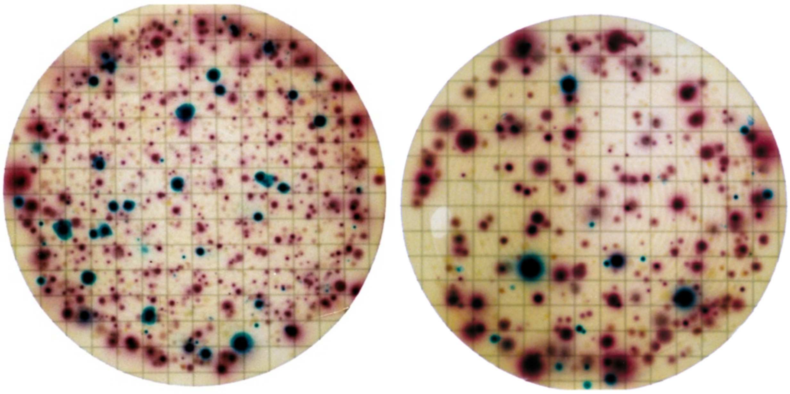
Compact Dry plates: Count the number of red and blue colonies



The number of blue colonies = E.coli

The number of red and blue colonies = Total Coliforms

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.

RESULTS

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

Village	Tank/Well owner	Type	Date	1 ml E.coli Count	50 ml E.coli Count	1 ml E.coli (count/100 ml)	50ml E.coli (count/100 ml)	E.coli (count/100 ml)
Autukia	Maria	W	19/11/2013	1	10	100	20	60
Autukia	Catholic priest	W	19/11/2013	2	17	200	34	117
Autukia	Village well	W	19/11/2013	38	999	3800	1998	2899
Autukia	Moantau	W	19/11/2013	0	3	0	6	3
Autukia	KPC well	W	19/11/2013	4	82	400	164	282
Autukia	Tuarere	W	19/11/2013	5	140	500	280	390
Autukia	Mikaere	W	19/11/2013	3	55	300	110	205
Autukia	James	W	19/11/2013	20	172	2000	344	1172
Autukia	Rouben	W	19/11/2013	0	0	0	0	0
Autukia	Village well (north)	W	19/11/2013	1	80	100	160	130
Autukia	Catholic tank	T	19/11/2013	0	12	0	24	12
Tabiang	Teiwaki	W	20/11/2013	0	4	0	8	4
Tabiang	Tebwa	W	20/11/2013	0	2	0	4	2
Tabiang	Buretu	W	20/11/2013	0	6	0	12	6
Tabiang	Mika	W	20/11/2013	0	0	0	0	0
Tabiang	Moannari	W	20/11/2013	0	0	0	0	0
Tabiang	Tenukai	W	20/11/2013	0	1	0	2	1
Tabiang	Merekitereka	W	20/11/2013	3	92	300	184	242
Tabiang	Maraawa	W	20/11/2013	0	2	0	4	2
Tabiang	Namon Primary School	W	20/11/2013	0	3	0	6	3
Tabiang	Medical Clinic	T	20/11/2013	0	8	0	16	8
Tabiang	Ioobu	W	20/11/2013	0	1	0	2	1
Tabiang	Kakiateman	W	20/11/2013	0	0	0	0	0
Tabiang	Tekita	W	20/11/2013	0	0	0	0	0

Village	Tank/Well owner	Type	Date	1 ml E.coli Count	50 ml E.coli Count	1 ml E.coli (count/100 ml)	50ml E.coli (count/100 ml)	E.coli (count/100 ml)
Tabiang	Taurope	W	20/11/2013	0	6	0	12	6
Tabiang	Teitei	W	21/11/2013	0	0	0	0	0
Tabiang	Tirebu	W	21/11/2013	0	12	0	24	12
Tabiang	Tabiang Central	W	21/11/2013	2	61	200	122	161
Tabiang	Teribwa - shared well	T	21/11/2013	0	1	0	2	1
Tabiang	Mantoa - shared well	W	21/11/2013	0	0	0	0	0
Tabiang	Timeri - shared well	W	21/11/2013	0	2	0	4	2
Aoniman	Aoniman north - shared well	W	21/11/2013	0	30	0	60	30
Aoniman	Aoniman south - shared well	W	21/11/2013	0	8	0	16	8
Aoniman	Pekuauea	W	21/11/2013	0	0	0	0	0
Aoniman	Aoniman village well 1	W	21/11/2013	1	35	100	70	85
Aoniman	Aoniman village well 1	W	21/11/2013	0	19	0	38	19
Nuka	Catholic church	T	22/11/2013	0	1	0	2	1
Nuka	Catholic church cistern	T	22/11/2013	0	13	0	26	13
Nuka	Bwebwe	W	22/11/2013	0	0	0	0	0
Nuka	Ribwataake	W	22/11/2013	0	0	0	0	0
Nuka	Catholic community well	W	22/11/2013	0	60	0	120	60
Nuka	Rongorongo solar pump well	W	22/11/2013	0	19	0	38	19
Nuka	Rongorongo dining hall well 1	W	22/11/2013	0	34	0	68	34
Nuka	Rongorongo dining hall well 2	W	22/11/2013	1	66	100	132	116
Nuka	Patimea	W	22/11/2013	0	1	0	2	1
Nuka	Old Nuka Village well	W	22/11/2013	2	125	200	250	225
Nuka	Ribwataake	W	22/11/2013	0	33	0	66	33
Nuka	Nuka (Miang) Village well	W	22/11/2013	0	16	0	32	16
Nuka	Primary school drinking well	W	22/11/2013	0	13	0	26	13
Nuka	Primary school shared well	W	22/11/2013	0	3	0	6	3
Nuka	Temoaniman JSS well	W	22/11/2013	0	8	0	16	8
Nuka	JSS Principal (Tetaa) well	W	22/11/2013	114	999	11400	1998	6699

Village	Tank/Well owner	Type	Date	1 ml E.coli Count	50 ml E.coli Count	1 ml E.coli (count/100 ml)	50ml E.coli (count/100 ml)	E.coli (count/100 ml)
Nuka	Central Nuka community well	W	23/11/2013	0	15	0	30	15
Nuka	Teaurai	W	23/11/2013	0	35	0	70	35
Taboiaki	Community well 1 Taboiaki south	W	23/11/2013	0	0	0	0	0
Nuka	Community well 2 - Nuka miaki	W	23/11/2013	0	6	0	12	6
Taboiaki	Old drinking well Taboiaki	W	23/11/2013	0	19	0	38	19
Taboiaki	Central Tabiaki - community wells	W	23/11/2013	0	17	0	34	17
Teteirio	Meraina	W	25/11/2013	52	999	5200	1998	3599
Teteirio	Village well - 3 hand pumps	W	25/11/2013	4	222	400	444	422
Teteirio	Reireitemate	W	25/11/2013	0	6	0	12	6
Teteirio	Puteua	W	25/11/2013	8	999	800	1998	1399
Teteirio	Toromon	W	25/11/2013	0	14	0	28	14
Teteirio	KPC rainwater tank	T	25/11/2013	0	8	0	16	8
Taubukiniberu	Hotel well	W	26/11/2013	2	56	200	112	156
Taubukiniberu	Fisheries well	W	26/11/2013	0	25	0	50	25
Taubukiniberu	Agriculture well	W	26/11/2013	0	6	0	12	6
Taubukiniberu	Village well 1 - northern end	W	26/11/2013	0	0	0	0	0
Taubukiniberu	Village well 2 - southern end	W	26/11/2013	0	1	0	2	1
Teteirio	Kaiua	W	26/11/2013	9	TNTC	900	999	949.5
Teteirio	Medical clinic well	W	26/11/2013	0	3	0	6	3
Teteirio	MA well	W	26/11/2013	0	5	0	10	5
Teteirio	Tekeuea	W	26/11/2013	0	0	0	0	0
Taubukiniberu	Fisheries Ice Plant rainwater tank	T	26/11/2013	0	0	0	0	0
Teteirio	Medical clinic rainwater tank	T	26/11/2013	1	81	100	162	131

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

Annex 6

Beru Village Water Resources Assessment Maps

Annex 6 presents the water resources assessment maps for each target village in Beru that includes:

- 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.
- Freshwater lens map showing the 2.5m-interval freshwater lens contour, with existing saline and freshwater wells to provide constraint for the freshwater body towards the coast.
- Contamination map – showing the status of E.coli contamination in the tested wells and rainwater tanks (using compact dry plate filtration membrane procedure) and the estimated freshwater lens contours (as a backdrop) to determine the current status of contamination above and around the projected freshwater body and to aid the community members in the selection of potential groundwater development sites.

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

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

Figure A6.0 – BERU ATOLL INDEX MAP

GILBERT ISLAND GROUP

LEGEND:

★ - Beru Atoll

— - WRA target villages

NOTES

* index of target village maps

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Beru Atoll Index Map

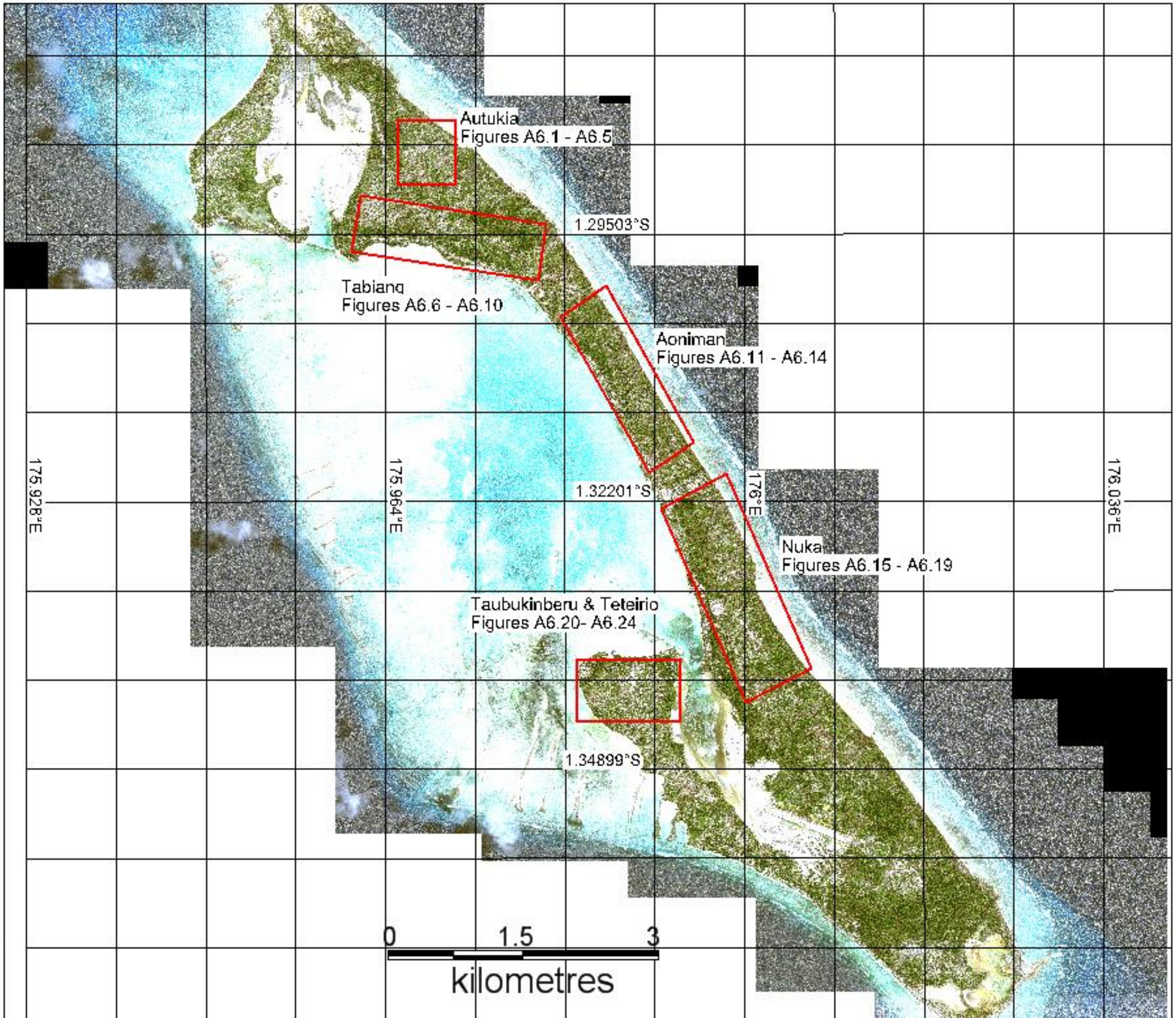


Figure A6.1 – AUTUKIA, BERU – WATER RESOURCES SURVEY MAP

BERU ATOLL

LEGEND:

- freshwater wells (salinity <= 2.5mS/cm)
- saline wells (salinity > 2.5mS/cm)
- EM34 reading locations
- surveyed rainwater storage tanks
- surveyed buildings
- village boundary

NOTES

* the island council buildings, together with the government offices, were also surveyed

* survey is restricted to the target village extents

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Autukia, Beru Atoll

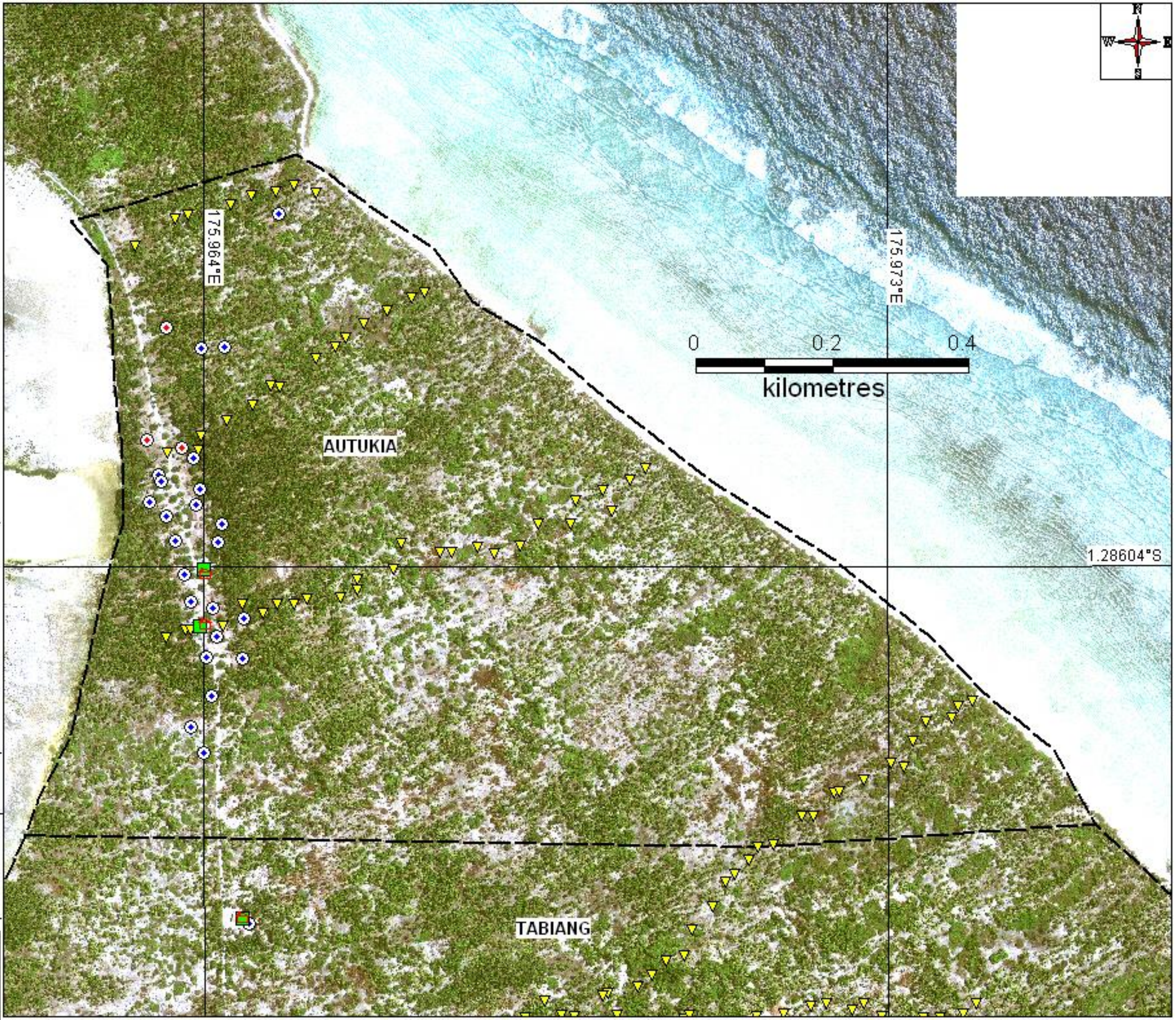


Figure A6.2 – AUTUKIA, BERU – TARGET COMMUNAL BUILDING FOR RWH

BERU ATOLL

LEGEND:

- surveyed buildings

NOTES

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

* Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Autukia, Beru Atoll

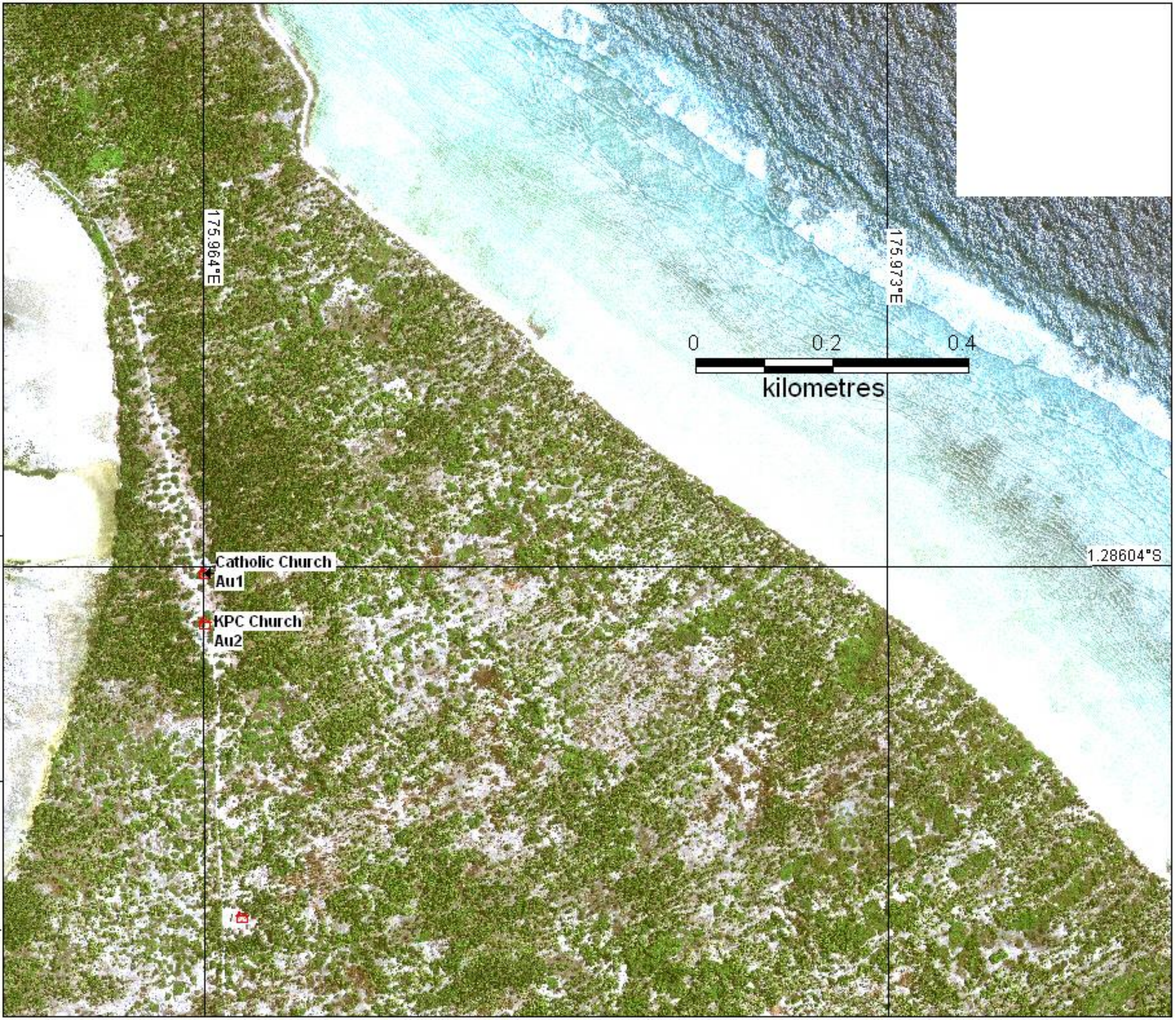


Figure A6.3 – AUTUKIA, BERU – CTD DIVER LOCATIONS

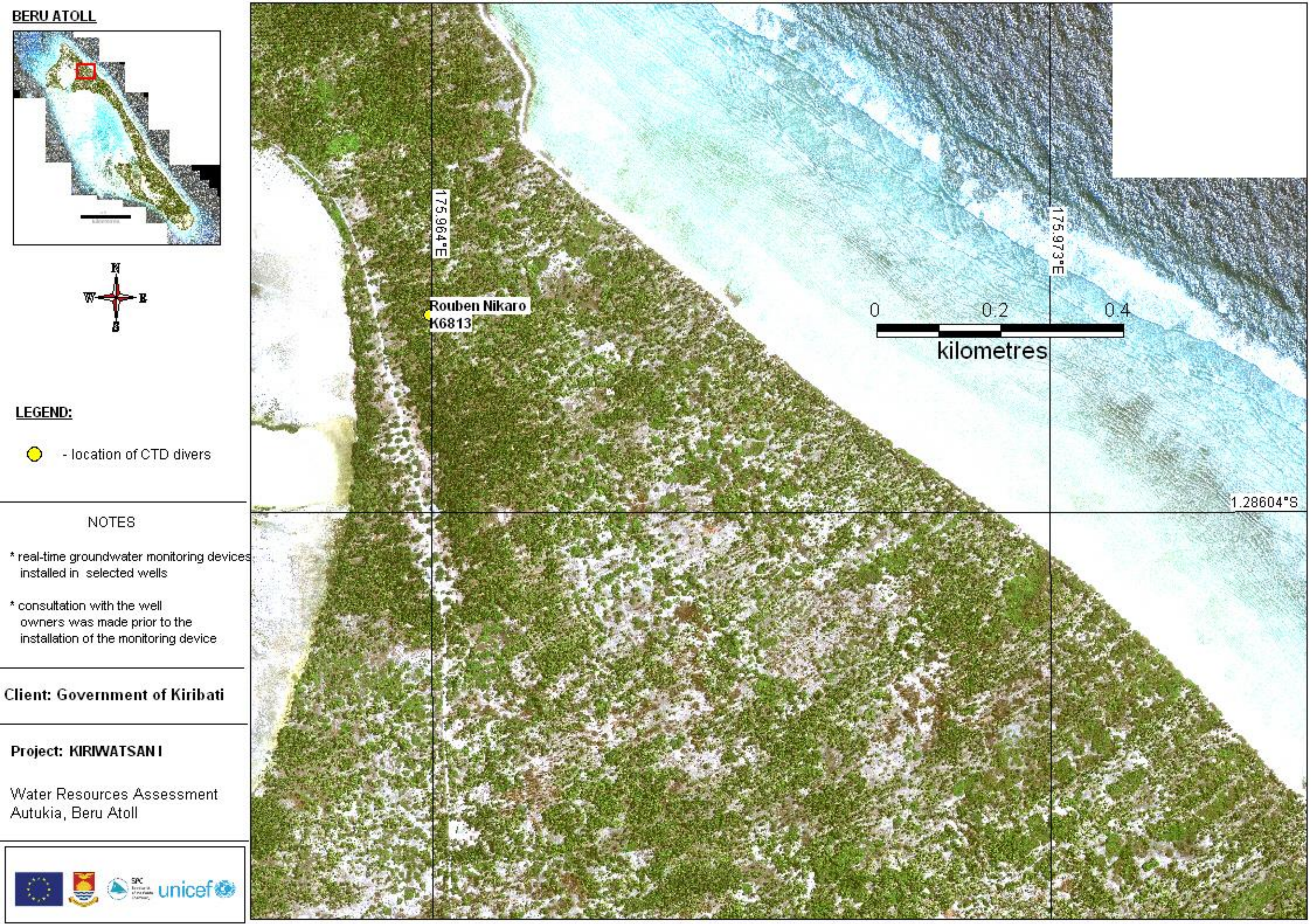


Figure A6.4 – AUTUKIA, BERU – FRESH GROUNDWATER LENS POTENTIAL

BERU ATOLL

LEGEND:

- freshwater wells (salinity <= 2.5mS/cm)
- saline wells (salinity > 2.5mS/cm)
- 2.5m freshwater lens thickness contour
- village boundary

NOTES

* the option and location of groundwater development should be confirmed in consultation with the landholders and village council with consideration to freshwater thickness and potential contamination sources

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Autukia, Beru Atoll

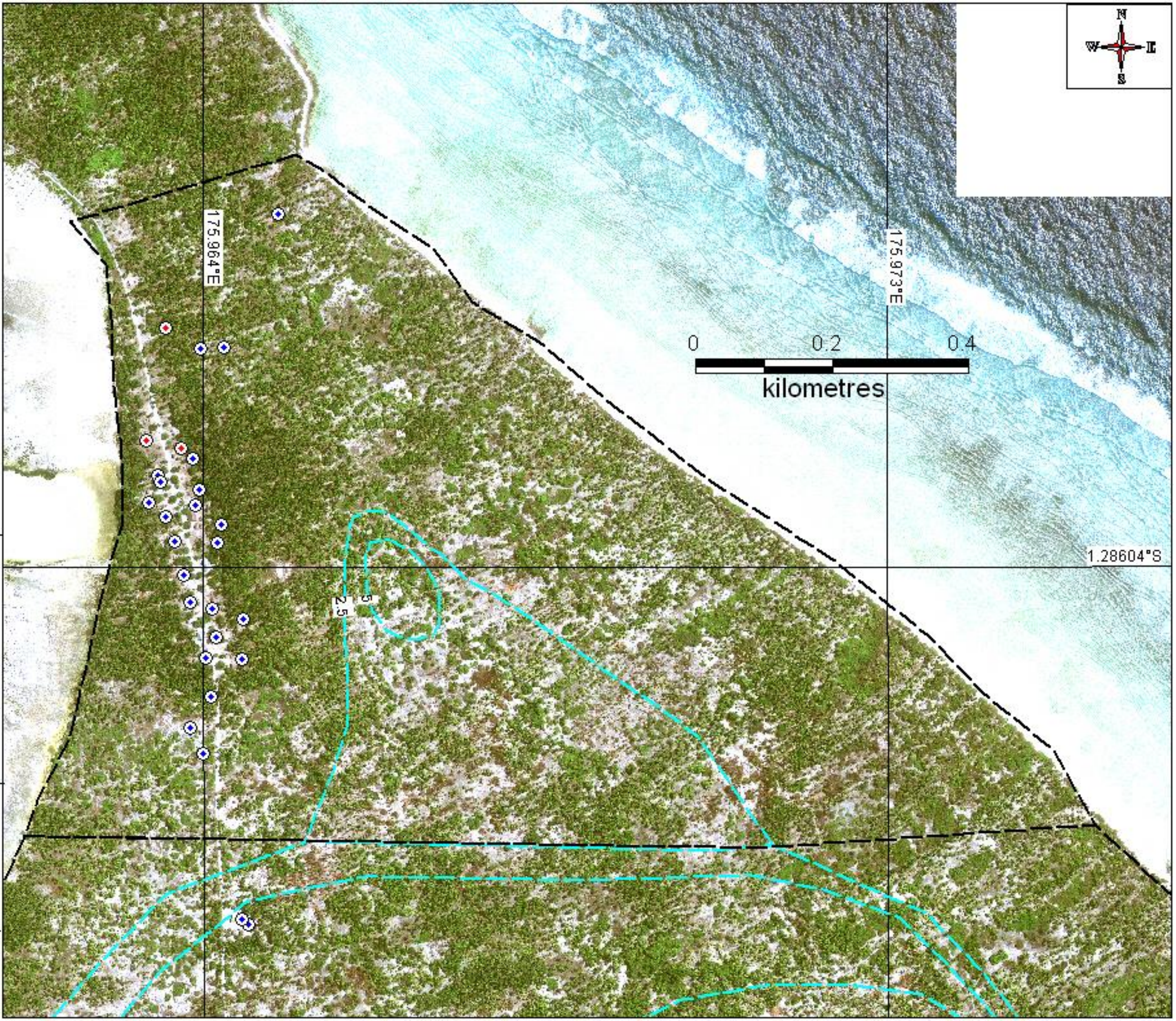


Figure A6.5 – AUTUKIA, BERU – BACTERIOLOGICAL SAMPLING

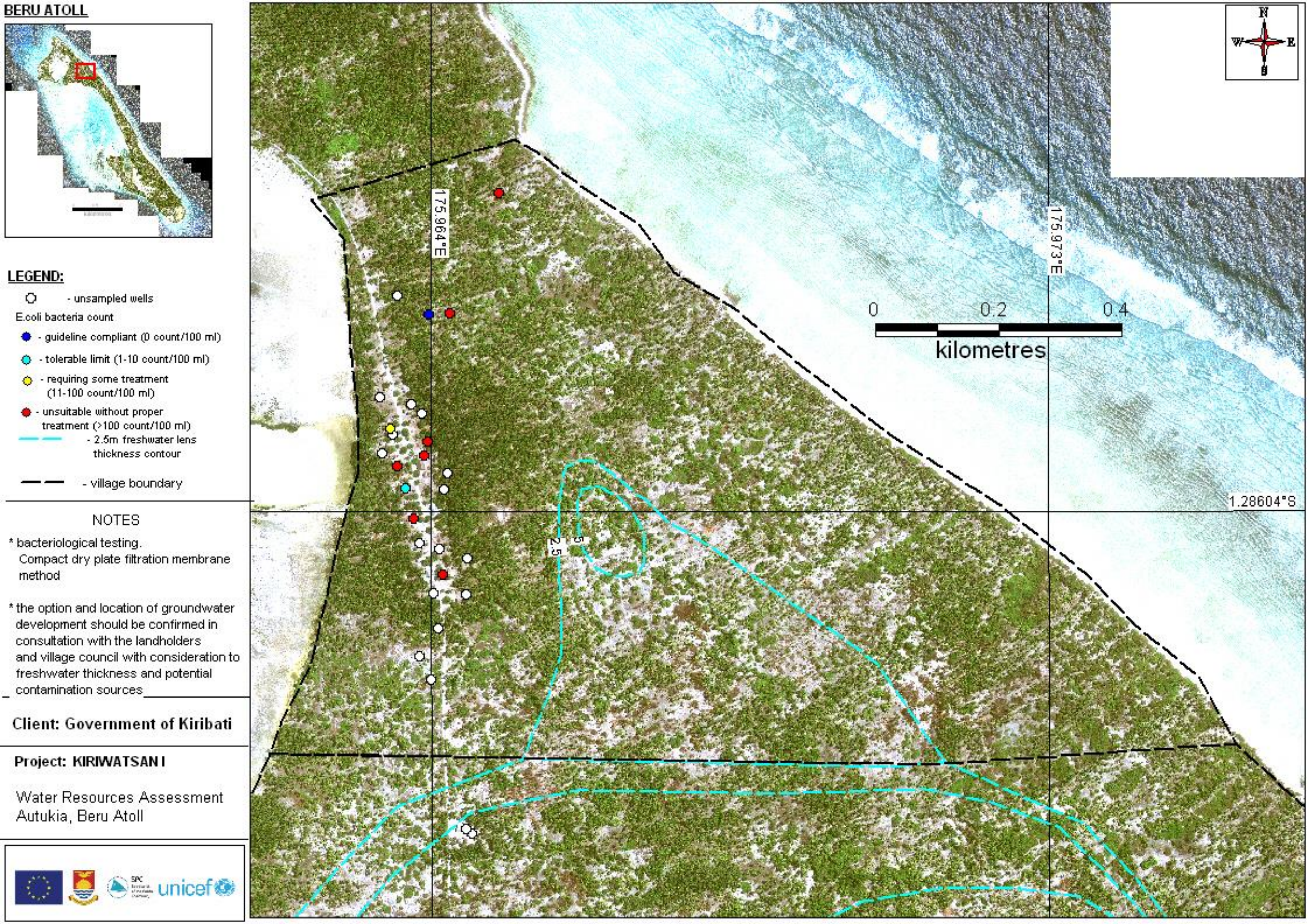


Figure A6.6 – TABIANG, BERU – WATER RESOURCES SURVEY MAP

Figure A6.7 – TABIANG, BERU – TARGET COMMUNAL BUILDING FOR RWH

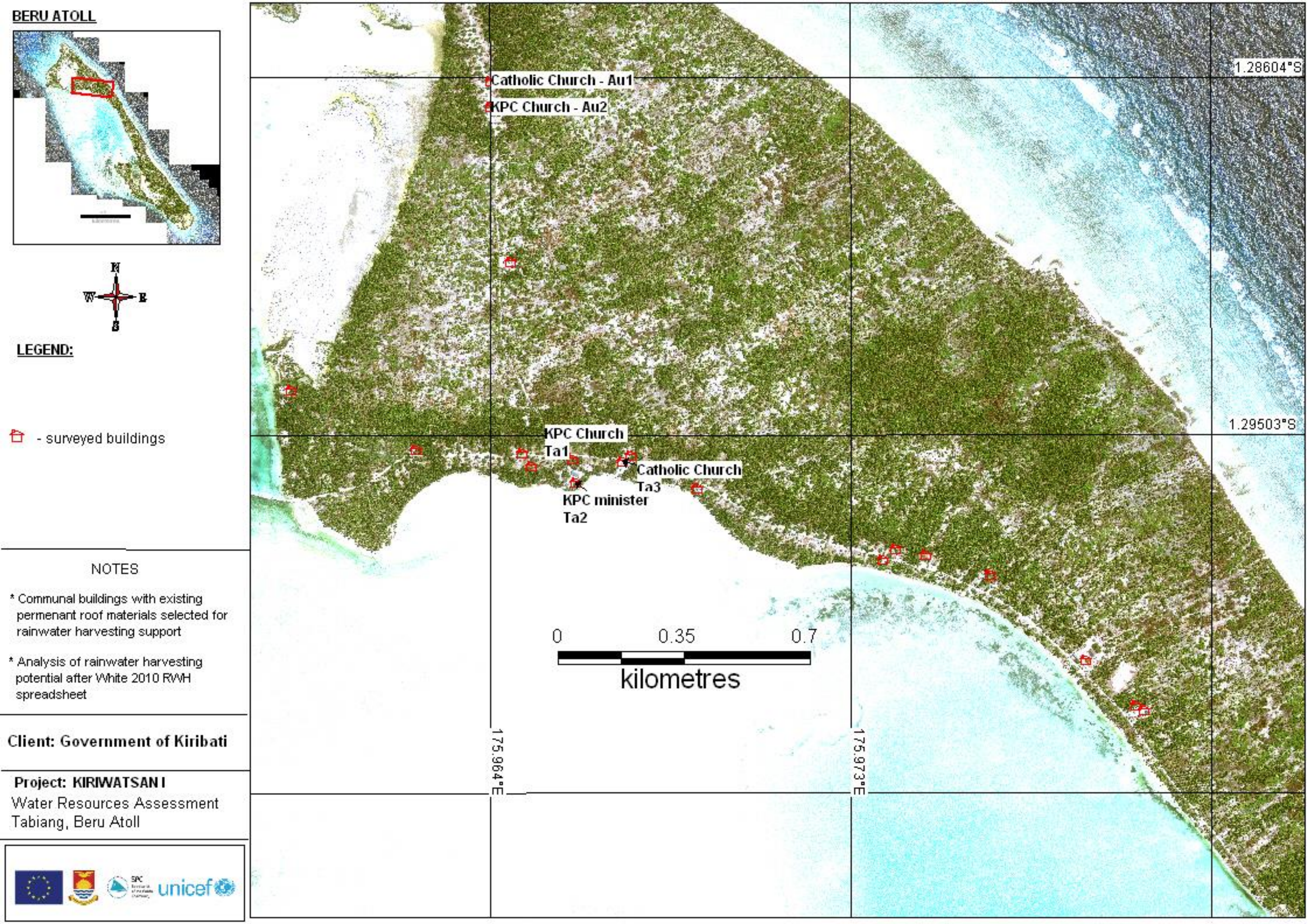


Figure A6.8 – TABIANG, BERU – CTD DIVER LOCATIONS

BERU ATOLL

LEGEND:

- location of CTD divers

NOTES

* real-time groundwater monitoring devices installed in selected wells

* consultation with the well owners was made prior to the installation of the monitoring device

Client: Government of Kiribati

Project: KIRIWATSAN I
Water Resources Assessment
Tabiang, Beru Atoll

Figure A6.9 – TABIANG, BERU – FRESH GROUNDWATER LENS POTENTIAL

BERU ATOLL

LEGEND:

- freshwater wells (salinity <= 2.5mS/cm)
- saline wells (salinity > 2.5mS/cm)
- 2.5m freshwater lens thickness contour
- optimal fresh groundwater lens thickness, >= 6m
- village boundary

NOTES

* the option and location of groundwater development should be confirmed in consultation with the landholders and village council with consideration to freshwater thickness and potential contamination sources

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Tabiang, Beru Atoll

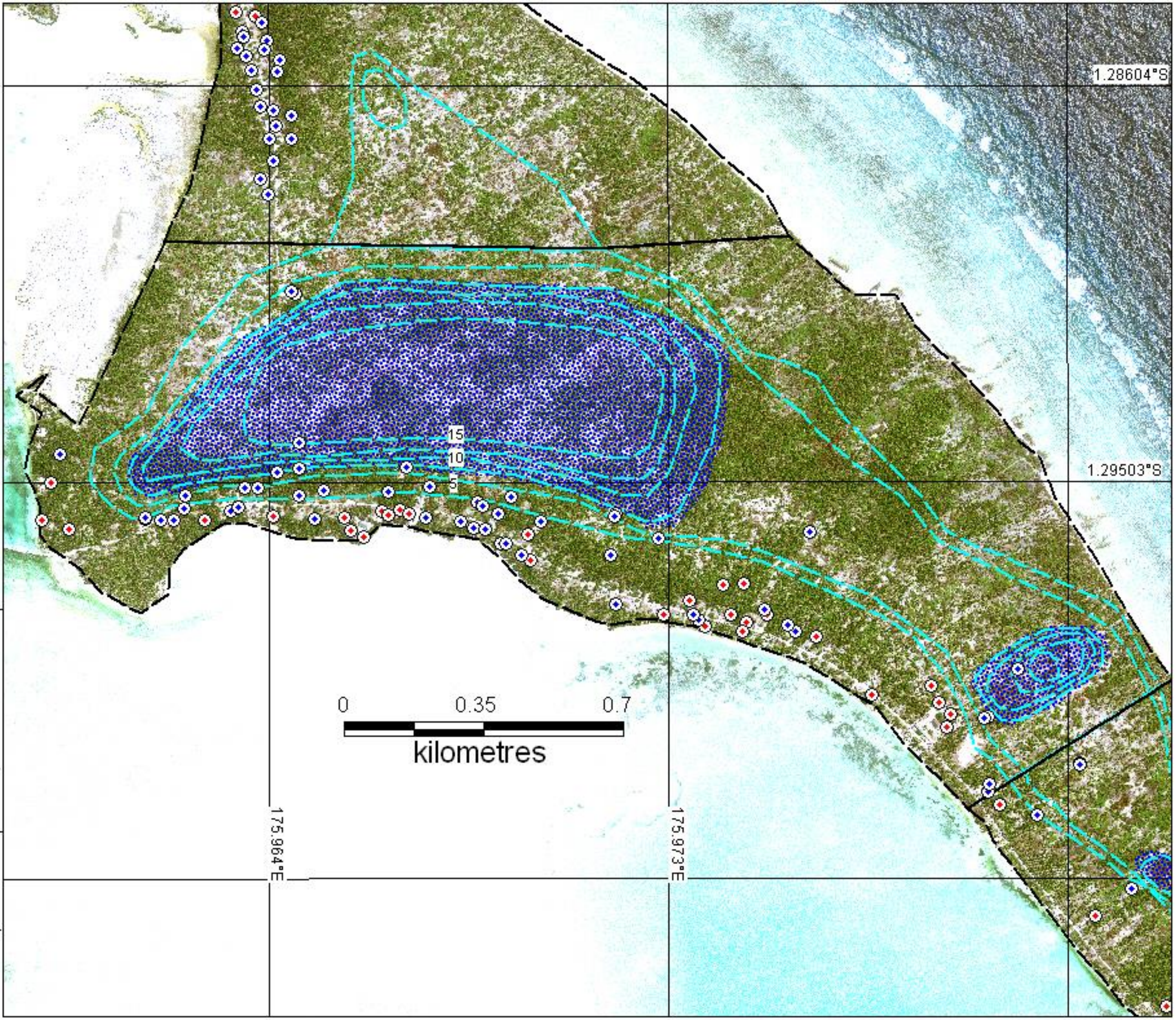


Figure A6.10 – TABIANG, BERU – BACTERIOLOGICAL SAMPLING

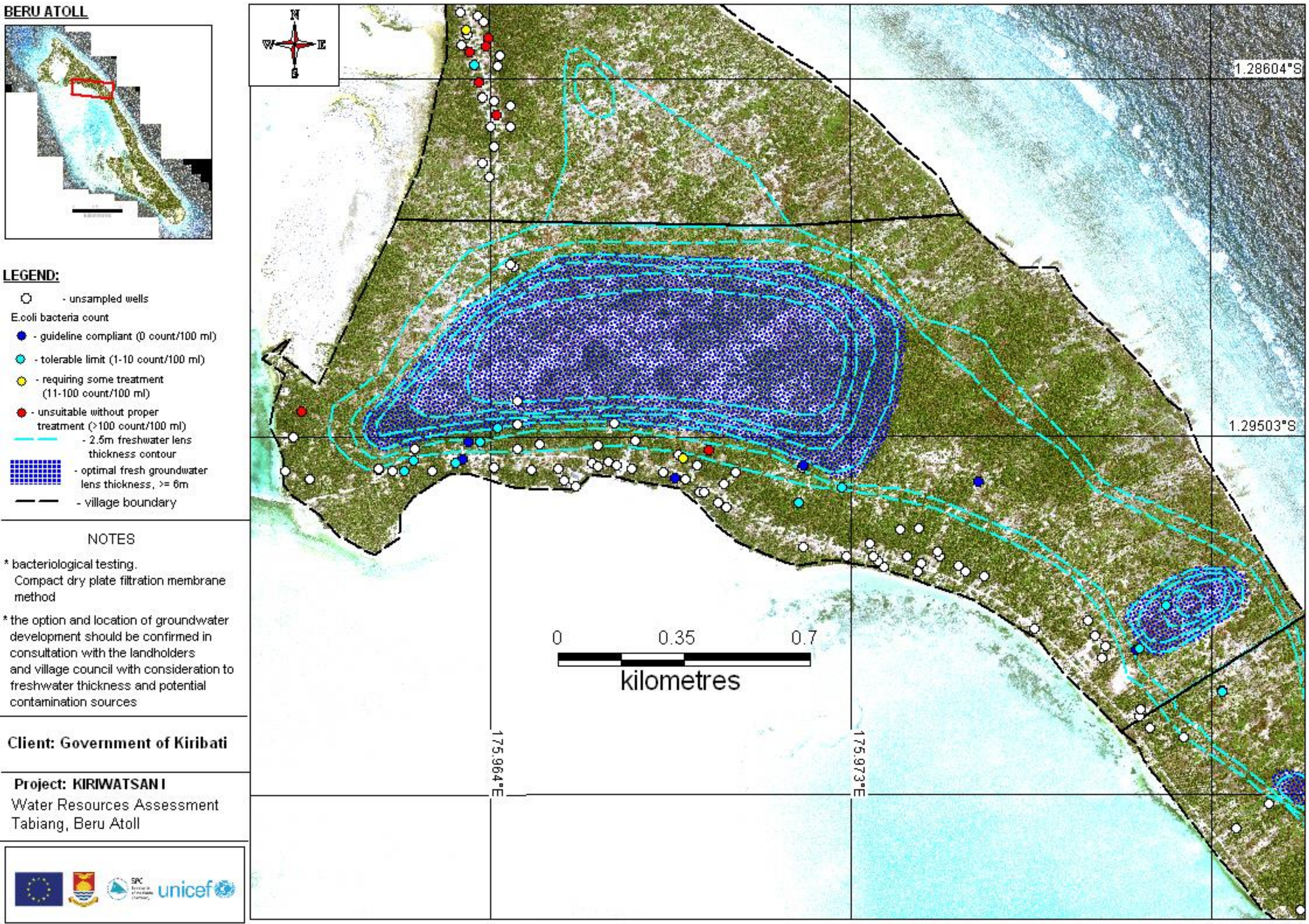


Figure A6.11 – AONIMAN, BERU – WATER RESOURCES SURVEY MAP

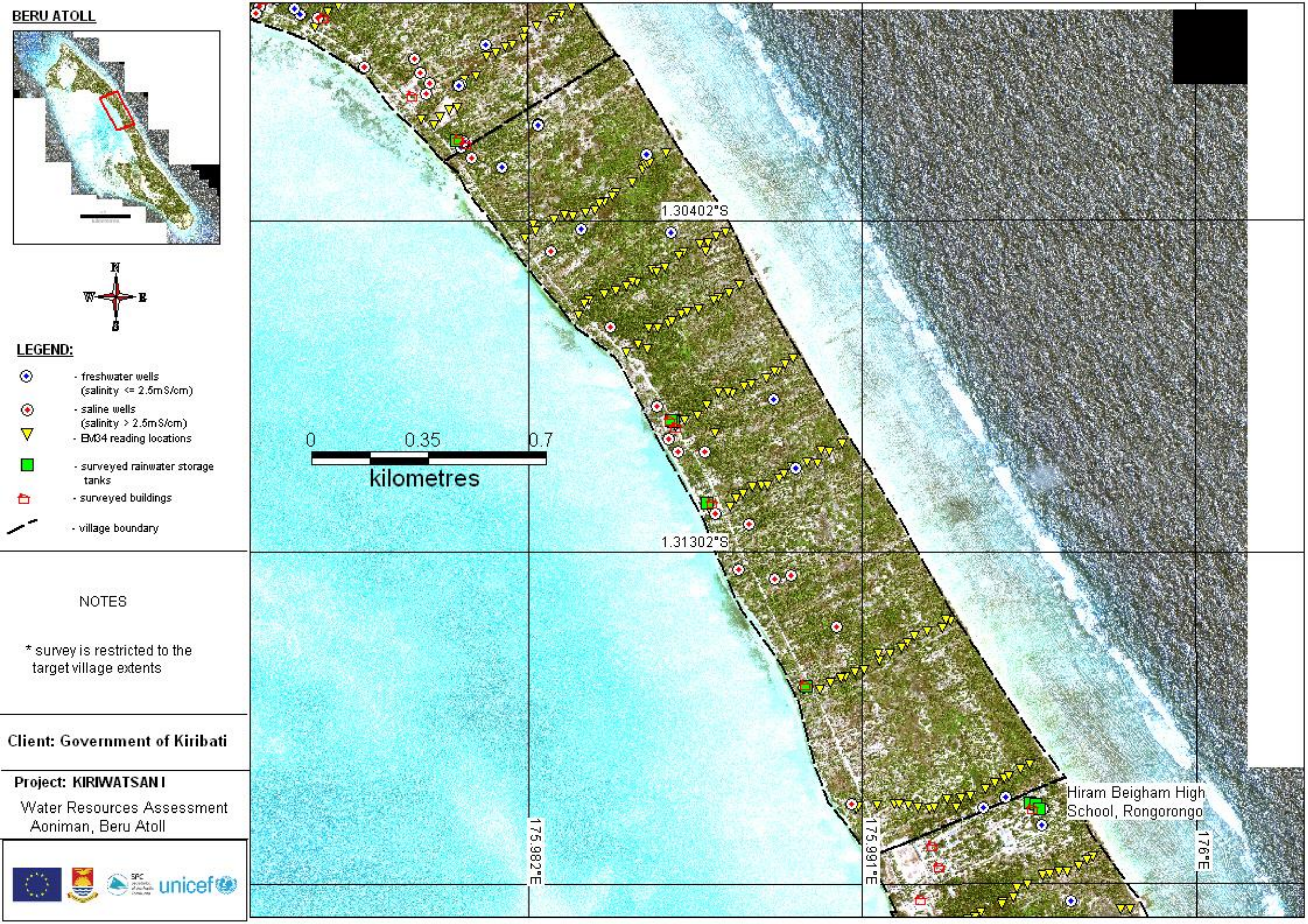


Figure A6.12 – AONIMAN, BERU – TARGET COMMUNAL BUILDINGS FOR RWH

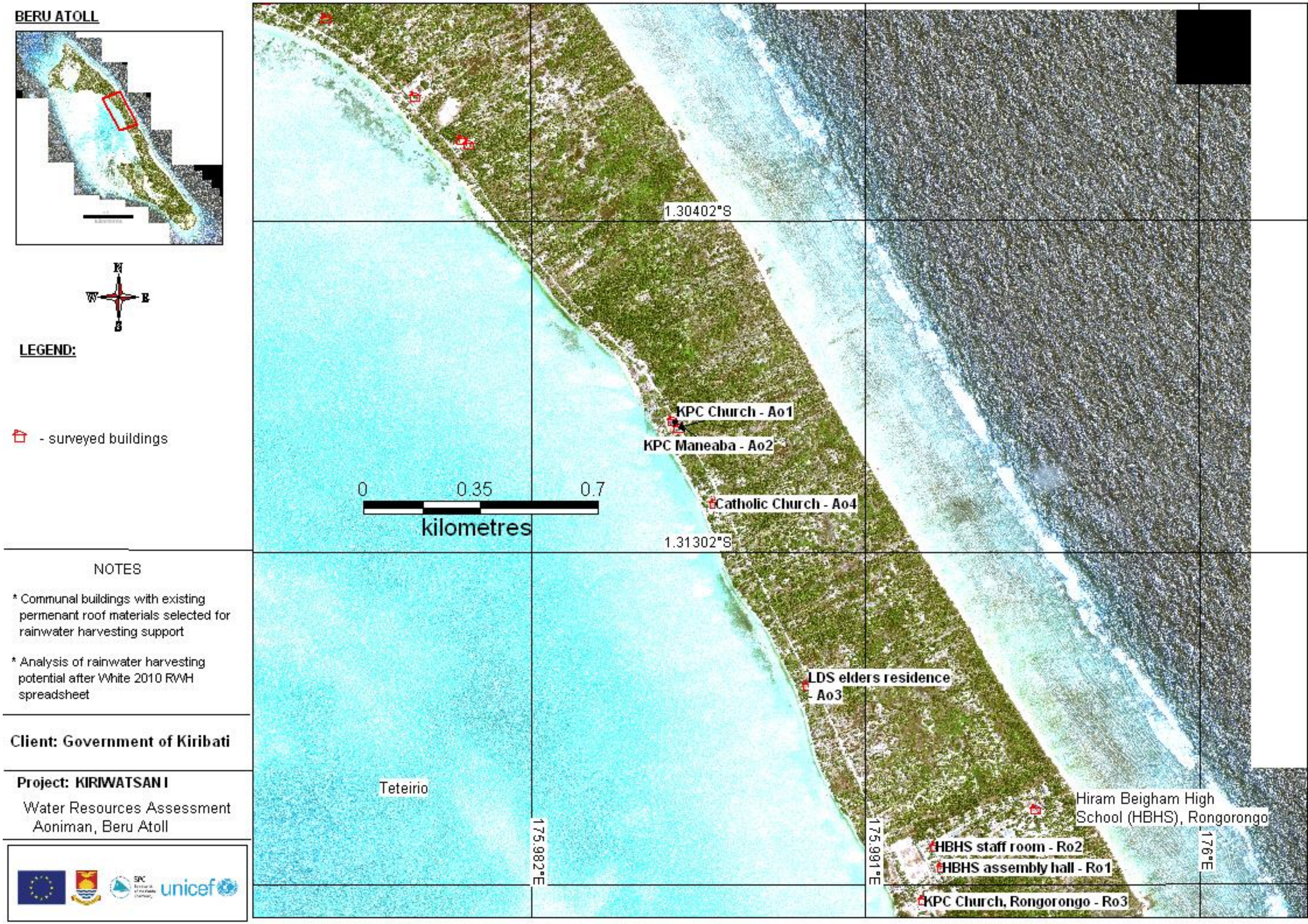


Figure A6.13 – AONIMAN, BERU – FRESH GROUNDWATER LENS POTENTIAL

BERU ATOLL

LEGEND:

- freshwater wells (salinity <= 2.5mS/cm)
- saline wells (salinity > 2.5mS/cm)
- 2.5m freshwater lens thickness contour
- optimal fresh groundwater lens thickness, >= 6m
- village boundary

NOTES

* the option and location of groundwater development should be confirmed in consultation with the landholders and village council with consideration to freshwater thickness and potential contamination sources

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Aoniman, Beru Atoll

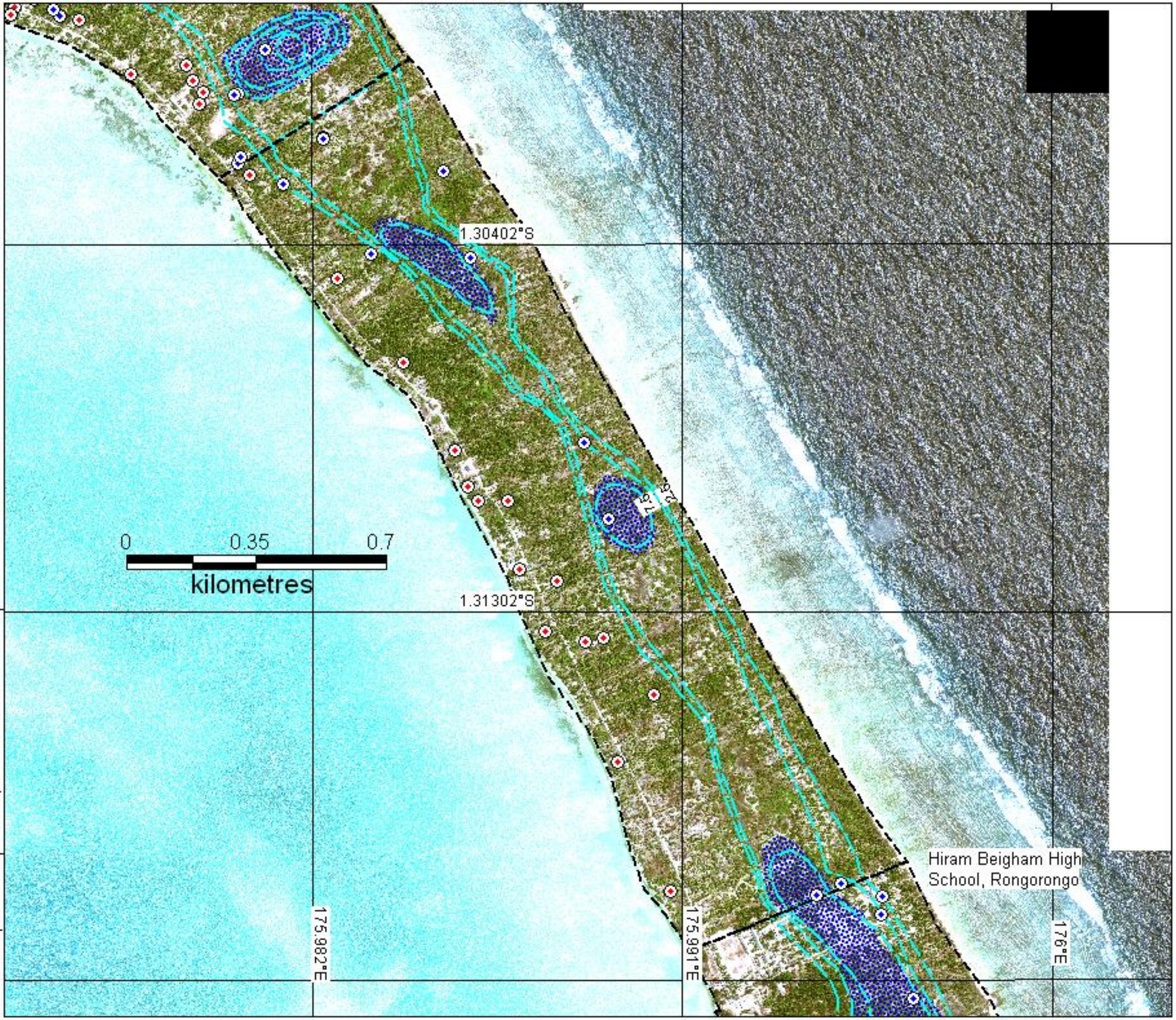


Figure A6.14 – AONIMAN, BERU – BACTERIOLOGICAL SAMPLING

BERU 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)
- 2.5m freshwater lens thickness contour
- optimal fresh groundwater lens thickness, >= 6m
- village boundary

NOTES

* bacteriological testing. Compact dry plate filtration membrane method

* the option and location of groundwater development should be confirmed in consultation with the landholders and village council with consideration to freshwater thickness and potential contamination sources

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Aoniman, Beru Atoll

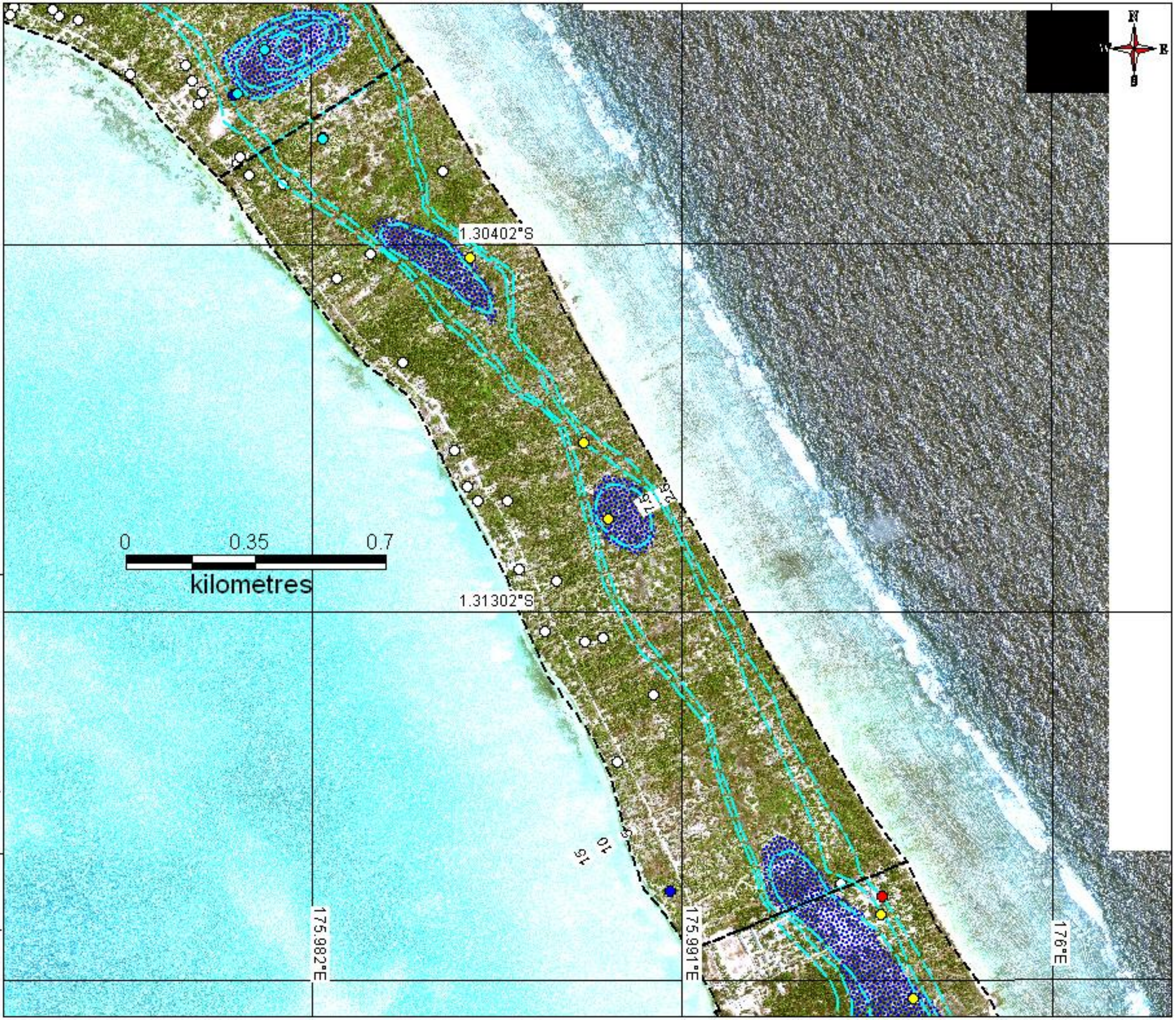
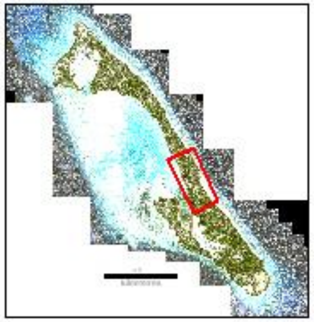


Figure A6.15 – NUKA, BERU – WATER RESOURCES SURVEY MAP

BERU ATOLL



LEGEND:

- freshwater wells (salinity <= 2.5mS/cm)
- saline wells (salinity > 2.5mS/cm)
- EM34 reading locations
- surveyed rainwater storage tanks
- surveyed buildings

NOTES

* Hiram Beigham High School (HBHS) in Rongorongo Village, and Teibubutei Primary School and Beru JSS in Nuka were also surveyed

* survey is restricted to the target village extents

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Nuka, Beru Atoll

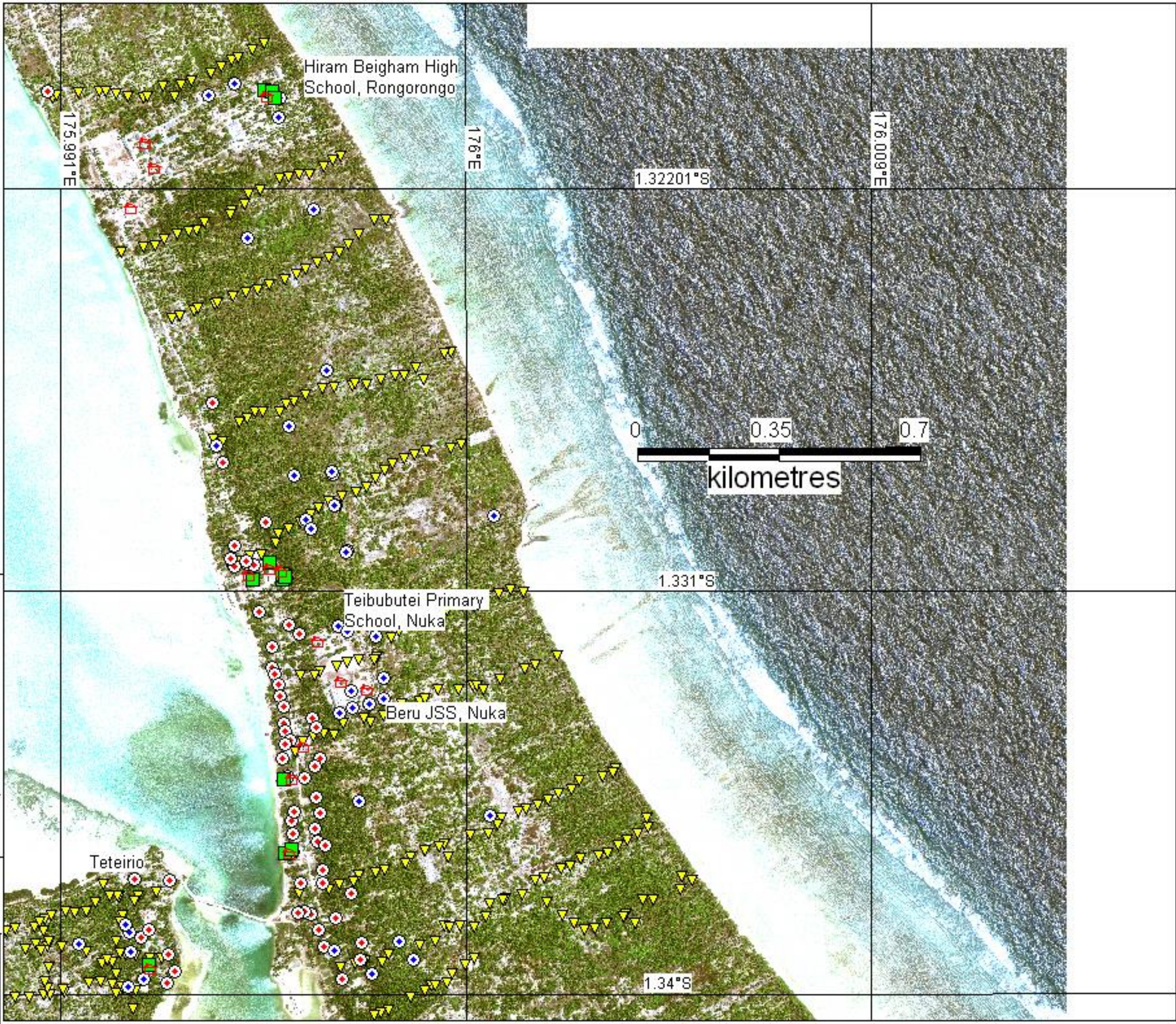


Figure A6.16 – NUKA, BERU – TARGET COMMUNAL BUILDINGS FOR RWH

BERU ATOLL

LEGEND:

- surveyed buildings

NOTES

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

* Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Nuka, Beru Atoll

unicef

Figure A6.17 – NUKA, BERU – CTD DIVER LOCATIONS

BERU ATOLL

LEGEND:

- location of CTD divers

NOTES

* real-time groundwater monitoring devices installed in selected wells

* consultation with the well owners was made prior to the installation of the monitoring device

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Nuka, Beru Atoll

Figure A6.18 – NUKA, BERU – FRESH GROUNDWATER LENS POTENTIAL

BERU ATOLL

LEGEND:

- freshwater wells (salinity <= 2.5mS/cm)
- saline wells (salinity > 2.5mS/cm)
- 2.5m freshwater lens thickness contour
- optimal fresh groundwater lens thickness, >= 6m
- village boundary

NOTES

* the option and location of groundwater development should be confirmed in consultation with the landholders and village council with consideration to freshwater thickness and potential contamination sources

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Nuka, Beru Atoll

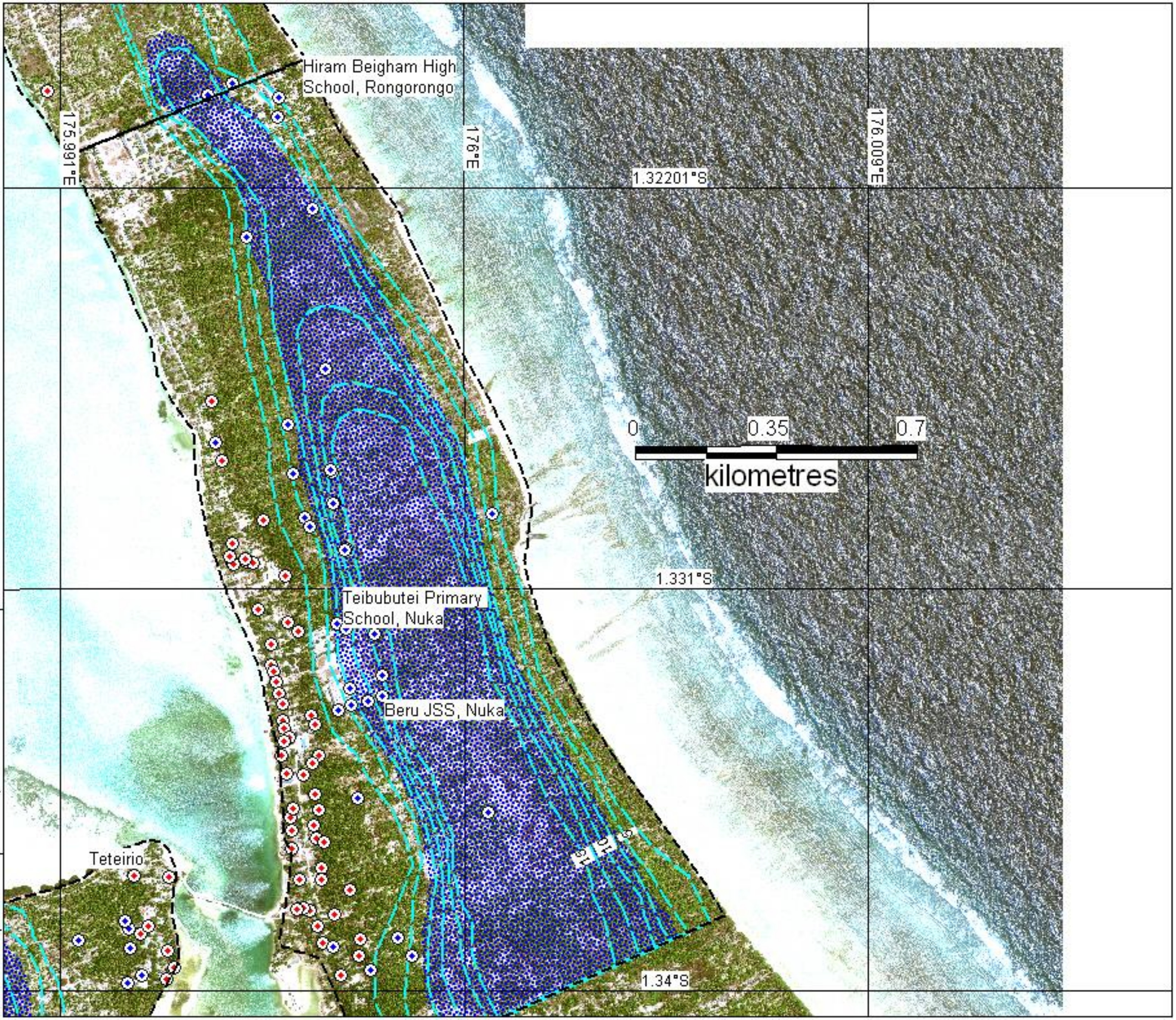
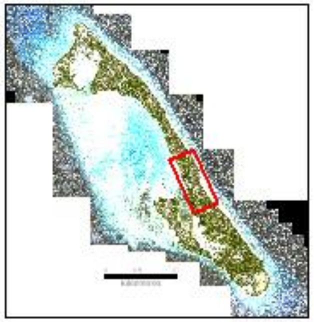
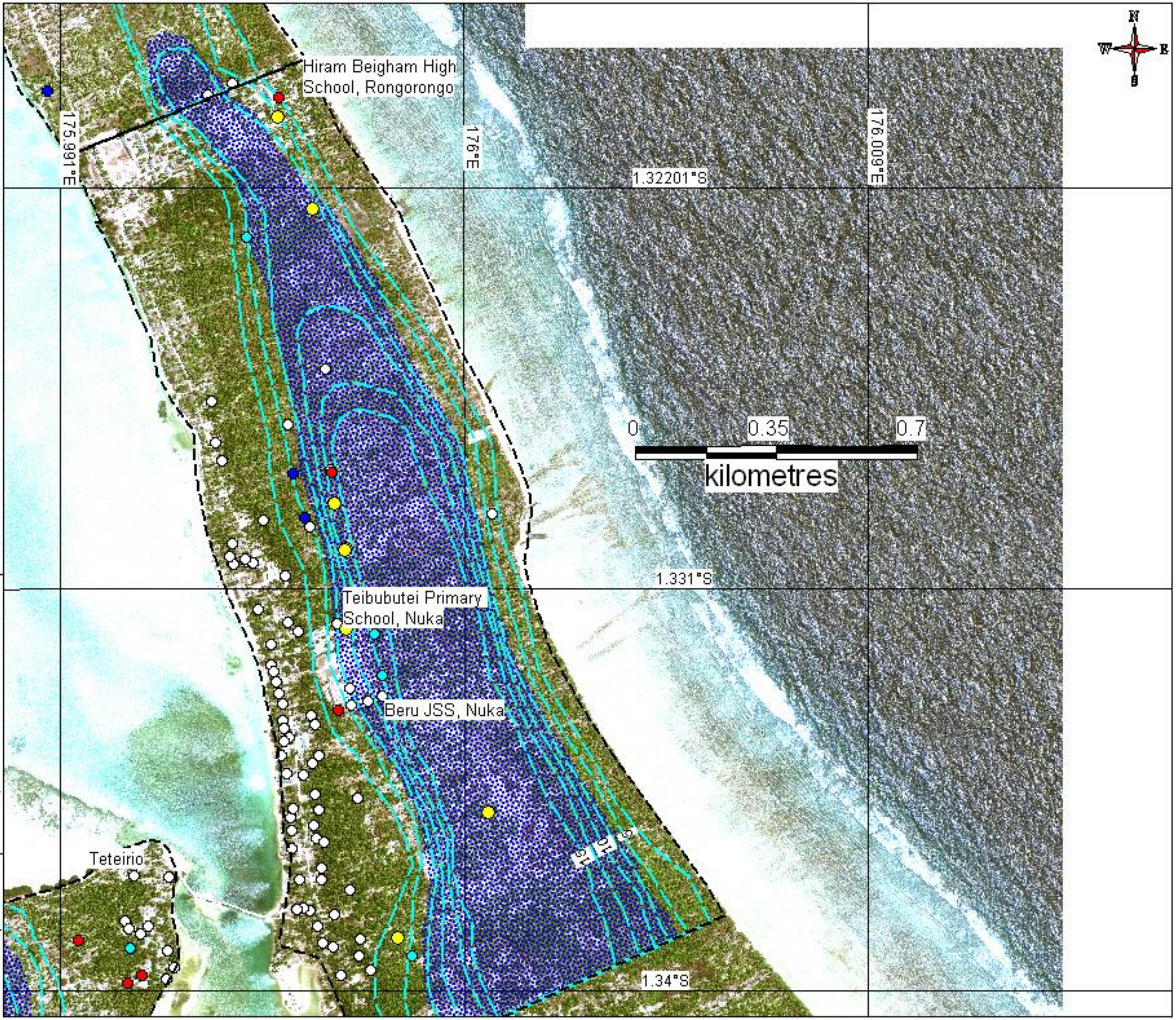


Figure A6.19 – NUKA, BERU – BACTERIOLOGICAL SAMPLING

BERU 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)
- 2.5m freshwater lens thickness contour
- optimal fresh groundwater lens thickness, >= 6m
- village boundary

NOTES

* bacteriological testing. Compact dry plate filtration membrane method
* the option and location of groundwater development should be confirmed in consultation with the landholders and village council with consideration to freshwater thickness and potential contamination sources

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Nuka, Beru Atoll

Figure A6.20 – TETEIRIO AND TAUBUKINIBERU, BERU – WATER RESOURCES SURVEY

BERU ATOLL

LEGEND:

- freshwater wells (salinity <= 2.5mS/cm)
- saline wells (salinity > 2.5mS/cm)
- EM34 reading locations
- surveyed rainwater storage tanks
- surveyed buildings
- village boundary

NOTES

* the island council buildings, together with the government offices, were also surveyed

* survey is restricted to the target village extents

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Teteirio and Taubukinberu,
Beru Atoll

unicef

Figure A6.21 – TETEIRIO AND TAUBUKINIBERU, BERU – TARGET COMMUNAL BUILDINGS, RWH

BERU ATOLL

LEGEND:

- surveyed buildings

NOTES

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

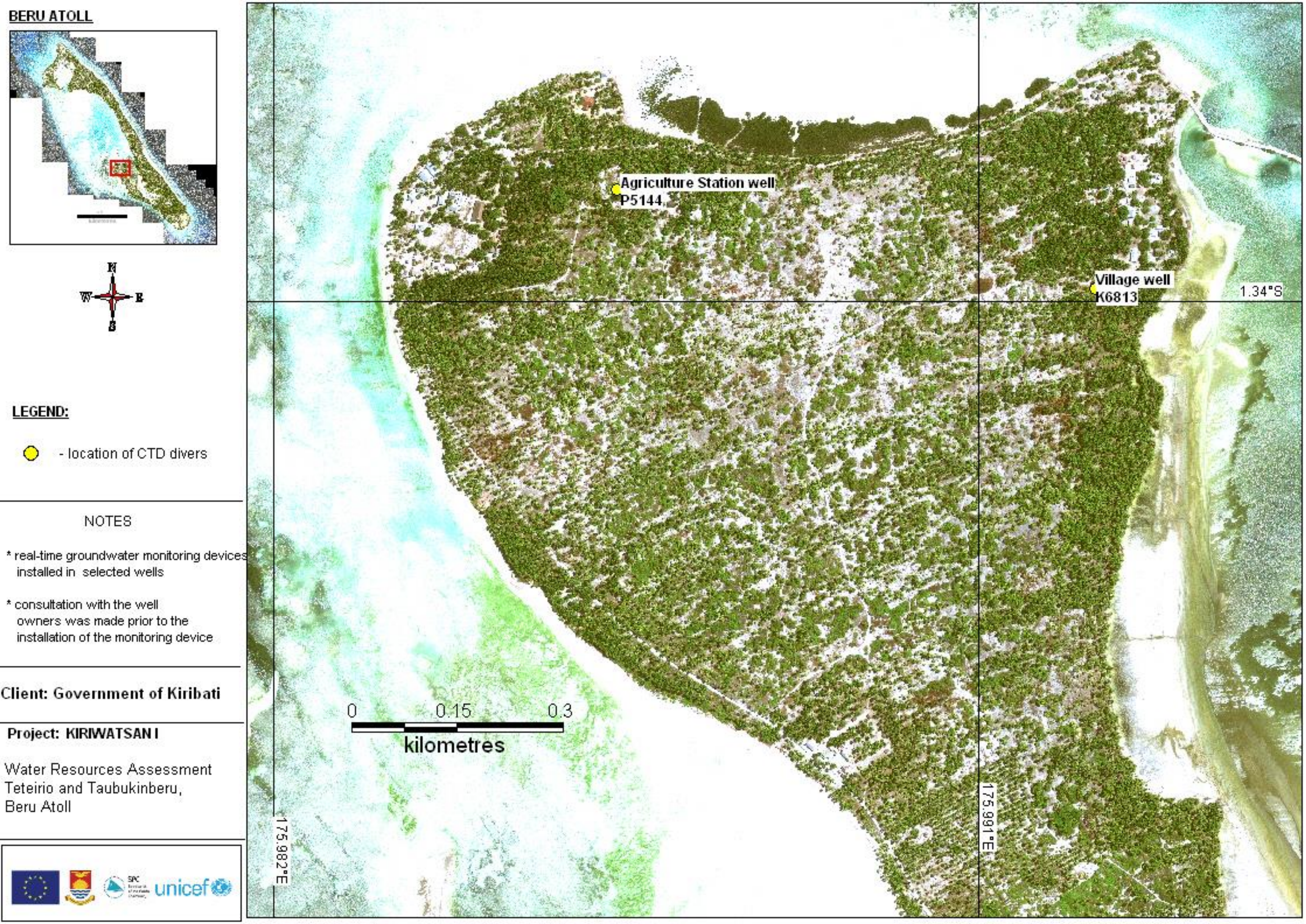
* Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Teteirio and Taubukinberu,
Beru Atoll

Figure A6.22 – TETEIRIO AND TAUBUKINIBERU, BERU – CTD DIVER LOCATION



NOTES

* real-time groundwater monitoring devices installed in selected wells

* consultation with the well owners was made prior to the installation of the monitoring device

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Teteirio and Taubukinberu,
Beru Atoll

Figure A6.23 – TETEIRIO AND TAUBUKINIBERU, BERU – FRESH GROUNDWATER LENS POTENTIAL

BERU ATOLL

LEGEND:

- freshwater wells (salinity <= 2.5mS/cm)
- saline wells (salinity > 2.5mS/cm)
- 2.5m freshwater lens thickness contour
- optimal fresh groundwater lens thickness, >= 6m
- village boundary

NOTES

* the option and location of groundwater development should be confirmed in consultation with the landholders and village council with consideration to freshwater thickness and potential contamination sources

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Teteirio and Taubukinberu,
Beru Atoll

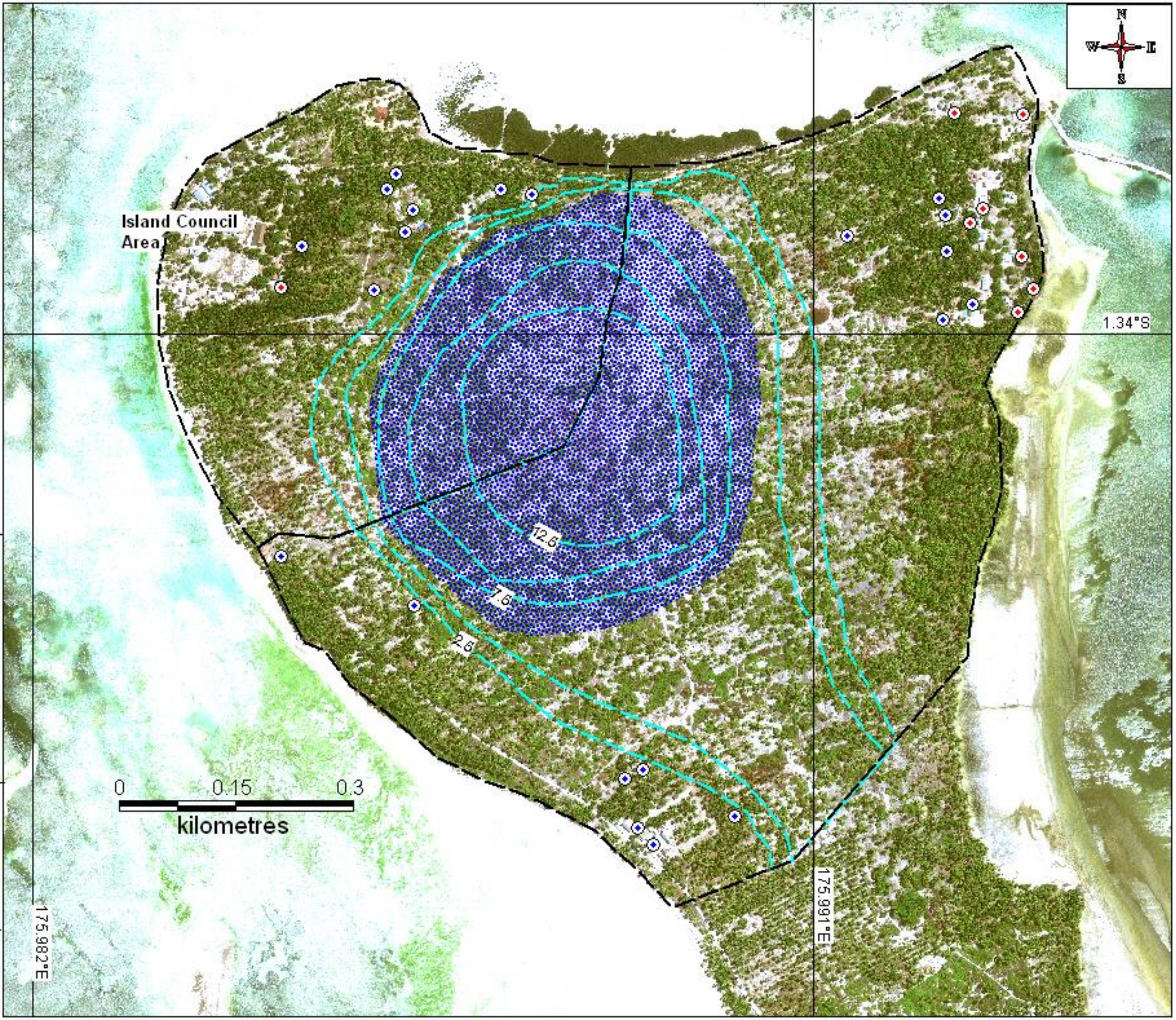
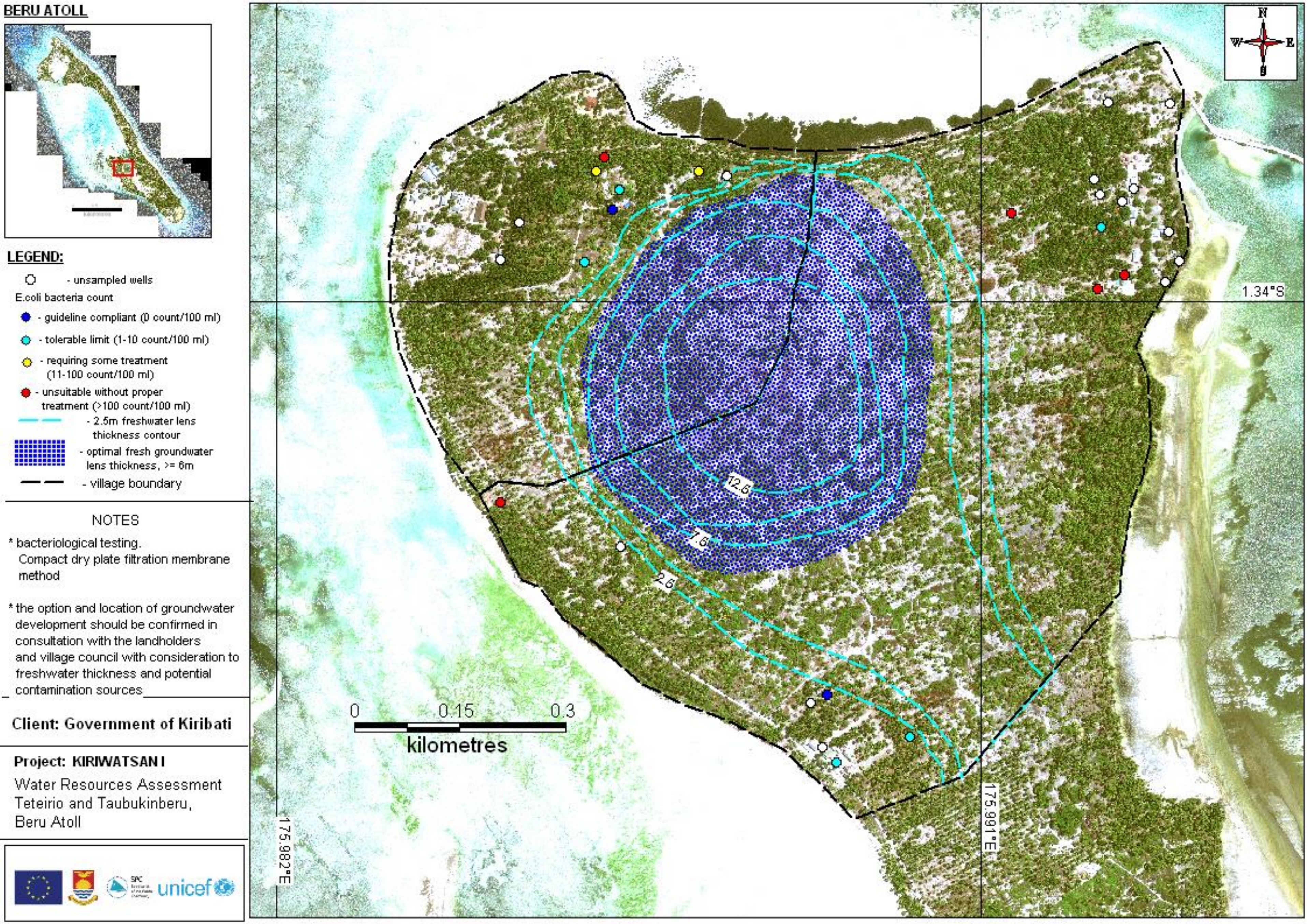


Figure A6.24 – TETEIRIO AND TAUBUKINIBERU, BERU – BACTERIOLOGICAL SAMPLING



Annex 7

EM34 Geophysics Principles & Beru 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 Beru 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 µS/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);
- November 2013 results of the KIRIWATSAN Project field measurements; and
- the combined KIRIWATSAN & 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 Islands group at the times of the surveys.

The three calibration datasets are presented as logarithmic curves and equations (Figure A7-1), which the KIRIWATSAN Team used to calculate freshwater thickness.

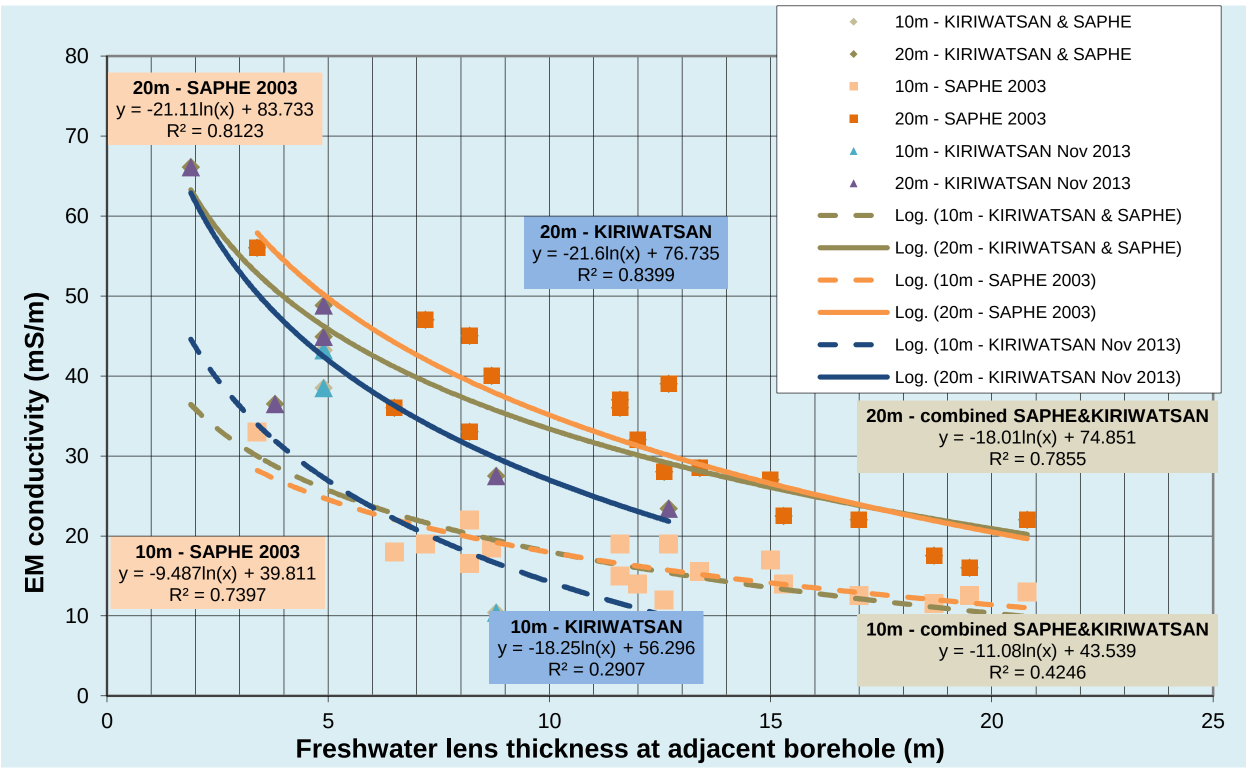


Figure A7-1. Calibration data from (1) SAPHE 2003; (2) KIRIWATSAN; and combined (3) KIRIWATSAN & SAPHE 2003. Note that (3) was used to estimate the freshwater lens thickness for 10 m and 20 m separations.

SAPHE 2003 data shows a good fit for the Nov-2003, 20-m spacing measurements, expressed by a high coefficient of determination of 0.81 (R^2), whilst the l0-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 slightly higher trend and slightly more scatter for the 20-m measurements, expressed by a higher slope of -21.6 and a slightly higher R^2 value of 0.84, in relation to the SAPHE 2003 – 20 m. Hence, the KIRIWATSAN dataset appears to be a reasonable fit due to its slightly higher R^2 value. The KIRIWATSAN 10 m, mostly plotted below the 10 m for SAPHE 2003, and shows a slightly lower slope of -18.25 with an extremely low R^2 value of 0.29. This low EM response overall, is attributed to the subsurface conditions prevalent during the Beru Island field assessment.

The combined SAPHE-KIRIWATSAN readings provided an average of both the datasets, which generated reasonable trend and R^2 value.

Additional "rules of thumb" or practical guidance notes used to interpret the freshwater lens thickness at each measurement point are as follows:

- 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 combined SAPHE-KIRIWATSAN logarithmic relationship, shown in 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 specific *in-situ* conditions and "rules of thumb". A summary of all the survey lines in the different target villages and the estimated maximum freshwater lens thickness are presented in Table A7-1.

Freshwater lens thicknesses were contoured using a 2.5 m contour interval of the ground conductivity of EM34 readings less than 2500 µS/cm, to show the spatial extent and depth variability of freshwater across the target villages. This inferred fresh groundwater resource, can be utilised for resource estimation, planning, development and management purposes.

Further analysis was conducted to delineate the optimal freshwater zone underneath each target village. This was based on the predicted freshwater lens thickness reduction of 5.5 m using the 1998-2000 drought data of the Tarawa water reserve (Falkland & White, 2009). Consequently, field readings with an estimated lens thickness of 6 m, or more, were classified as an optimal and resilient resource, and represented ideal options for sustainable groundwater use and management.

4) Summary of Findings

Clearly, EM34 provides a useful and rapid method of estimating freshwater lens thicknesses based on salinity during the time of the survey. It does not make any inference on the potability of the groundwater or its risk from contamination. Water quality testing is required to determine the likelihood of contamination of the groundwater from various sources in any specific area. Details of the groundwater quality sampling undertaken and the results indicating the level of contamination is provided in Annex 5.

Table A7-1. Summary of EM34 survey lines in each target village and maximum freshwater lens thickness.

Survey Line	Date	Village	Width of island from lagoon to ocean side (m)	Maximum estimated freshwater thickness (m)
EM-BEZ1	19/11/2013	Autukia	270	0.8
EM-BEZ2	19/11/2013	Autukia	450	1.7
EM-BEZ3	19/11/2013	Autukia	780	2.5
EM-BEZ4	19/11/2013	Autukia	1470	2.0
EM-BEZ5	20/11/2013	Tabiang	720	36.2
EM-BEZ6	20/11/2013	Tabiang	1050	29.2
EM-BEZ7	20/11/2013	Tabiang	960	12.2
EM-BEZ8	20/11/2013	Tabiang	690	5.4
EM-BEZ9	20/11/2013	Tabiang	570	15.8
EM-BEZ10	21/11/2013	Aoniman	540	7.5
EM-BEZ11	21/11/2013	Aoniman	540	7.8
EM-BEZ12	21/11/2013	Aoniman	420	3.1
EM-BEZ13	21/11/2013	Aoniman	450	2.6
EM-BEZ14	21/11/2013	Aoniman	450	7.3
EM-BEZ15	21/11/2013	Aoniman	480	4.6
EM-BEZ16	21/11/2013	Aoniman	570	7.9
EM-BEZ17	22/11/2013	Nuka	600	7.4
EM-BEZ18	22/11/2013	Nuka	600	7.5
EM-BEZ19	22/11/2013	Nuka	660	13.8
EM-BEZ20	22/11/2013	Nuka	630	16.5
EM-BEZ21	22/11/2013	Nuka	660	19.8
EM-BEZ22	23/11/2013	Nuka	690	21.4
EM-BEZ23	24/11/2013	Nuka	840	22.7
EM-BEZ24	24/11/2013	Nuka	930	25.4
EM-BEZ25	24/11/2013	Nuka	810	27.0
EM-BEZ26	25/11/2013	Teteirio	960	15.9
EM-BEZ27	25/11/2013	Teteirio	1050	8.5
EM-BEZ28	25/11/2013	Teteirio	870	13.3
EM-BEZ29	26/11/2013	Taubukiniberu	480	9.9
EM-BEZ30	26/11/2013	Taubukiniberu	390	11.5
EM-BEZ31	26/11/2013	Taubukiniberu	270	9.0
EM-BEZ32	26/11/2013	Taubukiniberu	210	3.7
EM-BEZ33	26/11/2013	Taubukiniberu	300	1.0
EM-BEZ34	27/11/2013	Taubukiniberu	900	10.7

RESULTS

The results from the EM34 survey lines are presented below with the location and spatial extent of freshwater lens underlying each village shown in Annex 6.

Table A7-2. All survey results around the target villages on Beru.

Waypoint	Field measurements			Freshwater (FW) lens thickness estimation			Location	
	Distance from the coast (m)	10 m_EM response	20 m_EM response	10 m_FW lens estimated thickness	20 m_FW lens estimated thickness	Adopted FW lens thickness	N degrees	E degrees
BEZ1X1	0	54.1	88.1	0.4	0.5	0.4	00°59.57.7'	173°02.02.2'
BEZ1X2	10	50.7	84.5	0.5	0.6	0.5	01°16.54.5'	173°57.47.4'
BEZ1X3	40	46.5	81.9	0.8	0.7	0.8	01°16.53.2'	173°57.49.4'
BEZ1X4	70	45.9	77.6	0.8	0.9	0.8	01°16.53.9'	173°57.50.0'
BEZ1X5	100	46.2	84.4	0.8	0.6	0.8	01°16.53.0'	173°57.51.0'
BEZ1X6	130	49.1	81.6	0.6	0.7	0.6	01°16.52.6'	173°57.51.5'
BEZ1X7	160	50.3	88.7	0.5	0.5	0.5	01°16.52.3'	173°57.54.3'
BEZ1X8	190	52.5	91.5	0.4	0.4	0.4		
BEZ1X9	220	57.7	107.3	0.3	0.2	0.3	01°16.51.8'	173°57.56.0'
BEZ2X1	0	43.3	79.9	1.0	0.8	1.0	01°16.56.7'	175°58.0.12'
BEZ2X2	10	40.5	74.3	1.3	1.0	1.3	01°16.56.9'	175°58.0.06'
BEZ2X3	40	37.5	64.7	1.7	1.8	1.7	01°16.57.6'	175°57.59.4'
BEZ2X4	70	37.2	62.8	1.8	2.0	1.8	01°16.58.2'	175°57.58.3'
BEZ2X5	100	37.2	59.3	1.8	2.4	1.8	01°16.58.9'	175°57.57.4'
BEZ2X6	130	37.9	59.7	1.7	2.3	1.7	01°16.59.3'	175°57.57.0'
BEZ2X7	160	48.2	60.7	0.7	2.2	0.7	01°16.59.8'	175°57.56.1'
BEZ2X8	190	46.5	66.3	0.8	1.6	0.8	01°17.01.2'	175°57.54.4'
BEZ2X9	220	48.5	67.8	0.6	1.5	0.6	01°17.01.1'	175°57.53.9'
BEZ2X10	250	60.5	78.5	0.2	0.8	0.2	01°17.02.1'	175°57.53.1'
BEZ2X11	280	66.3	87.9	0.1	0.5	0.1	01°17.02.8'	175°57.51.8'
BEZ2X12	310	76.6	85.5	0.1	0.6	0.1	01°17.03.5'	175°57.50.6'
BEZ2X13	340	59.0	73.8	0.2	1.1	0.2	01°17.04.2'	175°57.50.5'
BEZ2X14	370	48.3	56.4	0.7	2.8	0.7	01°17.03.9'	175°57.49.2'
BEZ2X15	400	44.8	69.3	0.9	1.4	0.9	01°17.04.3'	175°57.49.0'
BEZ3X1	0	33.9	44.3	2.4	5.5	2.4	01°17.13.1'	175°57.49.0'
BEZ3X2	10	34.8	45.2	2.2	5.2	2.2	01°17.12.7'	175°57.49.9'
BEZ3X3	40	34.4	44.5	2.3	5.4	2.3	01°17.12.8'	175°57.50.1'
BEZ3X4	70	35.3	48.2	2.1	4.4	2.1	01°17.12.6'	175°57.51.7'
BEZ3X5	100	38.1	46.1	1.6	4.9	1.6	01°17.11.5'	175°57.52.6'
BEZ3X6	130	40.2	50.2	1.4	3.9	1.4	01°17.11.9'	175°57.53.5'
BEZ3X7	160	39.8	49.2	1.4	4.2	1.4	01°17.11.5'	175°57.54.2'
BEZ3X8	190	37.7	48.8	1.7	4.2	1.7	01°17.11.5'	175°57.55.0'
BEZ3X9	220	37.3	46.2	1.8	4.9	1.8	01°17.11.3'	175°57.55.6'
BEZ3X10	250	34.7	41.2	2.2	6.5	2.2	01°17.11.2'	175°57.57.2'
BEZ3X11	280	34.7	44.2	2.2	5.5	2.2	01°17.10.9'	175°57.58.0'

BEZ3X12	310	34.0	45.2	2.4	5.2	2.4	01°17.10.3'	175°57.58.0'
BEZ3X13	340	33.3	43.2	2.5	5.8	2.5	01°17.09.9'	175°57.59.7'
BEZ3X14	370	35.2	46.9	2.1	4.7	2.1	01°17.08.7'	175°58.00.1'
BEZ3X15	400	35.1	47.6	2.2	4.5	2.2	01°17.09.1'	175°58.02.0'
BEZ3X16	430	33.6	47.2	2.5	4.6	2.5	01°17.09.0'	175°58.02.4'
BEZ3X17	460	34.6	46.8	2.3	4.7	2.3	01°17.08.0'	175°58.03.7'
BEZ3X18	490	34.3	45.9	2.3	5.0	2.3	01°17.09.1'	175°58.04.2'
BEZ3X19	520	35.4	50.2	2.1	3.9	2.1	01°17.08.8'	175°58.05.7'
BEZ3X20	550	35.7	51.5	2.0	3.7	2.0	01°17.07.7'	175°58.06.6'
BEZ3X21	580	38.4	55.7	1.6	2.9	1.6	01°17.07.7'	175°58.08.2'
BEZ3X22	610	38.2	56.2	1.6	2.8	1.6	01°17.06.6'	175°58.08.4'
BEZ3X23	640	39.2	61.8	1.5	2.1	1.5	01°17.07.1'	175°58.10.1'
BEZ3X24	670	40.4	62.7	1.3	2.0	1.3	01°17.06.1'	175°58.09.6'
BEZ3X25	700	41.2	68.8	1.2	1.4	1.2	01°17.05.6'	175°58.10.9'
BEZ3X26	730	45.2	81.6	0.9	0.7	0.9	01°17.05.1'	175°58.11.7'
BEZ4X1	0	78.9	114.6	0.0	0.1	0.0	01°17.16.2'	175°58.27.2'
BEZ4X2	10	46.3	80.7	0.8	0.7	0.8	01°17.16.4'	175°58.26.5'
BEZ4X3	40	46.7	76.4	0.8	0.9	0.8	01°17.17.0'	175°58.26.2'
BEZ4X4	70	46.2	73.0	0.8	1.1	0.8	01°17.17.2'	175°58.25.0'
BEZ4X5	100	47.8	73.8	0.7	1.1	0.7	01°17.18.1'	175°58.24.4'
BEZ4X6	130	49.3	76.1	0.6	0.9	0.6	01°17.19.3'	175°58.23.9'
BEZ4X7	160	53.1	80.2	0.4	0.7	0.4	01°17.19.1'	175°58.23.3'
BEZ4X8	190	57.4	83.7	0.3	0.6	0.3	01°17.19.9'	175°58.22.0'
BEZ4X9	220	51.1	76.3	0.5	0.9	0.5	01°17.20.5'	175°58.20.8'
BEZ4X10	250	42.3	64.6	1.1	1.8	1.1	01°17.20.6'	175°58.20.6'
BEZ4X11	280	40.9	60.3	1.3	2.2	1.3	01°17.21.6'	175°58.19.6'
BEZ4X12	310	41.0	57.5	1.3	2.6	1.3	01°17.21.6'	175°58.19.1'
BEZ4X13	340	38.7	54.6	1.6	3.1	1.6	01°17.23.0'	175°58.17.7'
BEZ4X14	370	36.9	50.6	1.8	3.8	1.8	01°17.23.1'	175°58.17.0'
BEZ4X15	400	37.7	49.3	1.7	4.1	1.7	01°17.23.7'	175°58.16.6'
BEZ4X16	430	37.8	49.4	1.7	4.1	1.7	01°17.24.4'	175°58.15.8'
BEZ4X17	460	38.4	49.7	1.6	4.0	1.6	01°17.24.8'	175°58.15.5'
BEZ4X18	490	37.9	48.1	1.7	4.4	1.7	01°17.25.9'	175°58.14.8'
BEZ4X19	520	37.5	48.3	1.7	4.4	1.7	01°17.27.1'	175°58.13.9'
BEZ4X20	550	40.3	50.1	1.3	4.0	1.3	01°17.28.3'	175°58.13.5'
BEZ4X21	580	41.8	49.9	1.2	4.0	1.2	01°17.28.5'	175°58.12.7'
BEZ4X22	610	42.2	50.8	1.1	3.8	1.1	01°17.29.2'	175°58.11.9'
BEZ4X23	640	43.7	50.2	1.0	3.9	1.0	01°17.29.8'	175°58.11.3'
BEZ4X24	670	41.0	47.7	1.3	4.5	1.3	01°17.30.1'	175°58.09.9'
BEZ4X25	700	40.0	48.5	1.4	4.3	1.4	01°17.30.2'	175°58.09.6'
BEZ4X26	730	36.2	47.5	1.9	4.6	1.9	01°17.31.2'	175°58.08.3'
BEZ4X27	760	35.4	45.0	2.1	5.2	2.1	01°17.31.1'	175°58.07.7'
BEZ4X28	790	36.3	44.6	1.9	5.4	1.9	01°17.30.4'	175°58.06.8'
BEZ4X29	820	35.9	45.5	2.0	5.1	2.0	01°17.31.2'	175°58.06.0'
BEZ4X30	850	36.7	46.0	1.9	5.0	1.9	01°17.31.5'	175°58.04.7'
BEZ4X31	880	36.6	46.0	1.9	5.0	1.9	01°17.31.8'	175°58.03.9'

BEZ4X32	910	37.2	46.6	1.8	4.8	1.8	01°17.32.3'	175°58.03.1'
BEZ4X33	940	35.8	47.6	2.0	4.5	2.0	01°17.33.4'	175°58.01.6'
BEZ4X34	970	37.9	47.1	1.7	4.7	1.7	01°17.33.5'	175°58.01.2'
BEZ4X35	1000	39.5	48.6	1.4	4.3	1.4	01°17.32.6'	175°58.00.6'
BEZ4X36	1030	37.9	46.6	1.7	4.8	1.7	01°17.33.1'	175°57.59.1'
BEZ4X37	1060	37.9	46.7	1.7	4.8	1.7	01°17.34.1'	175°57.57.9'
BEZ4X38	1090	36.0	45.1	2.0	5.2	2.0	01°17.34.5'	175°57.57.1'
BEZ4X39	1120	36.8	45.6	1.8	5.1	1.8	01°17.35.3'	175°57.56.6'
BEZ4X40	1150	36.8	47.2	1.8	4.6	1.8	01°17.35.9'	175°57.56.1'
BEZ4X41	1180	37.0	46.2	1.8	4.9	1.8	01°17.38.5'	175°57.54.9'
BEZ4X42	1210	36.1	46.9	2.0	4.7	2.0	01°17.37.5'	175°57.54.6'
BEZ4X43	1240	38.1	47.1	1.6	4.7	1.6	01°17.38.4'	175°57.54.2'
BEZ4X44	1270	38.7	49.4	1.6	4.1	1.6	01°17.39.1'	175°57.54.2'
BEZ4X45	1300	41.5	50.8	1.2	3.8	1.2	01°17.39.8'	175°57.53.8'
BEZ4X46	1330	44.3	55.2	0.9	3.0	0.9	01°17.41.3'	175°57.53.4'
BEZ4X47	1360	47.3	57.7	0.7	2.6	0.7	01°17.42.1'	175°57.53.0'
BEZ4X48	1390	52.7	65.5	0.4	1.7	0.4	01°17.42.9'	175°57.52.7'
BEZ4X49	1420	61.7	78.9	0.2	0.8	0.2	01°17.44.0'	175°57.52.1'
BEZ5X1	0	66.0	69.0	0.1	1.4	0.1	01°17.48.3'	175°57.40.6'
BEZ5X2	10	34.6	62.8	2.3	2.0	2.3	01°17.47.8'	175°57.40.7'
BEZ5X3	40	36.1	55.2	2.0	3.0	2.0	01°17.48.3'	175°57.40.6'
BEZ5X4	70	34.3	61.7	2.3	2.1	2.3	01°17.45.5'	175°57.40.2'
BEZ5X5	100	33.3	60.8	2.5	2.2	2.5	01°17.45.0'	175°57.40.0'
BEZ5X6	130	25.2	45.9	5.3	5.0	5.3	01°17.44.0'	175°57.40.3'
BEZ5X7	160	24.1	48.2	5.8	4.4	5.8	01°17.43.0'	175°57.40.4'
BEZ5X8	190	18.6	39.9	9.5	7.0	7.0	01°17.42.7'	175°57.40.6'
BEZ5X9	220	13.2	33.3	15.5	10.0	10.0	01°17.41.2'	175°57.41.7'
BEZ5X10	250	9.3	25.2	22.1	15.8	15.8	01°17.40.3'	175°57.42.5'
BEZ5X11	280	9.3	21.6	22.1	19.2	19.2	01°17.39.8'	175°57.42.0'
BEZ5X12	310	8.3	22.3	24.2	18.5	18.5	01°17.39.1'	175°57.43.0'
BEZ5X13	340	5.6	10.2	30.8	36.2	36.2	01°17.38.8'	175°57.43.6'
BEZ5X14	370	6.9	18.4	27.4	23.0	23.0	01°17.38.0'	175°57.44.5'
BEZ5X15	400	6.3	18.7	29.0	22.6	22.6	01°17.37.2'	175°57.45.3'
BEZ5X16	430	7.0	18.9	27.2	22.3	22.3	01°17.24.4'	175°57.45.7'
BEZ5X17	460	7.2	17.0	26.7	24.8	24.8	01°17.34.7'	175°57.47.0'
BEZ5X18	490	5.6	14.5	30.8	28.5	28.5		
BEZ5X19	520	5.2	14.4	32.0	28.7	28.7	01°17.34.2'	175°57.47.7'
BEZ5X20	550	5.6	13.0	30.8	31.0	31.0	01°17.34.0'	175°57.48.7'
BEZ5X21	580	5.2	14.5	32.0	28.5	28.5		
BEZ5X22	610	6.0	14.8	29.8	28.1	28.1	01°17.33.2'	175°57.50.4'
BEZ5X23	640	5.7	14.7	30.6	28.2	28.2	01°17.32.5'	175°57.51.4'
BEZ5X24	670	6.8	13.9	27.7	29.5	29.5	01°17.32.3'	175°57.51.8'
BEZ6X1	0	34.5	49.3	2.3	4.1	2.3	01°17.41.3'	175°58.01.7'
BEZ6X2	10	26.5	38.4	4.7	7.6	4.7	01°17.41.5'	175°57.03.5'
BEZ6X3	40	18.6	28.6	9.5	13.0	13.0	01°17.41.2'	175°57.03.8'
BEZ6X4	70	15.5	27.2	12.6	14.1	14.1	01°17.40.0'	175°57.04.4'

BEZ6X5	100	12.2	24.6	17.0	16.3	16.3	01°17.39.3'	175°57.05.0'
BEZ6X6	130	11.7	20.7	17.8	20.2	20.2	01°17.38.8'	175°57.05.7'
BEZ6X7	160	10.5	21.6	19.8	19.2	19.2	01°17.37.5'	175°57.05.8'
BEZ6X8	190	9.5	19.3	21.7	21.9	21.9	01°17.37.1'	175°57.06.9'
BEZ6X9	220	8.0	17.9	24.8	23.6	23.6	01°17.36.7'	175°57.07.0'
BEZ6X10	250	6.8	15.2	27.7	27.4	27.4	01°17.35.2'	175°57.07.4'
BEZ6X11	280	8.6	19.4	23.5	21.7	21.7	01°17.34.7'	175°57.08.4'
BEZ6X12	310	9.8	14.1	21.1	29.2	29.2	01°17.34.4'	175°57.08.7'
BEZ6X13	340	10.2	20.7	20.4	20.2	20.2	01°17.32.7'	175°57.09.3'
BEZ6X14	370	12.2	21.4	17.0	19.5	19.5	01°17.32.1'	175°57.09.9'
BEZ6X15	400	11.4	21.4	18.3	19.5	19.5	01°17.31.8'	175°57.10.9'
BEZ6X16	430	12.7	23.3	16.3	17.5	17.5	01°17.31.5'	175°57.12.0'
BEZ6X17	460	14.5	24.1	13.8	16.7	16.7	01°17.31.3'	175°57.13.5'
BEZ6X18	490	15.5	22.7	12.6	18.1	18.1	01°17.31.7'	175°57.13.7'
BEZ6X19	520	12.3	22.4	16.8	18.4	18.4	01°17.31.5'	175°57.14.3'
BEZ6X20	550	12.1	22.8	17.2	18.0	18.0	01°17.31.6'	175°57.15.1'
BEZ6X21	580	10.9	22.2	19.1	18.6	18.6	01°17.32.0'	175°57.16.2'
BEZ6X22	610	11.3	22.5	18.4	18.3	18.3	01°17.31.2'	175°57.16.9'
BEZ6X23	640	10.1	21.4	20.5	19.5	19.5	01°17.31.1'	175°57.18.2'
BEZ6X24	670	8.0	17.8	24.8	23.8	23.8	01°17.30.7'	175°57.19.5'
BEZ6X25	700	3.9	18.6	36.0	22.7	22.7	01°17.30.6'	175°57.20.2'
BEZ6X26	730	5.9	19.5	30.0	21.6	21.6	01°17.30.9'	175°57.21.5'
BEZ6X27	760	8.2	16.8	24.4	25.1	25.1	01°17.30.6'	175°57.22.0'
BEZ6X28	790	8.7	20.4	23.3	20.6	20.6	01°17.31.2'	175°57.22.8'
BEZ6X29	820	6.5	19.9	28.4	21.1	21.1	01°17.31.4'	175°57.24.1'
BEZ6X30	850	9.5	23.4	21.7	17.4	17.4	01°17.31.3'	175°57.24.8'
BEZ6X31	880	6.7	19.9	27.9	21.1	21.1	01°17.31.2'	175°57.25.8'
BEZ6X32	910	7.3	25.9	26.5	15.1	15.1	01°17.31.1'	175°57.26.7'
BEZ6X33	940	9.7	24.8	21.3	16.1	16.1	01°17.30.6'	175°57.27.3'
BEZ6X34	970	8.9	28.5	22.9	13.1	13.1	01°17.27.9'	175°57.30.5'
BEZ6X35	1000	8.1	33.4	24.6	10.0	10.0	01°17.27.1'	175°57.30.5'
BEZ7X1	0	42.4	65.3	1.1	1.7	1.1	01°17.30.8'	175°58.40.8'
BEZ7X2	10	41.4	48.4	1.2	4.3	1.2	01°17.31.2'	175°58.40.3'
BEZ7X3	40	42.1	58.6	1.1	2.5	1.1	01°17.31.6'	175°58.38.9'
BEZ7X4	70	44.9	67.7	0.9	1.5	0.9	01°17.31.9'	175°58.38.8'
BEZ7X5	100	36.5	66.4	1.9	1.6	1.9	01°17.33.0'	175°58.37.8'
BEZ7X6	130	35.2	65.9	2.1	1.6	2.1	01°17.32.9'	175°58.37.4'
BEZ7X7	160	38.2	60.5	1.6	2.2	1.6	01°17.34.5'	175°58.36.0'
BEZ7X8	190	34.0	60.8	2.4	2.2	2.4	01°17.35.0'	175°58.35.8'
BEZ7X9	220	30.9	58.4	3.1	2.5	3.1	01°17.35.6'	175°58.35.6'
BEZ7X10	250	32.9	46.7	2.6	4.8	2.6	01°17.35.9'	175°58.34.3'
BEZ7X11	280	26.9	45.3	4.5	5.2	4.5	01°17.36.3'	175°58.33.9'
BEZ7X12	310	30.2	50.1	3.3	4.0	3.3	01°17.36.8'	175°58.33.0'
BEZ7X13	340	36.8	53.3	1.8	3.3	1.8	01°17.38.4'	175°58.32.3'
BEZ7X14	370	55.1	62.6	0.4	2.0	0.4	01°17.38.4'	175°58.30.8'
BEZ7X15	400	47.5	65.9	0.7	1.6	0.7	01°17.38.9'	175°58.30.4'

BEZ7X16	430	42.7	52.8	1.1	3.4	1.1	01°17.39.0'	175°58.29.4'
BEZ7X17	460	29.7	42.7	3.5	6.0	3.5	01°17.39.2'	175°58.28.4'
BEZ7X18	490	28.9	47.8	3.8	4.5	3.8	01°17.40.0'	175°58.27.8'
BEZ7X19	520	23.2	36.9	6.3	8.2	8.2	01°17.40.3'	175°58.26.9'
BEZ7X20	550	21.1	34.5	7.6	9.4	9.4	01°17.41.0'	175°58.26.4'
BEZ7X21	580	21.4	35.2	7.4	9.0	9.0	01°17.41.7'	175°58.24.5'
BEZ7X22	610	11.9	29.8	17.5	12.2	12.2	01°17.41.8'	175°58.23.5'
BEZ7X23	640	11.3	24.6	18.4	16.3	16.3	01°17.43.2'	175°58.23.0'
BEZ7X24	670	14.1	31.0	14.3	11.4	11.4	01°17.4.7'	175°58.22.0'
BEZ7X25	700	16.8	31.4	11.2	11.2	11.2	01°17.45.1'	175°58.22.3'
BEZ7X26	730	19.0	38.7	9.2	7.4	7.4	01°17.45.4'	175°58.21.6'
BEZ7X27	760	29.9	40.1	3.4	6.9	3.4	01°17.46.3'	175°58.21.2'
BEZ7X28	790	28.5	53.6	3.9	3.3	3.9	01°17.47.4'	175°58.20.7'
BEZ7X29	820	34.2	60.0	2.3	2.3	2.3	01°17.47.4'	175°58.19.9'
BEZ7X30	850	38.1	64.2	1.6	1.8	1.6	01°17.48.6'	175°58.19.3'
BEZ7X31	880	52.3	59.5	0.5	2.3	0.5	01°17.50.2'	175°58.18.8'
BEZ7X32	910	56.7	65.7	0.3	1.7	0.3	01°17.50.7'	175°58.17.8'
BEZ8X1	0	52.6	101.4	0.4	0.2	0.4	01°17.55.6'	175°58.35.0'
BEZ8X2	10	61.5	76.4	0.2	0.9	0.2	01°17.54.8'	175°58.35.4'
BEZ8X3	40	58.9	72.8	0.3	1.1	0.3	01°17.54.1'	175°58.36.1'
BEZ8X4	70	59.9	67.9	0.2	1.5	0.2	01°17.53.6'	175°58.37.2'
BEZ8X5	100	39.9	50.0	1.4	4.0	1.4	01°17.52.9'	175°58.38.1'
BEZ8X6	130	35.4	59.6	2.1	2.3	2.1	01°17.52.9'	175°58.38.7'
BEZ8X7	160	31.6	55.9	3.0	2.9	3.0	01°17.52.7'	175°58.39.6'
BEZ8X8	190	28.3	54.8	4.0	3.0	4.0	01°17.51.9'	175°58.41.0'
BEZ8X9	220	27.9	56.9	4.1	2.7	4.1	01°17.51.6'	175°58.41.2'
BEZ8X10	250	25.0	50.4	5.4	3.9	5.4	01°17.51.6'	175°58.41.4'
BEZ8X11	280	17.9	46.8	10.2	4.7	4.7	01°17.50.2'	175°58.42.2'
BEZ8X12	310	26.2	45.6	4.8	5.1	4.8	01°17.49.6'	175°58.43.8'
BEZ8X13	340	29.4	53.9	3.6	3.2	3.6	01°17.48.9'	175°58.44.0'
BEZ8X14	370	24.9	56.8	5.4	2.7	5.4	01°17.48.8'	175°58.44.5'
BEZ8X15	400	29.2	40.9	3.7	6.6	3.7	01°17.48.4'	175°58.45.4'
BEZ8X16	430	30.6	50.4	3.2	3.9	3.2	01°17.47.6'	175°58.46.9'
BEZ8X17	460	35.9	48.2	2.0	4.4	2.0	01°17.47.3'	175°58.48.0'
BEZ8X18	490	37.3	59.2	1.8	2.4	1.8	01°17.46.9'	175°58.48.8'
BEZ8X19	520	34.0	48.0	2.4	4.4	2.4	01°17.46.6'	175°58.50.0'
BEZ8X20	550	36.2	58.2	1.9	2.5	1.9	01°17.46.2'	175°58.50.8'
BEZ8X21	580	33.2	53.9	2.6	3.2	2.6	01°17.45.8'	175°58.51.8'
BEZ8X22	610	31.4	51.8	3.0	3.6	3.0	01°17.45.4'	175°58.52.7'
BEZ8X23	640	27.8	46.6	4.2	4.8	4.2	01°17.45.2'	175°58.53.5'
BEZ9X1	0	31.2	59.0	3.1	2.4	3.1	01°17.53.7'	175°58.59.7'
BEZ9X2	10	16.4	54.6	11.6	3.1	3.1	01°17.54.3'	175°58.58.7'
BEZ9X3	40	12.0	39.6	17.3	7.1	7.1	01°17.54.6'	175°58.58.2'
BEZ9X4	70	8.7	33.3	23.3	10.0	10.0	01°17.54.9'	175°58.57.9'
BEZ9X5	100	7.9	28.6	25.1	13.0	13.0	01°17.55.5'	175°58.56.3'
BEZ9X6	130	7.2	26.2	26.7	14.9	14.9	01°17.55.9'	175°58.55.3'

BEZ9X7	160	20.9	27.2	7.8	14.1	14.1	01°17.56.6'	175°58.55.1'
BEZ9X8	190	7.4	25.6	26.2	15.4	15.4	01°17.57.3'	175°58.54.0'
BEZ9X9	220	6.4	25.2	28.7	15.8	15.8	01°17.57.6'	175°58.53.3'
BEZ9X10	250	7.2	28.6	26.7	13.0	13.0	01°17.58.6'	175°58.52.4'
BEZ9X11	280	9.8	30.5	21.1	11.7	11.7	01°17.58.5'	175°58.51.5'
BEZ9X12	310	12.2	36.8	17.0	8.3	8.3	01°18.00.4'	175°58.50.5'
BEZ9X13	340	15.4	40.3	12.7	6.8	6.8	01°18.00.7'	175°58.49.4'
BEZ9X14	370	18.9	38.0	9.3	7.7	7.7	01°18.01.3'	175°58.48.7'
BEZ9X15	400	32.3	63.9	2.8	1.8	2.8	01°18.03.5'	175°58.48.6'
BEZ9X16	430	38.0	70.3	1.7	1.3	1.7	01°18.03.7'	175°58.47.8'
BEZ9X17	460	46.0	88.6	0.8	0.5	0.8	01°18.04.4'	175°58.47.1'
BEZ9X18	490	55.6	109.5	0.3	0.1	0.3	01°18.05.2'	175°58.46.4'
BEZ9X19	520	78.4	146.2	0.0	0.0	0.0	01°18.04.6'	175°58.45.2'
BEZ10X1	0	98.4	157.9	0.0	0.0	0.0	01°18.16.2'	175°58.55.2'
BEZ10X2	10	88.5	146.3	0.0	0.0	0.0	01°18.14.9'	175°58.56.0'
BEZ10X3	40	85.6	132.2	0.0	0.0	0.0	01°18.15.5'	175°58.56.2'
BEZ10X4	70	73.6	112.6	0.1	0.1	0.1	01°18.14.5'	175°58.58.0'
BEZ10X5	100	41.5	81.5	1.2	0.7	1.2	01°18.14.0'	175°58.59.1'
BEZ10X6	130	36.7	56.5	1.9	2.8	1.9	01°18.14.1'	175°58.59.9'
BEZ10X7	160	23.9	53.7	5.9	3.2	5.9	01°18.13.7'	175°59.01.2'
BEZ10X8	190	21.2	53.5	7.5	3.3	7.5	01°18.13.4'	175°59.02.6'
BEZ10X9	220	19.5	50.8	8.8	3.8	3.8	01°18.12.8'	175°59.02.5'
BEZ10X10	250	16.1	47.4	12.0	4.6	4.6	01°18.12.7'	175°59.03.0'
BEZ10X11	280	15.8	47.0	12.3	4.7	4.7	01°18.11.8'	175°59.04.0'
BEZ10X12	310	13.5	52.4	15.1	3.5	3.5	01°18.12.1'	175°59.03.8'
BEZ10X13	340	17.7	58.7	10.3	2.5	2.5	01°18.10.7'	175°59.05.7'
BEZ10X14	370	23.8	68.5	6.0	1.4	6.0	01°18.09.5'	175°59.06.7'
BEZ10X15	400	30.3	82.7	3.3	0.6	3.3	01°18.09.0'	175°59.06.9'
BEZ10X16	430	35.2	98.5	2.1	0.3	2.1	01°18.09.0'	175°59.07.2'
BEZ10X17	460	48.2	113.0	0.7	0.1	0.7	01°18.08.9'	175°59.07.4'
BEZ10X18	490	66.5	118.2	0.1	0.1	0.1	01°18.07.9'	175°59.08.9'
BEZ11X1	0	36.8	99.4	1.8	0.3	1.8	01°18.15.7'	175°58.14.7'
BEZ11X2	10	35.5	90.5	2.1	0.4	2.1	01°18.16.0'	175°58.13.7'
BEZ11X3	40	36.3	88.4	1.9	0.5	1.9	01°18.16.7'	175°58.13.0'
BEZ11X4	70	30.3	80.9	3.3	0.7	3.3	01°18.17.4'	175°58.12.8'
BEZ11X5	100	26.6	71.3	4.6	1.2	4.6	01°18.16.8'	175°58.12.2'
BEZ11X6	130	20.8	62.5	7.8	2.0	7.8	01°18.17.7'	175°58.10.7'
BEZ11X7	160	21.8	59.7	7.1	2.3	7.1	01°18.18.0'	175°59.10.2'
BEZ11X8	190	22.9	57.0	6.5	2.7	6.5	01°18.19.1'	175°59.08.9'
BEZ11X9	220	26.5	65.3	4.7	1.7	4.7	01°18.19.6'	175°59.08.0'
BEZ11X10	250	15.8	62.3	12.3	2.0	2.0	01°18.19.3'	175°59.07.6'
BEZ11X11	280	30.0	66.0	3.4	1.6	3.4	01°18.20.6'	175°59.06.1'
BEZ11X12	310	43.2	77.7	1.0	0.9	1.0	01°18.20.4'	175°59.05.6'
BEZ11X13	340	52.8	88.3	0.4	0.5	0.4	01°18.20.9'	175°59.05.0'
BEZ11X14	370	70.4	116.5	0.1	0.1	0.1	01°18.21.3'	175°59.04.1'
BEZ11X15	400	113.6	152.9	0.0	0.0	0.0	01°18.21.6'	175°59.02.9'

BEZ11X16	430	155.2	181.4	0.0	0.0	0.0	01°18.22.2'	175°59.01.5'
BEZ11X17	460	139.0	187.3	0.0	0.0	0.0	01°18.22.6'	175°59.01.0'
BEZ11X18	490	121.3	189.2	0.0	0.0	0.0	01°18.23.8'	175°59.00.4'
BEZ12X1	0	92.9	153.9	0.0	0.0	0.0	01°18.27.4'	175°59.05.1'
BEZ12X2	10	93.9	143.0	0.0	0.0	0.0	01°18.26.5'	175°59.06.2'
BEZ12X3	40	72.2	126.7	0.1	0.1	0.1	01°18.27.0'	175°59.07.1'
BEZ12X4	70	107.3	130.7	0.0	0.0	0.0	01°18.25.0'	175°59.07.2'
BEZ12X5	100	67.3	101.9	0.1	0.2	0.1	01°18.25.0'	175°59.08.1'
BEZ12X6	130	44.8	88.6	0.9	0.5	0.9	01°18.24.5'	175°59.09.2'
BEZ12X7	160	39.3	78.2	1.5	0.8	1.5	01°18.24.3'	175°59.09.5'
BEZ12X8	190	36.9	79.9	1.8	0.8	1.8	01°18.23.7'	175°59.10.4'
BEZ12X9	220	34.6	78.4	2.3	0.8	2.3	01°18.23.4'	175°59.10.9'
BEZ12X10	250	31.2	73.8	3.1	1.1	3.1	01°18.23.2'	175°59.12.0'
BEZ12X11	280	35.2	80.2	2.1	0.7	2.1	01°18.22.3'	175°59.13.5'
BEZ12X12	310	42.9	84.6	1.1	0.6	1.1	01°18.22.1'	175°59.14.0'
BEZ12X13	340	38.7	86.2	1.6	0.5	1.6	01°18.21.6'	175°59.15.0'
BEZ12X14	370	43.9	95.4	1.0	0.3	1.0	01°18.20.8'	175°59.16.1'
BEZ13X1	0	62.2	124.3	0.2	0.1	0.2	01°18.28.0'	175°59.21.3'
BEZ13X2	10	40.1	94.2	1.4	0.3	1.4	01°18.28.6'	175°59.20.5'
BEZ13X3	40	33.2	79.3	2.6	0.8	2.6	01°18.29.2'	175°59.19.8'
BEZ13X4	70	34.0	64.8	2.4	1.7	2.4	01°18.29.2'	175°59.19.4'
BEZ13X5	100	37.1	64.8	1.8	1.7	1.8	01°18.29.9'	175°59.18.6'
BEZ13X6	130	38.4	74.1	1.6	1.0	1.6	01°18.30.5'	175°59.17.2'
BEZ13X7	160	53.9	87.1	0.4	0.5	0.4	01°18.30.7'	175°59.16.4'
BEZ13X8	190	53.1	89.3	0.4	0.4	0.4	01°18.31.4'	175°59.15.4'
BEZ13X9	220	64.9	102.3	0.1	0.2	0.1	01°18.31.2'	175°59.15.0'
BEZ13X10	250	77.7	127.8	0.0	0.1	0.0	01°18.31.3'	175°59.14.0'
BEZ13X11	280	106.3	158.9	0.0	0.0	0.0	01°18.32.5'	175°59.12.9'
BEZ13X12	310	149.0	177.6	0.0	0.0	0.0	01°18.33.6'	175°59.12.0'
BEZ13X13	340	117.2	168.5	0.0	0.0	0.0	01°18.35.2'	175°59.13.6'
BEZ13X14	370	68.3	162.8	0.1	0.0	0.1	01°18.34.0'	175°59.10.7'
BEZ13X15	400	107.7	162.2	0.0	0.0	0.0	01°18.34.6'	175°59.09.8'
BEZ14X1	0	94.2	149.2	0.0	0.0	0.0	01°18.43.1'	175°59.13.3'
BEZ14X2	10	80.9	128.9	0.0	0.0	0.0	01°18.42.4'	175°59.15.2'
BEZ14X3	40	78.9	120.1	0.0	0.1	0.0	01°18.41.7'	175°59.15.7'
BEZ14X4	70	88.2	120.9	0.0	0.1	0.0	01°18.41.1'	175°59.16.4'
BEZ14X5	100	79.8	109.6	0.0	0.1	0.0	01°18.40.4'	175°59.17.3'
BEZ14X6	130	80.7	105.9	0.0	0.2	0.0	01°18.40.3'	175°59.18.1'
BEZ14X7	160	57.2	88.4	0.3	0.5	0.3	01°18.40.3'	175°59.18.7'
BEZ14X8	190	36.9	72.3	1.8	1.2	1.8	01°18.39.7'	175°59.19.8'
BEZ14X9	220	24.0	54.2	5.9	3.1	5.9	01°18.39.2'	175°59.20.4'
BEZ14X10	250	21.6	51.4	7.3	3.7	7.3	01°18.38.5'	175°59.21.2'
BEZ14X11	280	12.4	45.2	16.7	5.2	5.2	01°18.38.1'	175°59.22.6'
BEZ14X12	310	14.0	42.8	14.5	5.9	5.9	01°18.38.2'	175°59.23.6'
BEZ14X13	340	16.6	53.2	11.4	3.3	3.3	01°18.36.9'	175°59.24.0'
BEZ14X14	370	22.9	68.3	6.5	1.4	6.5	01°18.37.1'	175°59.24.8'

BEZ14X15	400	51.9	106.2	0.5	0.2	0.5	01°18.36.3'	175°59.26.0'
BEZ15X1	0	57.0	149.2	0.3	0.0	0.3	01°18.53.6'	175°59.36.5'
BEZ15X2	10	46.3	123.8	0.8	0.1	0.8	01°18.53.5'	175°59.36.0'
BEZ15X3	40	38.9	98.6	1.5	0.3	1.5	01°18.54.2'	175°59.35.7'
BEZ15X4	70	30.3	85.5	3.3	0.6	3.3	01°18.54.6'	175°59.34.3'
BEZ15X5	100	28.6	47.9	3.9	4.5	3.9	01°18.55.0'	175°59.32.9'
BEZ15X6	130	26.9	65.9	4.5	1.6	4.5	01°18.55.8'	175°59.32.3'
BEZ15X7	160	26.8	59.3	4.6	2.4	4.6	01°18.56.2'	175°59.31.7'
BEZ15X8	190	32.4	60.7	2.7	2.2	2.7	01°18.56.7'	175°59.30.7'
BEZ15X9	220	44.3	66.6	0.9	1.6	0.9	01°18.56.8'	175°59.29.5'
BEZ15X10	250	54.9	81.8	0.4	0.7	0.4	01°18.57.5'	175°59.29.6'
BEZ15X11	280	58.7	93.7	0.3	0.4	0.3	01°18.58.4'	175°59.28.2'
BEZ15X12	310	58.7	109.5	0.3	0.1	0.3	01°18.58.6'	175°59.27.2'
BEZ15X13	340	85.9	124.6	0.0	0.1	0.0	01°18.59.0'	175°59.26.3'
BEZ15X14	370	80.3	125.8	0.0	0.1	0.0	01°18.59.1'	175°59.25.8'
BEZ15X15	400	77.1	121.2	0.0	0.1	0.0	01°18.59.7'	175°59.24.9'
BEZ15X16	430	32.6	130.2	2.7	0.0	2.7	01°19.00.3'	175°59.23.9'
BEZ16X1	0	101.7	159.9	0.0	0.0	0.0	01°19.11.9'	175°59.27.3'
BEZ16X2	10	76.6	125.1	0.1	0.1	0.1	01°19.11.7'	175°59.27.5'
BEZ16X3	40	58.2	100.3	0.3	0.2	0.3	01°19.11.5'	175°59.29.3'
BEZ16X4	70	50.1	85.7	0.6	0.5	0.6	01°19.11.4'	175°59.31.1'
BEZ16X5	100	45.2	78.7	0.9	0.8	0.9	01°19.11.4'	175°59.31.5'
BEZ16X6	130	46.2	83.6	0.8	0.6	0.8	01°19.11.6'	175°59.32.4'
BEZ16X7	160	38.6	70.9	1.6	1.2	1.6	01°19.11.8'	175°59.33.4'
BEZ16X8	190	34.3	66.8	2.3	1.6	2.3	01°19.11.9'	175°59.34.5'
BEZ16X9	220	20.7	50.9	7.9	3.8	7.9	01°19.11.8'	175°59.34.9'
BEZ16X10	250	13.6	41.6	15.0	6.3	6.3	01°19.11.0'	175°59.36.1'
BEZ16X11	280	14.0	40.2	14.5	6.8	6.8	01°19.11.8'	175°59.37.0'
BEZ16X12	310	13.5	40.9	15.1	6.6	6.6	01°19.10.9'	175°59.37.5'
BEZ16X13	340	13.3	42.4	15.4	6.1	6.1	01°19.10.6'	175°59.38.4'
BEZ16X14	370	14.5	45.5	13.8	5.1	5.1	01°19.09.9'	175°59.39.9'
BEZ16X15	400	15.8	51.2	12.3	3.7	3.7	01°19.09.4'	175°5940.8'
BEZ16X16	430	13.0	53.7	15.8	3.2	3.2	01°19.08.9'	175°59.41.7'
BEZ16X17	460	18.4	57.9	9.7	2.6	2.6	01°19.08.7'	175°59.42.1'
BEZ16X18	490	7.6	63.8	25.8	1.8	1.8	01°19.08.1'	175°59.43.2'
BEZ16X19	520	30.5	81.5	3.3	0.7	3.3	01°19.11.9'	175°59.44.2'
BEZ17X1	0	38.9	111.7	1.5	0.1	1.5	01°19.16.6'	175°59.50.3'
BEZ17X2	10	19.8	66.9	8.6	1.6	1.6	01°19.16.9'	175°59.49.7'
BEZ17X3	40	18.3	59.3	9.8	2.4	2.4	01°19.17.4'	175°59.49.0'
BEZ17X4	70	15.7	51.7	12.4	3.6	3.6	01°19.18.1'	175°59.47.8'
BEZ17X5	100	12.1	41.5	17.2	6.4	6.4	01°19.18.1'	175°59.47.0'
BEZ17X6	130	11.7	38.9	17.8	7.4	7.4	01°19.18.3'	175°59.46.2'
BEZ17X7	160	12.3	42.0	16.8	6.2	6.2	01°19.18.4'	175°59.45.4'
BEZ17X8	190	15.1	42.3	13.1	6.1	6.1	01°19.19.3'	175°59.43.9'
BEZ17X9	220	15.0	45.8	13.2	5.0	5.0	01°19.19.7'	175°59.42.9'
BEZ17X10	250	23.6	54.9	6.1	3.0	6.1	01°19.20.5'	175°59.42.6'

BEZ17X11	280	64.8	78.5	0.1	0.8	0.1	01°19.21.0'	175°59.41.5'
BEZ17X12	310	68.3	92.6	0.1	0.4	0.1	01°19.21.3'	175°59.41.4'
BEZ17X13	340	79.6	99.8	0.0	0.3	0.0	01°19.22.0'	175°59.39.4'
BEZ17X14	370	102.4	118.3	0.0	0.1	0.0	01°19.22.5'	175°59.38.9'
BEZ17X15	400	124.6	139.0	0.0	0.0	0.0	01°19.22.7'	175°59.38.1'
BEZ17X16	430	114.9	140.5	0.0	0.0	0.0	01°19.22.9'	175°59.37.2'
BEZ17X17	460	93.3	122.0	0.0	0.1	0.0	01°19.23.2'	175°59.36.2'
BEZ17X18	490	35.1	141.3	2.2	0.0	2.2	01°19.23.9'	175°59.35.5'
BEZ17X19	520	95.9	147.4	0.0	0.0	0.0	01°19.23.9'	175°59.34.5'
BEZ17X20	550	138.9	181.6	0.0	0.0	0.0	01°19.24.3'	175°59.32.8'
BEZ18X1	0	116.2	161.9	0.0	0.0	0.0	01°19.29.6'	175°59.36.8'
BEZ18X2	10	105.1	161.4	0.0	0.0	0.0	01°19.29.4'	175°59.37.4'
BEZ18X3	40	122.8	161.2	0.0	0.0	0.0	01°19.29.0'	175°59.38.5'
BEZ18X4	70	111.9	138.1	0.0	0.0	0.0	01°19.28.8'	175°59.38.9'
BEZ18X5	100	59.7	89.0	0.2	0.5	0.2	01°19.28.5'	175°59.40.2'
BEZ18X6	130	34.8	59.9	2.2	2.3	2.2	01°19.28.4'	175°59.40.4'
BEZ18X7	160	33.7	51.7	2.4	3.6	2.4	01°19.27.9'	175°59.41.4'
BEZ18X8	190	27.8	52.9	4.2	3.4	4.2	01°19.27.6'	175°59.42.7'
BEZ18X9	220	25.0	49.8	5.4	4.0	5.4	01°19.27.3'	175°59.43.6'
BEZ18X10	250	30.9	49.9	3.1	4.0	3.1	01°19.27.0'	175°59.44.6'
BEZ18X11	280	20.2	46.9	8.3	4.7	4.7	01°19.26.6'	175°59.45.8'
BEZ18X12	310	19.5	45.5	8.8	5.1	5.1	01°19.26.1'	175°59.46.7'
BEZ18X13	340	21.2	48.2	7.5	4.4	7.5	01°19.25.7'	175°59.47.5'
BEZ18X14	370	25.3	53.1	5.2	3.3	5.2	01°19.25.2'	175°59.48.5'
BEZ18X15	400	22.9	56.0	6.5	2.8	6.5	01°19.24.7'	175°59.49.4'
BEZ18X16	430	21.6	56.2	7.3	2.8	7.3	01°19.24.3'	175°59.50.2'
BEZ18X17	460	26.5	68.8	4.7	1.4	4.7	01°19.23.7'	175°59.50.9'
BEZ18X18	490	33.7	80.8	2.4	0.7	2.4	01°19.22.9'	175°59.51.8'
BEZ18X19	520	40.4	93.6	1.3	0.4	1.3	01°19.21.7'	175°59.53.0'
BEZ18X20	550	50.9	113.0	0.5	0.1	0.5	01°19.21.7'	175°59.53.9'
BEZ19X1	0	39.5	99.3	1.4	0.3	1.4	01°19.32.4'	175°59.59.1'
BEZ19X2	10	19.0	61.2	9.2	2.1	2.1	01°19.32.4'	175°59.58.6'
BEZ19X3	40	25.6	45.0	5.1	5.2	5.1	01°19.34.5'	175°59.57.0'
BEZ19X4	70	10.6	35.1	19.6	9.1	9.1	01°19.33.6'	175°59.56.3'
BEZ19X5	100	9.8	31.5	21.1	11.1	11.1	01°19.34.2'	175°59.55.4'
BEZ19X6	130	9.6	30.5	21.5	11.7	11.7	01°19.34.2'	175°59.54.6'
BEZ19X7	160	10.3	29.7	20.2	12.3	12.3	01°19.34.5'	175°59.53.6'
BEZ19X8	190	10.7	29.4	19.5	12.5	12.5	01°19.35.0'	175°59.52.4'
BEZ19X9	220	10.9	28.8	19.1	12.9	12.9	01°19.34.8'	175°59.51.5'
BEZ19X10	250	10.3	27.6	20.2	13.8	13.8	01°19.35.1'	175°59.51.2'
BEZ19X11	280	18.0	34.9	10.1	9.2	9.2	01°19.35.2'	175°59.49.8'
BEZ19X12	310	19.7	38.6	8.6	7.5	7.5	01°19.35.3'	175°59.48.8'
BEZ19X13	340	20.7	55.3	7.9	3.0	7.9	01°19.35.8'	175°59.47.5'
BEZ19X14	370	23.5	41.4	6.1	6.4	6.1	01°19.36.3'	175°59.46.5'
BEZ19X15	400	24.9	45.1	5.4	5.2	5.4	01°19.36.6'	175°59.46.0'
BEZ19X16	430	30.0	46.3	3.4	4.9	3.4	01°19.37.2'	175°59.45.4'

BEZ19X17	460	52.9	66.9	0.4	1.6	0.4	01°19.37.2'	175°59.44.0'
BEZ19X18	490	52.8	73.3	0.4	1.1	0.4	01°19.37.2'	175°59.43.4'
BEZ19X19	520	86.4	104.1	0.0	0.2	0.0	01°19.37.7'	175°59.42.9'
BEZ19X20	550	77.5	150.9	0.0	0.0	0.0	01°19.38.0'	175°59.42.2'
BEZ19X21	580	100.8	152.8	0.0	0.0	0.0	01°19.39.5'	175°59.40.9'
BEZ19X22	610	160.9	166.7	0.0	0.0	0.0	01°19.39.3'	175°59.40.1'
BEZ20X1	0	89.2	151.9	0.0	0.0	0.0	01°19.49.2'	175°59.42.3'
BEZ20X2	10	79.4	132.3	0.0	0.0	0.0	01°19.48.7'	175°59.43.0'
BEZ20X3	40	90.3	119.5	0.0	0.1	0.0	01°19.48.7'	175°59.44.0'
BEZ20X4	70	94.6	113.2	0.0	0.1	0.0	01°19.47.7'	175°59.45.1'
BEZ20X5	100	58.2	67.4	0.3	1.5	0.3	01°19.46.9'	175°59.45.3'
BEZ20X6	130	30.7	48.4	3.2	4.3	3.2	01°19.46.5'	175°59.46.1'
BEZ20X7	160	19.7	38.5	8.6	7.5	7.5	01°19.46.0'	175°59.47.0'
BEZ20X8	190	15.4	34.2	12.7	9.6	9.6	01°19.45.4'	175°59.47.9'
BEZ20X9	220	18.8	33.9	9.4	9.7	9.7	01°19.44.9'	175°59.48.5'
BEZ20X10	250	10.9	25.8	19.1	15.2	15.2	01°19.44.4'	175°59.49.4'
BEZ20X11	280	9.5	24.5	21.7	16.4	16.4	01°19.44.0'	175°59.50.4'
BEZ20X12	310	8.6	25.8	23.5	15.2	15.2	01°19.43.7'	175°59.51.5'
BEZ20X13	340	6.8	25.7	27.7	15.3	15.3	01°19.43.2'	175°59.52.4'
BEZ20X14	370	7.6	24.4	25.8	16.5	16.5	01°19.42.5'	175°59.53.1'
BEZ20X15	400	8.3	26.2	24.2	14.9	14.9	01°19.41.9'	175°59.53.8'
BEZ20X16	430	8.9	26.9	22.9	14.3	14.3	01°19.41.3'	175°59.54.5'
BEZ20X17	460	8.5	27.5	23.7	13.9	13.9	01°19.41.0'	175°59.55.3'
BEZ20X18	490	8.3	25.8	24.2	15.2	15.2	01°19.40.6'	175°59.56.3'
BEZ20X19	520	7.9	26.2	25.1	14.9	14.9	01°19.40.3'	175°59.57.1'
BEZ20X20	550	10.2	30.9	20.4	11.5	11.5	01°19.40.0'	175°59.59.1'
BEZ20X21	580	12.3	35.9	16.8	8.7	8.7	01°19.39.8'	175°59.59.9'
BEZ21X1	0	40.4	86.7	1.3	0.5	1.3	01°19.51.7'	175°00.04.9'
BEZ21X2	10	16.6	39.0	11.4	7.3	7.3	01°19.51.5'	175°00.03.8'
BEZ21X3	40	16.2	30.9	11.8	11.5	11.5	01°19.51.8'	175°00.02.9'
BEZ21X4	70	14.3	28.9	14.1	12.8	12.8	01°19.52.4'	175°00.01.8'
BEZ21X5	100	13.4	26.0	15.3	15.1	15.1	01°19.52.8'	175°00.01.0'
BEZ21X6	130	12.1	26.9	17.2	14.3	14.3	01°19.52.7'	175°00.00.0'
BEZ21X7	160	7.2	25.8	26.7	15.2	15.2	01°19.53.2'	175°59.58.8'
BEZ21X8	190	10.4	24.6	20.0	16.3	16.3	01°19.53.4'	175°59.58.1'
BEZ21X9	220	8.0	22.4	24.8	18.4	18.4	01°19.53.7'	175°59.56.9'
BEZ21X10	250	7.7	21.1	25.5	19.8	19.8	01°19.53.8'	175°59.56.0'
BEZ21X11	280	7.8	22.2	25.3	18.6	18.6	01°19.54.2'	175°59.55.2'
BEZ21X12	310	8.1	22.2	24.6	18.6	18.6	01°19.54.8'	175°59.54.9'
BEZ21X13	340	6.8	21.1	27.7	19.8	19.8	01°19.55.3'	175°59.54.3'
BEZ21X14	370	9.1	22.6	22.5	18.2	18.2	01°19.56.9'	175°59.53.1'
BEZ21X15	400	13.2	26.2	15.5	14.9	14.9	01°19.57.1'	175°59.53.0'
BEZ21X16	430	12.0	51.8	17.3	3.6	3.6	01°19.57.0'	175°59.51.7'
BEZ21X17	460	13.3	31.6	15.4	11.0	11.0	01°19.57.3'	175°59.50.8'
BEZ21X18	490	16.2	36.2	11.8	8.6	8.6	01°19.57.7'	175°59.49.9'
BEZ21X19	520	22.8	48.4	6.5	4.3	6.5	01°19.58.0'	175°59.48.7'

BEZ21X20	550	39.2	70.4	1.5	1.3	1.5	01°19.58.3'	175°59.48.2'
BEZ21X21	580	54.8	91.9	0.4	0.4	0.4	01°19.58.4'	175°59.47.1'
BEZ21X22	610	67.2	122.8	0.1	0.1	0.1	01°19.58.2'	175°59.45.1'
BEZ22X1	0	84.0	139.5	0.0	0.0	0.0	01°20.04.6'	175°59.46.7'
BEZ22X2	10	74.3	113.4	0.1	0.1	0.1	01°20.03.7'	175°59.47.3'
BEZ22X3	40	61.4	96.4	0.2	0.3	0.2	01°20.03.2'	175°59.48.1'
BEZ22X4	70	47.9	80.6	0.7	0.7	0.7	01°20.03.0'	175°59.49.0'
BEZ22X5	100	34.2	62.8	2.3	2.0	2.3	01°20.03.1'	175°59.49.8'
BEZ22X6	130	24.5	47.5	5.6	4.6	5.6	01°20.02.2'	175°59.50.5'
BEZ22X7	160	23.0	41.4	6.4	6.4	6.4	01°20.01.8'	175°59.52.8'
BEZ22X8	200	13.6	32.9	15.0	10.3	10.3	01°20.02.1'	175°59.52.6'
BEZ22X9	220	16.8	27.3	11.2	14.0	14.0	01°20.01.5'	175°59.53.6'
BEZ22X10	250	10.2	22.5	20.4	18.3	18.3	01°20.01.2'	175°59.54.6'
BEZ22X11	280	6.4	20.0	28.7	21.0	21.0	01°20.00.7'	175°59.55.2'
BEZ22X12	310	7.5	20.7	26.0	20.2	20.2	01°20.00.4'	175°59.56.6'
BEZ22X13	340	6.8	20.2	27.7	20.8	20.8	01°20.00.2'	175°59.57.8'
BEZ22X14	370	9.9	20.2	20.9	20.8	20.8	01°19.59.4'	175°59.58.1'
BEZ22X15	400	7.5	20.0	26.0	21.0	21.0	01°19.59.5'	175°59.59.7'
BEZ22X16	430	7.8	20.1	25.3	20.9	20.9	01°19.59.2'	176°00.00.9'
BEZ22X17	460	9.2	21.5	22.3	19.3	19.3	01°19.59.2'	176°00.01.2'
BEZ22X18	490	8.8	22.3	23.1	18.5	18.5	01°19.59.2'	176°00.01.6'
BEZ22X19	520	11.2	25.3	18.6	15.7	15.7	01°19.58.6'	176°00.03.0'
BEZ22X20	550	11.4	27.1	18.3	14.2	14.2	01°19.58.2'	176°00.03.5'
BEZ22X21	580	12.2	38.2	17.0	7.7	7.7	01°19.57.9'	176°00.05.1'
BEZ22X22	610	15.4	31.2	12.7	11.3	11.3	01°19.57.5'	176°00.05.8'
BEZ22X23	640	21.5	48.4	7.3	4.3	7.3	01°19.56.5'	176°00.07.6'
BEZ23X1	0	27.5	60.5	4.3	2.2	4.3	01°20.05.9'	176°00.12.2'
BEZ23X2	10	18.9	36.5	9.3	8.4	8.4	01°20.06.1'	176°00.12.1'
BEZ23X3	40	15.2	32.0	13.0	10.8	10.8	01°20.06.8'	176°00.11.2'
BEZ23X4	70	13.4	29.2	15.3	12.6	12.6	01°20.07.5'	176°00.09.4'
BEZ23X5	100	12.4	26.1	16.7	15.0	15.0	01°20.07.9'	176°00.08.7'
BEZ23X6	130	11.3	22.5	18.4	18.3	18.3	01°20.08.3'	176°00.07.7'
BEZ23X7	160	10.9	23.5	19.1	17.3	17.3	01°20.08.8'	176°00.06.9'
BEZ23X8	200	9.2	21.6	22.3	19.2	19.2	01°20.09.1'	176°00.06.0'
BEZ23X9	220	8.1	19.7	24.6	21.4	21.4	01°20.09.3'	176°00.05.1'
BEZ23X10	250	7.6	19.8	25.8	21.3	21.3	01°20.09.8'	176°00.04.5'
BEZ23X11	280	7.4	18.6	26.2	22.7	22.7	01°20.10.3'	176°00.03.2'
BEZ23X12	310	7.9	19.5	25.1	21.6	21.6	01°20.11.1'	176°00.02.9'
BEZ23X13	340	8.8	20.8	23.1	20.1	20.1	01°20.11.2'	176°00.02.0'
BEZ23X14	370	9.2	20.7	22.3	20.2	20.2	01°19.12.9'	176°00.00.7'
BEZ23X15	400	9.6	20.4	21.5	20.6	20.6	01°19.11.9'	175°59.58.7'
BEZ23X16	430	9.2	21.7	22.3	19.1	19.1	01°19.12.1'	175°59.58.6'
BEZ23X17	460	9.5	21.3	21.7	19.6	19.6	01°19.12.4'	175°59.58.1'
BEZ23X18	490	11.0	25.0	18.9	15.9	15.9	01°19.13.0'	175°59.57.0'
BEZ23X19	520	18.7	32.7	9.5	10.4	10.4	01°19.13.5'	175°59.55.9'
BEZ23X20	550	23.2	39.7	6.3	7.0	6.3	01°19.14.0'	175°59.55.4'

BEZ23X21	580	30.1	46.3	3.4	4.9	3.4	01°19.14.2'	175°59.53.8'
BEZ23X22	610	35.4	55.5	2.1	2.9	2.1	01°19.14.4'	175°59.53.0'
BEZ23X23	640	40.9	60.7	1.3	2.2	1.3	01°19.15.2'	175°59.51.7'
BEZ23X24	670	46.0	68.1	0.8	1.5	0.8	01°19.14.9'	175°59.51.3'
BEZ23X25	700	56.7	83.9	0.3	0.6	0.3	01°19.15.2'	175°59.50.2'
BEZ23X26	730	72.2	101.9	0.1	0.2	0.1	01°19.15.6'	175°59.49.3'
BEZ23X27	760	83.3	129.8	0.0	0.0	0.0	01°19.16.2'	175°59.48.3'
BEZ23X28	790	96.4	147.8	0.0	0.0	0.0	01°19.16.5'	175°59.46.5'
BEZ24X1	0	78.4	114.9	0.0	0.1	0.0	01°20.21.8'	175°59.50.3'
BEZ24X2	10	56.9	82.4	0.3	0.7	0.3	01°20.21.5'	175°59.51.4'
BEZ24X3	40	48.2	72.0	0.7	1.2	0.7	01°20.21.2'	175°59.51.9'
BEZ24X4	70	33.4	56.9	2.5	2.7	2.5	01°20.21.3'	175°59.52.2'
BEZ24X5	100	26.1	46.0	4.8	5.0	4.8	01°20.21.4'	175°59.53.6'
BEZ24X6	130	21.9	39.5	7.1	7.1	7.1	01°20.20.8'	175°59.54.1'
BEZ24X7	160	19.8	37.0	8.6	8.2	8.2	01°20.15.9'	175°59.47.0'
BEZ24X8	200	9.4	34.3	21.9	9.5	9.5	01°20.20.0'	175°59.56.6'
BEZ24X9	220	14.4	44.2	13.9	5.5	5.5	01°20.19.8'	175°59.57.9'
BEZ24X10	250	12.4	29.8	16.7	12.2	12.2	01°20.18.5'	175°59.58.5'
BEZ24X11	280	11.7	24.6	17.8	16.3	16.3	01°20.18.5'	175°59.59.0'
BEZ24X12	310	11.7	23.3	17.8	17.5	17.5	01°20.18.5'	175°59.59.8'
BEZ24X13	340	10.3	22.8	20.2	18.0	18.0	01°20.18.6'	176°00.00.9'
BEZ24X14	370	8.0	21.1	24.8	19.8	19.8	01°19.16.7'	176°00.02.2'
BEZ24X15	400	9.4	20.2	21.9	20.8	20.8	01°19.16.7'	176°00.02.2'
BEZ24X16	430	7.7	19.5	25.5	21.6	21.6	01°19.16.3'	176°00.03.5'
BEZ24X17	460	8.2	16.6	24.4	25.4	25.4	01°19.16.4'	176°00.03.3'
BEZ24X18	490	6.4	18.0	28.7	23.5	23.5	01°19.16.0'	176°00.04.8'
BEZ24X19	520	6.6	18.0	28.2	23.5	23.5	01°19.14.8'	176°00.05.8'
BEZ24X20	550	7.8	19.3	25.3	21.9	21.9	01°19.14.6'	176°00.06.5'
BEZ24X21	580	9.9	21.3	20.9	19.6	19.6	01°19.14.6'	176°00.06.5'
BEZ24X22	610	9.5	21.0	21.7	19.9	19.9	01°19.13.9'	176°00.07.9'
BEZ24X23	640	8.6	20.0	23.5	21.0	21.0	01°19.13.7'	176°00.08.6'
BEZ24X24	670	11.0	23.7	18.9	17.1	17.1	01°19.13.1'	176°00.09.5'
BEZ24X25	700	12.5	25.6	16.5	15.4	15.4	01°19.12.8'	176°00.10.9'
BEZ24X26	730	13.5	25.9	15.1	15.1	15.1	01°19.12.7'	176°00.11.6'
BEZ24X27	760	13.3	29.5	15.4	12.4	12.4	01°19.12.0'	176°00.12.5'
BEZ24X28	790	15.2	32.9	13.0	10.3	10.3	01°19.11.6'	176°00.13.2'
BEZ24X29	820	20.5	38.3	8.0	7.6	7.6	01°19.11.1'	176°00.14.0'
BEZ24X30	850	24.7	49.2	5.5	4.2	5.5	01°19.10.5'	176°00.14.8'
BEZ24X31	880	45.0	87.5	0.9	0.5	0.9	01°19.09.8'	176°00.14.8'
BEZ25X1	0	46.5	78.4	0.8	0.8	0.8	01°20.14.8'	176°00.18.3'
BEZ25X2	10	30.6	50.3	3.2	3.9	3.2	01°20.14.6'	176°00.17.5'
BEZ25X3	40	27.2	44.5	4.4	5.4	4.4	01°20.15.6'	176°00.17.4'
BEZ25X4	70	23.2	38.6	6.3	7.5	6.3	01°20.18.2'	176°00.13.8'
BEZ25X5	100	19.7	34.5	8.6	9.4	9.4	01°20.16.4'	176°00.15.2'
BEZ25X6	130	18.0	32.2	10.1	10.7	10.7	01°20.16.4'	176°00.14.4'
BEZ25X7	160	17.2	28.7	10.8	13.0	13.0	01°20.17.5'	176°00.13.1'

BEZ25X8	200	18.5	52.3	9.6	3.5	3.5	01°20.17.5'	176°00.12.9'
BEZ25X9	220	11.1	22.3	18.8	18.5	18.5	01°20.18.3'	176°00.11.5'
BEZ25X10	250	9.7	22.0	21.3	18.8	18.8	01°20.18.7'	176°00.10.6'
BEZ25X11	280	9.1	20.6	22.5	20.3	20.3	01°20.18.8'	176°00.09.7'
BEZ25X12	310	7.2	19.5	26.7	21.6	21.6	01°20.18.3'	176°00.09.0'
BEZ25X13	340	7.7	15.5	25.5	27.0	27.0	01°20.17.6'	176°00.08.0'
BEZ25X14	370	9.1	19.6	22.5	21.5	21.5	01°20.17.1'	176°00.07.6'
BEZ25X15	400	22.5	18.2	6.7	23.2	23.2	01°20.17.1'	176°00.07.1'
BEZ25X16	430	8.0	20.9	24.8	20.0	20.0	01°20.15.4'	176°00.05.9'
BEZ25X17	460	19.7	34.4	8.6	9.5	9.5	01°20.21.1'	176°00.00.9'
BEZ25X18	490	21.2	35.8	7.5	8.7	8.7	01°20.21.6'	176°00.00.2'
BEZ25X19	520	20.7	35.9	7.9	8.7	8.7	01°20.22.4'	175°59.59.2'
BEZ25X20	550	20.0	34.2	8.4	9.6	9.6	01°20.23.5'	175°59.58.7'
BEZ25X21	580	19.7	37.0	8.6	8.2	8.2	01°20.23.3'	175°59.57.6'
BEZ25X22	610	21.1	39.6	7.6	7.1	7.6	01°20.23.3'	175°59.57.8'
BEZ25X23	640	21.8	46.8	7.1	4.7	7.1	01°20.23.7'	175°59.57.0'
BEZ25X24	670	32.5	55.5	2.7	2.9	2.7	01°20.24.2'	175°59.55.9'
BEZ25X25	700	44.0	54.9	1.0	3.0	1.0	01°20.25.2'	175°59.54.1'
BEZ25X26	730	54.3	81.7	0.4	0.7	0.4	01°20.25.5'	175°59.53.5'
BEZ25X27	760	66.0	98.8	0.1	0.3	0.1	01°20.25.7'	175°59.53.0'
BEZ26X1	0	88.0	124.3	0.0	0.1	0.0		
BEZ26X2	10	98.4	54.6	0.0	3.1	0.0	01°20.23.8'	175°59.34.6'
BEZ26X3	40	53.0	80.5	0.4	0.7	0.4	01°20.23.7'	175°59.34.0'
BEZ26X4	70	50.1	84.3	0.6	0.6	0.6	01°20.23.9'	175°59.32.3'
BEZ26X5	159	55.4	88.0	0.3	0.5	0.3	01°20.23.0'	175°59.31.1'
BEZ26X6	130	50.4	75.9	0.5	0.9	0.5	01°20.23.1'	175°59.30.2'
BEZ26X7	160	40.6	68.4	1.3	1.4	1.3	01°20.23.8'	175°59.28.2'
BEZ26X8	259	41.3	61.7	1.2	2.1	1.2	01°20.23.6'	175°59.28.1'
BEZ26X9	220	30.9	54.8	3.1	3.0	3.1	01°20.24.0'	175°59.27.1'
BEZ26X10	250	28.5	48.0	3.9	4.4	3.9	01°20.24.2'	175°59.26.5'
BEZ26X11	280	23.4	42.8	6.2	5.9	6.2	01°20.24.2'	175°59.25.4'
BEZ26X12	310	22.0	39.6	7.0	7.1	7.0	01°20.24.9'	175°59.24.2'
BEZ26X13	340	21.2	37.4	7.5	8.0	8.0	01°20.25.2'	175°59.23.0'
BEZ26X14	370	19.2	36.4	9.0	8.5	8.5	01°20.25.9'	175°59.22.7'
BEZ26X15	459	18.4	35.4	9.7	8.9	8.9	01°20.26.4'	175°59.21.8'
BEZ26X16	430	19.3	35.3	9.0	9.0	9.0	01°20.26.9'	175°59.20.9'
BEZ26X17	460	19.8	36.7	8.6	8.3	8.3	01°20.26.9'	175°59.19.3'
BEZ26X18	490	21.3	35.3	7.5	9.0	9.0	01°20.27.7'	175°59.18.3'
BEZ26X19	520	21.8	36.4	7.1	8.5	8.5	01°20.28.1'	175°59.17.6'
BEZ26X20	550	20.8	34.4	7.8	9.5	9.5	01°20.28.4'	175°59.16.9'
BEZ26X21	580	21.2	36.8	7.5	8.3	8.3	01°20.29.1'	175°59.16.1'
BEZ26X22	610	19.2	34.3	9.0	9.5	9.5	01°20.29.7'	175°59.15.3'
BEZ26X23	640	19.7	32.3	8.6	10.6	10.6	01°20.30.0'	175°59.14.8'
BEZ26X24	670	19.2	30.6	9.0	11.7	11.7	01°20.30.7'	175°59.14.1'
BEZ26X25	759	19.5	33.3	8.8	10.0	10.0	01°20.30.0'	175°59.13.1'
BEZ26X26	730	18.6	33.8	9.5	9.8	9.8	01°20.30.6'	175°59.12.2'

BEZ26X27	760	18.7	25.0	9.5	15.9	15.9	01°20.31.1'	175°59.11.1'
BEZ26X28	790	22.2	36.5	6.9	8.4	8.4	01°20.32.3'	175°59.10.2'
BEZ26X29	820	28.9	45.4	3.8	5.1	3.8	01°20.32.7'	175°59.09.5'
BEZ26X30	850	35.7	57.8	2.0	2.6	2.0	01°20.33.0'	175°59.08.4'
BEZ26X31	880	49.2	79.4	0.6	0.8	0.6	01°20.33.3'	175°59.06.4'
BEZ26X32	910	87.8	124.4	0.0	0.1	0.0	01°20.33.3'	175°59.06.7'
BEZ27X1	0	144.9	171.3	0.0	0.0	0.0	01°20.24.4'	175°59.03.0'
BEZ27X2	10	122.7	153.0	0.0	0.0	0.0	01°20.23.8'	175°59.03.0'
BEZ27X3	40	87.2	119.8	0.0	0.1	0.0	01°20.23.5'	175°59.03.7'
BEZ27X4	70	70.5	97.7	0.1	0.3	0.1	01°20.23.0'	175°59.04.7'
BEZ27X5	159	60.9	87.5	0.2	0.5	0.2	01°20.23.3'	175°59.06.9'
BEZ27X6	130	50.4	77.8	0.5	0.8	0.5	01°20.23.1'	175°59.07.9'
BEZ27X7	160	45.9	74.3	0.8	1.0	0.8	01°20.22.7'	175°59.08.5'
BEZ27X8	259	39.5	65.3	1.4	1.7	1.4	01°20.22.5'	175°59.09.4'
BEZ27X9	220	37.6	60.7	1.7	2.2	1.7	01°20.22.5'	175°59.10.6'
BEZ27X10	250	34.9	54.9	2.2	3.0	2.2	01°20.21.8'	175°59.11.1'
BEZ27X11	280	31.9	45.8	2.9	5.0	2.9	01°20.21.6'	175°59.12.0'
BEZ27X12	310	23.8	42.3	6.0	6.1	6.0	01°20.21.3'	175°59.13.3'
BEZ27X13	340	24.1	41.9	5.8	6.2	5.8	01°20.20.6'	175°59.14.3'
BEZ27X14	370	20.2	38.0	8.3	7.7	7.7	01°20.21.1'	175°59.14.7'
BEZ27X15	459	20.4	36.3	8.1	8.5	8.5	01°20.20.6'	175°59.16.3'
BEZ27X16	430	22.3	38.7	6.8	7.4	6.8	01°20.20.9'	175°59.16.9'
BEZ27X17	460	22.5	40.4	6.7	6.8	6.7	01°20.20.6'	175°59.18.4'
BEZ27X18	490	21.4	38.0	7.4	7.7	7.4	01°20.20.8'	175°59.18.8'
BEZ27X19	520	20.9	38.8	7.8	7.4	7.8	01°20.20.6'	175°59.19.6'
BEZ27X20	550	20.7	37.9	7.9	7.8	7.9	01°20.20.7'	175°59.21.0'
BEZ27X21	580	22.6	39.2	6.7	7.2	6.7	01°20.20.7'	175°59.22.3'
BEZ27X22	610	25.3	40.5	5.2	6.7	5.2	01°20.20.9'	175°59.23.0'
BEZ27X23	640	28.7	47.3	3.8	4.6	3.8	01°20.20.5'	175°59.24.0'
BEZ27X24	670	32.9	49.9	2.6	4.0	2.6	01°20.20.4'	175°59.25.1'
BEZ27X25	759	35.4	56.3	2.1	2.8	2.1	01°20.19.9'	175°59.25.9'
BEZ27X26	730	47.5	65.4	0.7	1.7	0.7	01°20.20.1'	175°59.26.9'
BEZ27X27	760	44.9	68.3	0.9	1.4	0.9	01°20.20.2'	175°59.28.0'
BEZ27X28	790	50.9	76.7	0.5	0.9	0.5	01°20.19.3'	175°59.29.3'
BEZ27X29	820	51.0	80.4	0.5	0.7	0.5	01°20.20.5'	175°59.29.9'
BEZ27X30	850	55.3	90.1	0.3	0.4	0.3	01°20.21.5'	175°59.31.2'
BEZ27X31	880	51.8	85.7	0.5	0.5	0.5	01°20.21.1'	175°59.31.6'
BEZ27X32	910	55.3	93.0	0.3	0.4	0.3	01°20.20.8'	175°59.33.0'
BEZ27X33	940	53.6	102.4	0.4	0.2	0.4	01°20.20.9'	175°59.33.9'
BEZ27X34	970	89.4	140.6	0.0	0.0	0.0	01°20.21.1'	175°59.35.0'
BEZ27X35	1000	89.7	154.3	0.0	0.0	0.0	01°20.21.1'	175°59.35.9'
BEZ28X1	0	113.0	185.4	0.0	0.0	0.0	01°20.15.8'	175°59.35.6'
BEZ28X2	10	93.6	167.7	0.0	0.0	0.0	01°20.16.0'	175°59.34.1'
BEZ28X3	40	27.8	166.5	4.2	0.0	4.2	01°20.16.5'	175°59.33.8'
BEZ28X4	70	103.2	153.3	0.0	0.0	0.0	01°20.16.2'	175°59.32.5'
BEZ28X5	159	106.2	154.9	0.0	0.0	0.0	01°20.16.1'	175°59.32.4'

BEZ28X6	130	23.9	142.3	5.9	0.0	5.9	01°20.16.6'	175°59.30.7'
BEZ28X7	160	83.3	118.2	0.0	0.1	0.0	01°20.17.3'	175°59.30.3'
BEZ28X8	259	74.9	112.8	0.1	0.1	0.1	01°20.17.4'	175°59.29.0'
BEZ28X9	220	62.3	99.9	0.2	0.2	0.2	01°20.17.4'	175°59.28.3'
BEZ28X10	250	50.6	82.2	0.5	0.7	0.5	01°20.17.6'	175°59.27.2'
BEZ28X11	280	42.9	65.0	1.1	1.7	1.1	01°20.18.0'	175°59.26.7'
BEZ28X12	310	34.1	58.1	2.4	2.5	2.4	01°20.18.6'	175°59.25.6'
BEZ28X13	340	31.6	51.8	3.0	3.6	3.0	01°20.18.7'	175°59.24.3'
BEZ28X14	370	28.5	48.3	3.9	4.4	3.9	01°20.18.8'	175°59.23.5'
BEZ28X15	459	24.5	43.6	5.6	5.7	5.6	01°20.18.9'	175°59.22.4'
BEZ28X16	430	21.3	42.5	7.5	6.0	7.5	01°20.18.9'	175°59.21.2'
BEZ28X17	460	19.1	37.7	9.1	7.9	7.9	01°20.18.6'	175°59.20.2'
BEZ28X18	490	21.1	40.6	7.6	6.7	7.6	01°20.18.7'	175°59.19.0'
BEZ28X19	520	24.1	41.5	5.8	6.4	5.8	01°20.19.0'	175°59.18.4'
BEZ28X20	550	24.5	43.5	5.6	5.7	5.6	01°20.18.6'	175°59.16.2'
BEZ28X21	580	25.1	39.5	5.3	7.1	5.3	01°20.19.0'	175°59.16.2'
BEZ28X22	610	14.2	28.2	14.2	13.3	13.3	01°20.18.9'	175°59.16.2'
BEZ28X23	640	37.3	60.9	1.8	2.2	1.8	01°20.19.0'	175°59.15.6'
BEZ28X24	670	39.2	65.1	1.5	1.7	1.5	01°20.18.4'	175°59.15.0'
BEZ28X25	759	18.0	66.0	10.1	1.6	1.6	01°20.17.8'	175°59.13.7'
BEZ28X26	730	47.0	78.0	0.7	0.8	0.7	01°20.17.1'	175°59.12.8'
BEZ28X27	760	67.0	121.0	0.1	0.1	0.1	01°20.16.9'	175°59.11.8'
BEZ28X28	790	66.0	101.0	0.1	0.2	0.1	01°20.17.0'	175°59.10.7'
BEZ28X29	820	121.0	144.0	0.0	0.0	0.0	01°20.18.1'	175°59.09.4'
BEZ29X1	0	72.5	111.1	0.1	0.1	0.1	01°20.17.3'	175°59.10.0'
BEZ29X2	10	49.0	84.7	0.6	0.6	0.6	01°20.18.3'	175°59.10.0'
BEZ29X3	40	39.9	71.3	1.4	1.2	1.4	01°20.19.4'	175°59.09.7'
BEZ29X4	70	48.1	72.8	0.7	1.1	0.7	01°20.20.5'	175°59.09.6'
BEZ29X5	159	45.5	73.8	0.8	1.1	0.8	01°20.21.6'	175°59.09.5'
BEZ29X6	130	42.3	69.0	1.1	1.4	1.1	01°20.22.4'	175°59.09.2'
BEZ29X7	160	36.9	62.8	1.8	2.0	1.8	01°20.22.3'	175°59.07.3'
BEZ29X8	259	30.3	56.3	3.3	2.8	3.3	01°20.24.1'	175°59.09.9'
BEZ29X9	220	27.0	48.8	4.5	4.2	4.5	01°20.24.9'	175°59.10.0'
BEZ29X10	250	19.9	42.2	8.5	6.1	6.1	01°20.26.0'	175°59.10.2'
BEZ29X11	280	15.1	33.5	13.1	9.9	9.9	01°20.26.5'	175°59.10.6'
BEZ29X12	310	15.6	34.4	12.5	9.5	9.5	01°20.27.7'	175°59.10.5'
BEZ29X13	340	19.2	35.8	9.0	8.7	8.7	01°20.29.2'	175°59.10.8'
BEZ29X14	370	20.8	36.6	7.8	8.4	8.4	01°20.30.4'	175°59.10.7'
BEZ29X15	459	16.7	33.8	11.3	9.8	9.8	01°20.30.6'	175°59.10.8'
BEZ29X16	430	19.7	35.6	8.6	8.8	8.8	01°20.31.3'	175°59.10.6'
BEZ30X1	0	19.9	34.5	8.5	9.4	9.4	01°20.29.0'	175°59.16.4'
BEZ30X2	10	19.4	34.1	8.9	9.6	9.6	01°20.28.0'	175°59.16.2'
BEZ30X3	40	17.8	32.9	10.3	10.3	10.3	01°20.27.7'	175°59.16.1'
BEZ30X4	70	17.5	32.2	10.5	10.7	10.7	01°20.25.8'	175°59.15.6'
BEZ30X5	159	17.6	31.6	10.4	11.0	11.0	01°20.24.8'	175°59.14.8'
BEZ30X6	130	18.0	30.9	10.1	11.5	11.5	01°20.33.9'	175°59.15.0'

BEZ30X7	160	19.4	35.8	8.9	8.7	8.7	01°20.22.9'	175°59.15.0'
BEZ30X8	259	25.8	36.8	5.0	8.3	8.3	01°20.21.9'	175°59.15.7'
BEZ30X9	220	20.0	37.6	8.4	7.9	7.9	01°20.21.9'	175°59.14.8'
BEZ30X10	250	19.2	35.2	9.0	9.0	9.0	01°20.20.2'	175°59.15.8'
BEZ30X11	280	17.0	43.5	11.0	5.7	5.7	01°20.19.8'	175°59.15.3'
BEZ30X12	310	35.2	57.7	2.1	2.6	2.1	01°20.18.3'	175°59.15.6'
BEZ30X13	340	52.6	87.8	0.4	0.5	0.4	01°20.16.9'	175°59.15.7'
BEZ31X1	0	29.6	58.8	3.5	2.4	3.5	01°20.18.4'	175°59.20.7'
BEZ31X2	10	21.8	42.0	7.1	6.2	7.1	01°20.19.6'	175°59.21.7'
BEZ31X3	40	20.5	39.5	8.0	7.1	7.1	01°20.20.0'	175°59.21.9'
BEZ31X4	70	23.4	37.9	6.2	7.8	6.2	01°20.20.1'	175°59.22.0'
BEZ31X5	159	21.5	38.2	7.3	7.7	7.3	01°20.21.0'	175°59.21.9'
BEZ31X6	130	19.4	36.3	8.9	8.5	8.5	01°20.22.1'	175°59.22.0'
BEZ31X7	160	19.1	36.4	9.1	8.5	8.5	01°20.23.4'	175°59.21.6'
BEZ31X8	259	18.8	35.7	9.4	8.8	8.8	01°20.24.7'	175°59.21.6'
BEZ31X9	220	18.6	35.2	9.5	9.0	9.0	01°20.25.7'	175°59.21.4'
BEZ32X1	0	30.3	50.0	3.3	4.0	3.3	01°20.23.5'	175°59.26.8'
BEZ32X2	10	31.0	51.2	3.1	3.7	3.1	01°20.23.0'	175°59.26.7'
BEZ32X3	40	29.1	52.8	3.7	3.4	3.7	01°20.21.8'	175°59.26.9'
BEZ32X4	70	38.4	58.5	1.6	2.5	1.6	01°20.20.4'	175°59.26.3'
BEZ32X5	159	35.6	60.4	2.1	2.2	2.1	01°20.19.8'	175°59.26.9'
BEZ32X6	130	38.5	62.5	1.6	2.0	1.6	01°20.18.9'	175°59.26.5'
BEZ32X7	160	50.1	81.4	0.6	0.7	0.6	01°20.18.2'	175°59.26.2'
BEZ33X1	0	111.6	180.7	0.0	0.0	0.0	01°20.15.2'	175°59.31.3'
BEZ33X2	10	111.7	161.2	0.0	0.0	0.0	01°20.16.1'	175°59.31.8'
BEZ33X3	40	97.2	130.6	0.0	0.0	0.0	01°20.17.7'	175°59.31.9'
BEZ33X4	70	70.7	126.3	0.1	0.1	0.1	01°20.18.2'	175°59.32.6'
BEZ33X5	159	65.5	115.7	0.1	0.1	0.1	01°20.19.7'	175°59.33.3'
BEZ33X6	130	53.5	93.9	0.4	0.3	0.4	01°20.19.7'	175°59.32.3'
BEZ33X7	160	64.9	96.5	0.1	0.3	0.1	01°20.20.7'	175°59.32.7'
BEZ33X8	200	50.3	84.2	0.5	0.6	0.5	01°20.22.3'	175°59.32.4'
BEZ33X9	240	43.2	79.2	1.0	0.8	1.0	01°20.21.4'	175°59.32.0'
BEZ33X10	280	44.4	82.2	0.9	0.7	0.9	01°20.23.1'	175°59.33.0'
BEZ34X1	0	32.1	50.9	2.8	3.8	2.8	01°20.38.7'	175°59.11.9'
BEZ34X2	10	24.5	42.6	5.6	6.0	5.6	01°20.38.3'	175°59.12.8'
BEZ34X3	40	21.0	37.7	7.7	7.9	7.7	01°20.33.3'	175°59.18.6'
BEZ34X4	70	17.9	33.7	10.2	9.8	9.8	01°20.34.9'	175°59.13.8'
BEZ34X5	159	16.7	33.3	11.3	10.0	10.0	01°20.35.9'	175°59.14.9'
BEZ34X6	130	16.9	32.2	11.1	10.7	10.7	01°20.36.0'	175°59.15.3'
BEZ34X7	160	16.2	32.3	11.8	10.6	10.6	01°20.35.7'	175°59.16.9'
BEZ34X8	200	18.6	34.7	9.5	9.3	9.3	01°20.34.9'	175°59.18.3'
BEZ34X9	240	19.2	34.6	9.0	9.3	9.3	01°20.34.0'	175°59.18.9'
BEZ34X10	280	20.9	36.1	7.8	8.6	8.6	01°20.33.5'	175°59.20.7'
BEZ34X11	320	22.6	37.4	6.7	8.0	8.0	01°20.34.0'	175°59.21.5'
BEZ34X12	360	23.6	37.7	6.1	7.9	6.1	01°20.33.4'	175°59.22.8'
BEZ34X13	400	21.9	40.1	7.1	6.9	7.1	01°20.33.5'	175°59.23.7'

BEZ34X14	440	20.3	36.3	8.2	8.5	8.5	01°20.33.2'	175°59.24.5'
BEZ34X15	480	20.7	37.3	7.9	8.0	8.0	01°20.32.7'	175°59.23.7'
BEZ34X16	520	22.7	41.5	6.6	6.4	6.6	01°20.32.6'	175°59.24.5'
BEZ34X17	560	19.9	38.5	8.5	7.5	7.5	01°20.32.5'	175°59.24.8'
BEZ34X18	600	23.3	36.7	6.2	8.3	8.3	01°20.31.3'	175°59.24.0'
BEZ34X19	640	24.7	40.3	5.5	6.8	5.5	01°20.30.4'	175°59.24.0'
BEZ34X20	680	20.6	37.0	8.0	8.2	8.2	01°20.29.5'	175°59.24.0'
BEZ34X21	720	21.4	40.8	7.4	6.6	7.4	01°20.29.5'	175°59.24.8'
BEZ34X22	760	25.6	44.0	5.1	5.5	5.1	01°20.29.3'	175°59.26.1'
BEZ34X23	800	26.6	46.0	4.6	5.0	4.6	01°20.29.1'	175°59.26.7'
BEZ34X24	840	28.4	48.2	3.9	4.4	3.9	01°20.29.8'	175°59.27.0'
BEZ34X25	880	36.9	59.8	1.8	2.3	1.8	01°20.28.8'	175°59.28.4'
BEZ34X26	920	40.9	61.8	1.3	2.1	1.3	01°20.28.2'	175°59.30.3'
BEZ34X27	960	46.1	73.4	0.8	1.1	0.8	01°20.28.3'	175°59.30.4'
BEZ34X28	1000	36.5	77.4	1.9	0.9	1.9	01°20.28.2'	175°59.30.9'
BEZ34X29	1040	40.9	79.2	1.3	0.8	1.3	01°20.28.2'	175°59.30.3'
BEZ34X30	1080	46.9	82.9	0.7	0.6	0.7	01°20.25.2'	175°59.33.7'

Annex 8

Village CTD Diver Data, Beru

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 Beru.

Table A8-1. Summary of water level data collected at Agriculture Station well, Taubukiniberu Village, abstracted by diesel electrical pump.

Beru predicted tides			Agriculture station well, Taubukiniberu				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
26/11/2013 4:26	1.28						
26/11/2013 10:50	1.91	0.55	26/11/2013 12:54	0.38	0.03	2:03	6%
26/11/2013 16:56	1.37	-0.62	26/11/2013 18:24	0.34	-0.05	1:27	8%
26/11/2013 23:13	1.99	0.75	27/11/2013 2:06	0.39	0.05	2:52	6%
27/11/2013 5:45	1.24	-0.76	27/11/2013 7:54	0.34	-0.04	2:08	5%
27/11/2013 12:11	2.00	0.71	27/11/2013 15:12	0.38	0.04	3:00	5%
27/11/2013 18:21	1.29	-0.76	27/11/2013 20:54	0.34	-0.05	2:32	6%
28/11/2013 0:30	2.05	0.90	28/11/2013 2:30	0.39	0.06	1:59	6%
28/11/2013 6:51	1.15	-0.99	28/11/2013 9:06	0.33			
28/11/2013 13:13	2.14						
28/11/2013 19:25	1.16						
Mean						2:17	6%

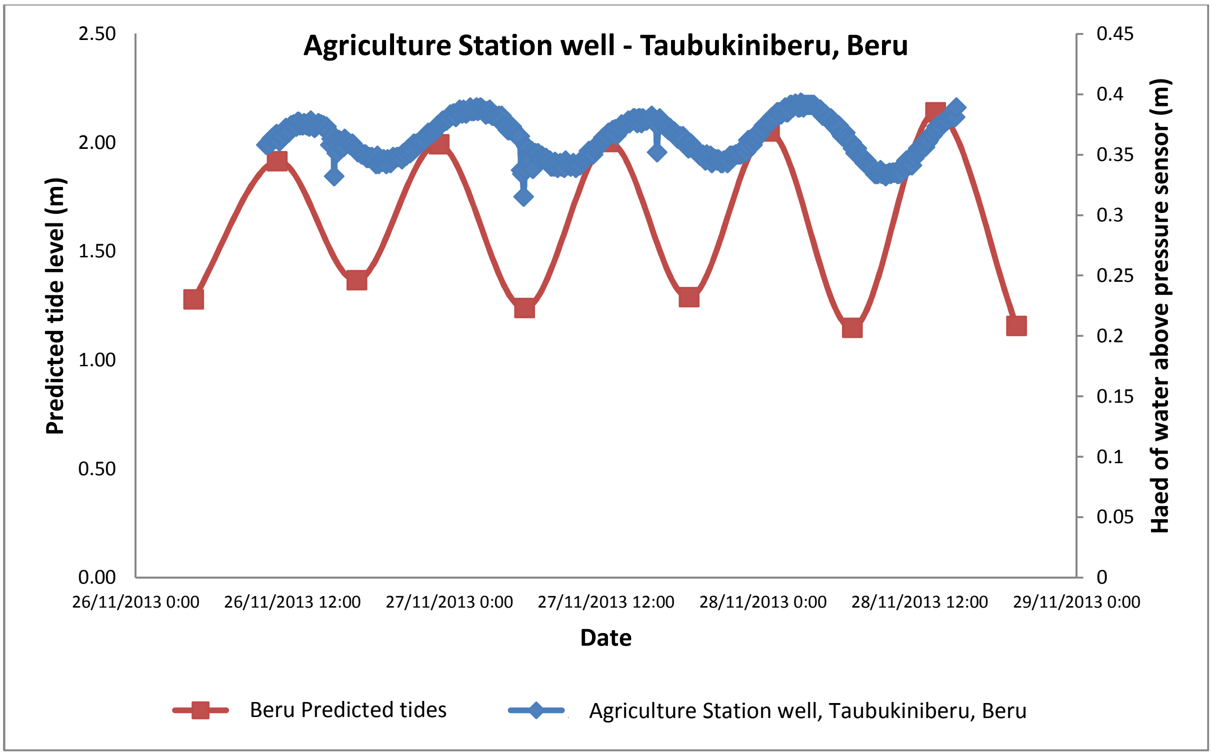


Figure A8-1. Graph of water level fluctuation for the Agriculture Station well in relation to predicted tidal data.

Table A8-2. Summary of measured groundwater level and predicted tidal data at a communal well in Teteirio, abstracted by multiple hand pumps.

Beru predicted tides			Village well, Teteirio				
Date and time	**Tide Height m**	**Tidal range m**	**Date and time**	**Tide Height m**	**Tidal range m**	**Tidal lag**	**Tidal efficiency**
25/11/2013 9:24	1.26	-0.64	25/11/2013 11:30	0.34	0.03	2:05	-5%
25/11/2013 15:23	1.90	0.54	25/11/2013 17:24	0.31	-0.04	2:00	-8%
25/11/2013 21:46	1.36	-0.64	26/11/2013 0:12	0.36	0.06	2:25	-9%
26/11/2013 4:26	2.00	0.72	26/11/2013 7:18	0.30	-0.04	2:51	-5%
26/11/2013 10:50	1.28	-0.63	26/11/2013 13:18	0.34	0.03	2:27	-5%
26/11/2013 16:56	1.91	0.55	26/11/2013 18:12	0.30	-0.04	1:15	-8%
26/11/2013 23:13	1.37	-0.62	27/11/2013 1:36	0.35	0.06	2:22	-10%
27/11/2013 5:45	1.99	0.75	27/11/2013 8:48	0.28	-0.05	3:02	-7%
27/11/2013 12:11	1.24	-0.76	27/11/2013 14:00	0.34	0.02	1:48	-3%
27/11/2013 18:21	2.00	0.71	27/11/2013 20:30	0.32	-0.04	2:08	-6%
28/11/2013 0:30	1.29	-0.76	28/11/2013 2:18	0.36	0.07	1:47	-9%
28/11/2013 6:51	2.05	0.90	28/11/2013 9:36	0.29	-0.07	2:44	-7%
28/11/2013 13:13	1.15	-0.99					
Mean						2:15	-7%

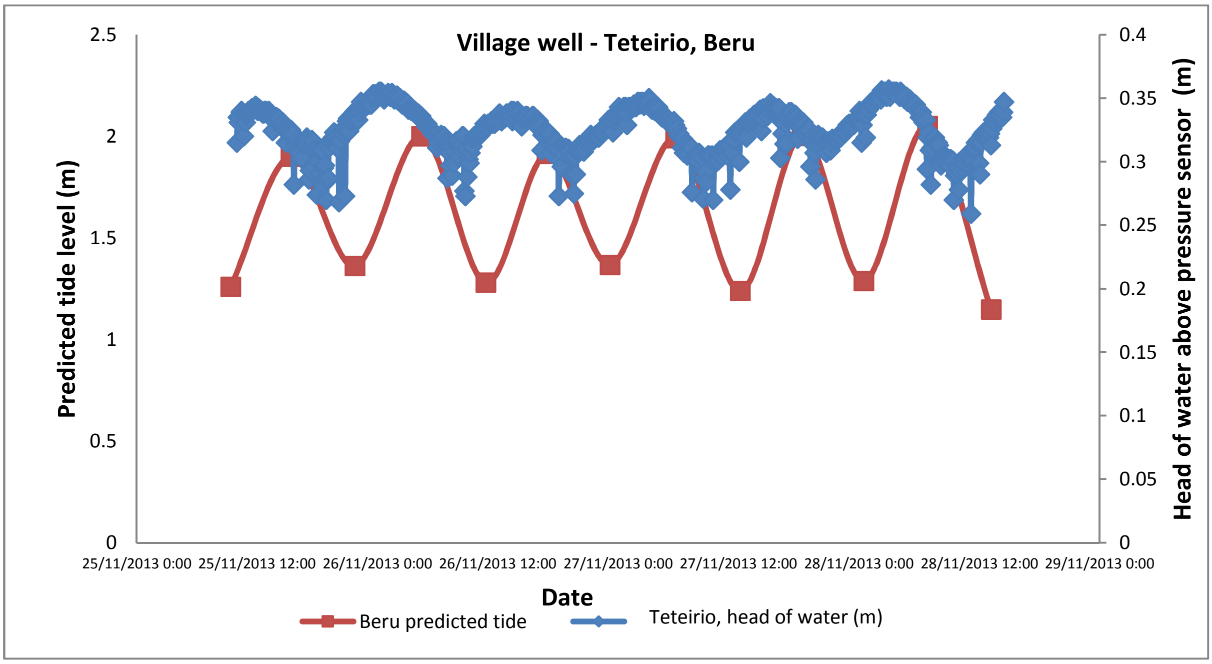


Figure A8-2. Groundwater level and predicted tidal data for the village well in Teteirio.

Table A8-3. Summary of measured groundwater level and predicted tidal data at the Catholic Church in Nuka Village.

Beru predicted tides			Catholic church well, Nuka				
Date and time	**Tide Height m**	**Tidal range m**	**Date and time**	**Tide Height m**	**Tidal range m**	**Tidal lag**	**Tidal efficiency**
22/11/2013 0:51	1.05						
22/11/2013 6:50	2.08	0.96	22/11/2013 9:54	0.19	0.04	3:03	4%
22/11/2013 12:45	1.12	-1.13	22/11/2013 15:24	0.15	-0.04	2:38	4%
22/11/2013 19:04	2.25	1.13	22/11/2013 22:36	0.20	0.04	3:31	3%
23/11/2013 1:27	1.13	-0.88	23/11/2013 4:18	0.16	-0.02	2:50	2%
23/11/2013 7:28	2.01	0.80	23/11/2013 9:18	0.18	0.03	1:49	3%
23/11/2013 13:23	1.21	-0.95	23/11/2013 15:24	0.15	-0.04	2:00	4%
23/11/2013 19:43	2.16	0.96	23/11/2013 23:48	0.19	0.03	4:04	3%
24/11/2013 2:11	1.20	-0.74	24/11/2013 5:42	0.16	-0.02	3:30	2%
24/11/2013 8:17	1.94	0.65	24/11/2013 10:30	0.17	0.03	2:12	4%
24/11/2013 14:12	1.29	-0.77	24/11/2013 16:00	0.15	-0.03	1:47	4%
24/11/2013 20:35	2.07	0.81	24/11/2013 22:54	0.18	0.03	2:18	4%
25/11/2013 3:10	1.26	0.81	25/11/2013 8:18	0.15			
Mean						2:42	4%

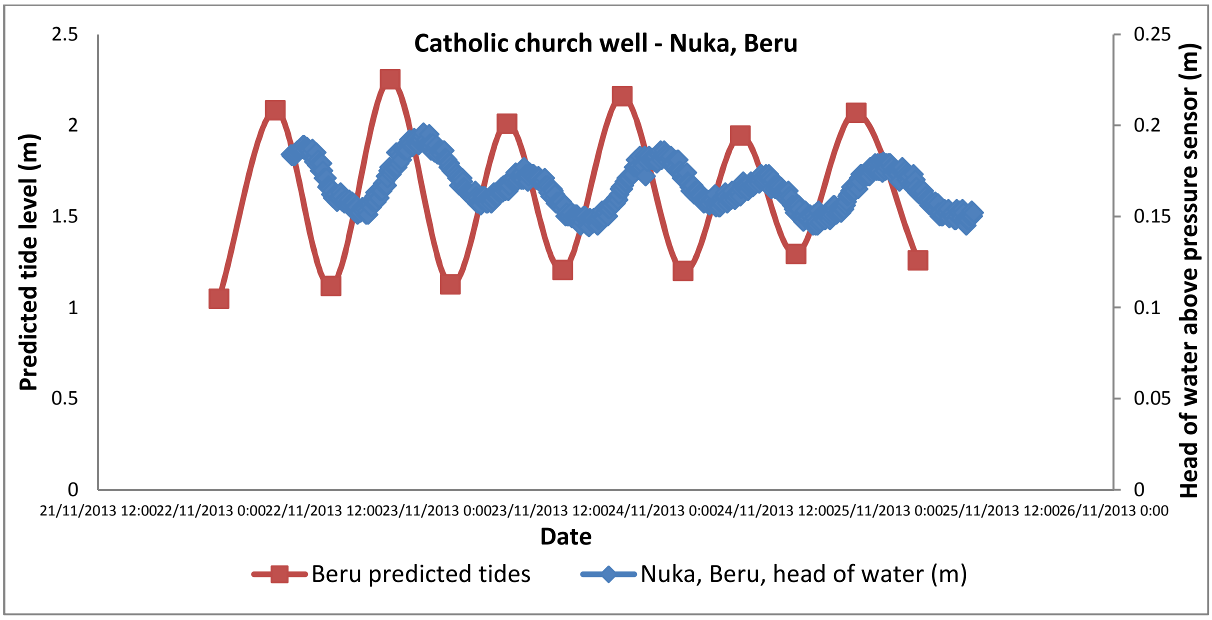


Figure A8-3. Groundwater level and predicted tidal data for the Catholic Church well in Nuka Village.

Table A8-4. Summary of measured groundwater level and predicted tidal data at the Rongorongo High School community well, abstracted by a solar pump system.

Beru predicted tides			Rongorongo High School, Beru				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
22/11/2013 6:50	2.08						
22/11/2013 12:45	1.12	-1.13	22/11/2013 14:54	0.46	-0.10	2:08	9%
22/11/2013 19:04	2.25	1.13	22/11/2013 23:00	0.57	0.06	3:55	5%
23/11/2013 1:27	1.13	-0.88	23/11/2013 4:42	0.51	-0.03	3:14	3%
23/11/2013 7:28	2.01	0.80	23/11/2013 8:00	0.53	0.07	0:31	8%
23/11/2013 13:23	1.21	-0.95	23/11/2013 13:48	0.47	-0.08	0:24	9%
23/11/2013 19:43	2.16	0.96	23/11/2013 22:36	0.55	0.05	2:52	5%
24/11/2013 2:11	1.20	-0.74	24/11/2013 5:48	0.50	-0.02	3:36	2%
24/11/2013 8:17	1.94	0.65	24/11/2013 8:12	0.52	0.05	###########	8%
24/11/2013 14:12	1.29	-0.77	24/11/2013 14:24	0.47	-0.07	0:11	10%
24/11/2013 20:35	2.07	0.81	25/11/2013 0:12	0.54	0.07	3:36	9%
25/11/2013 3:10	1.26	0.81	25/11/2013 8:18				
Mean						2:02	7%

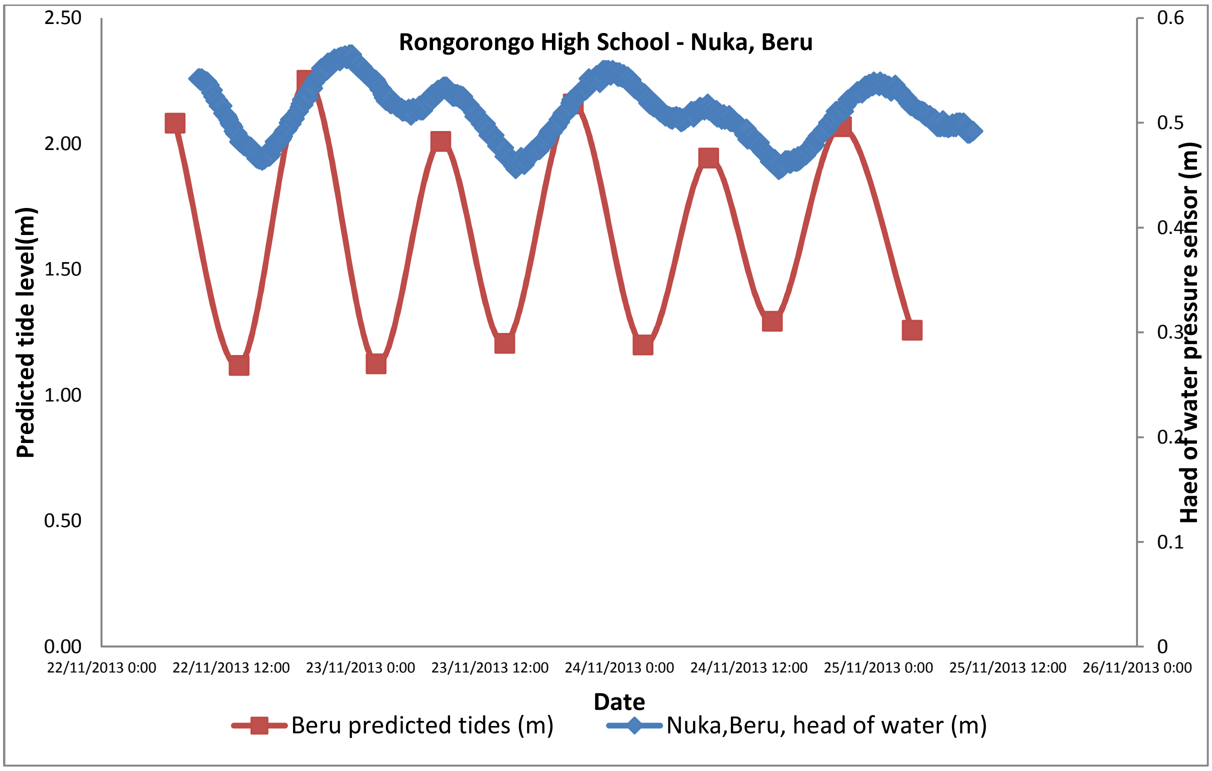


Figure A8-4. Groundwater level and predicted tidal data for the Rongorongo High School community well.

Table A8-5. Summary of measured groundwater level and predicted tidal data at Kaireiti's well in Tabiang Village.

Beru predicted tides			Kaireiti's well, Tabiang				
Date and time	**Tide Height m**	**Tidal range m**	**Date and time**	**Tide Height m**	**Tidal range m**	**Tidal lag**	**Tidal efficiency**
20/11/2013 5:47	2.22						
20/11/2013 11:43	0.96	-1.46	20/11/2013 14:54	0.38	-0.11	3:10	8%
20/11/2013 18:00	2.42	1.45	20/11/2013 21:18	0.49	0.08	3:17	5%
21/11/2013 0:19	0.97	-1.18	21/11/2013 3:24	0.41	-0.08	3:04	7%
21/11/2013 6:17	2.15	1.12					
21/11/2013 12:13	1.04	1.12					
Mean						3:11	7%

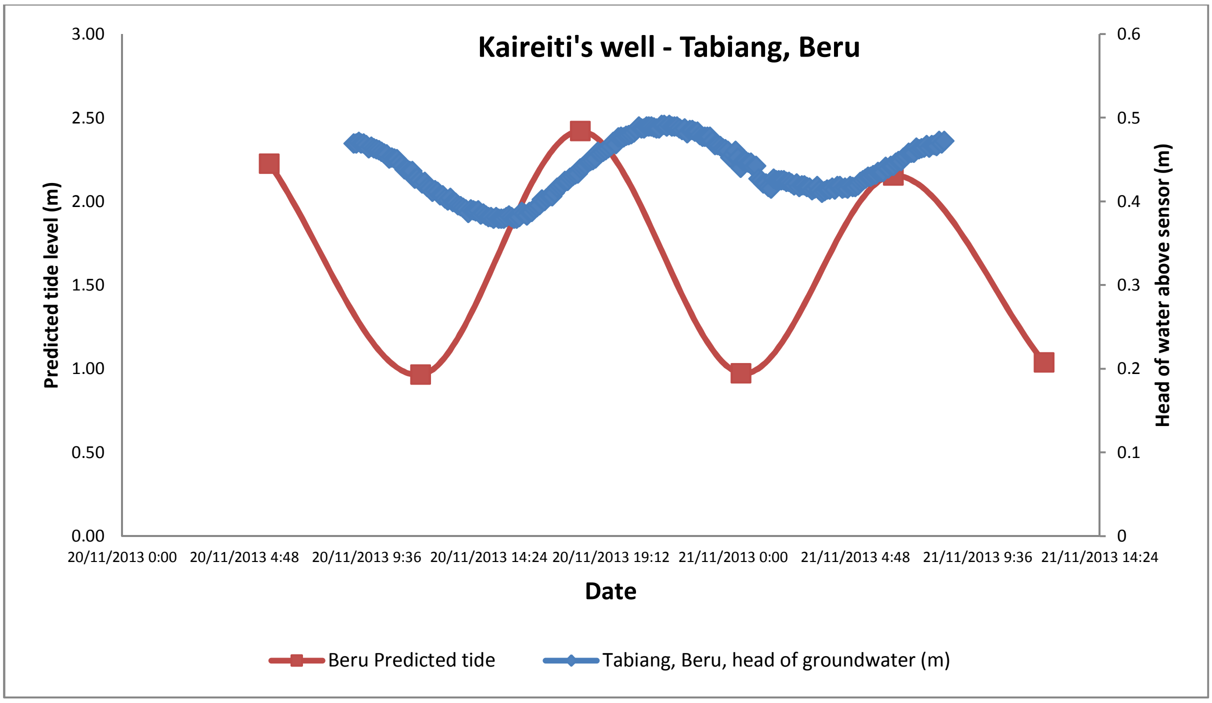


Figure A8-5. Groundwater level and predicted tidal data for Kaireiti's household well in Tabiang Village.

Table A8-6. Summary of measured groundwater level and predicted tidal data at Ubwanteman's well in Tabiang Village.

Beru predicted tides			Ubwanteman's well, Tabiang				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
20/11/2013 5:47	2.22						
20/11/2013 11:43	0.96	-1.46	20/11/2013 14:18	0.40	-0.07	2:34	5%
20/11/2013 18:00	2.42	1.45	20/11/2013 20:18	0.47	0.06	2:17	4%
21/11/2013 0:19	0.97	-1.18	21/11/2013 3:06	0.41	-0.05	2:46	5%
21/11/2013 6:17	2.15	1.12	21/11/2013 9:12	0.46		2:54	
21/11/2013 12:13	1.04	1.12					
Mean						2:38	4%

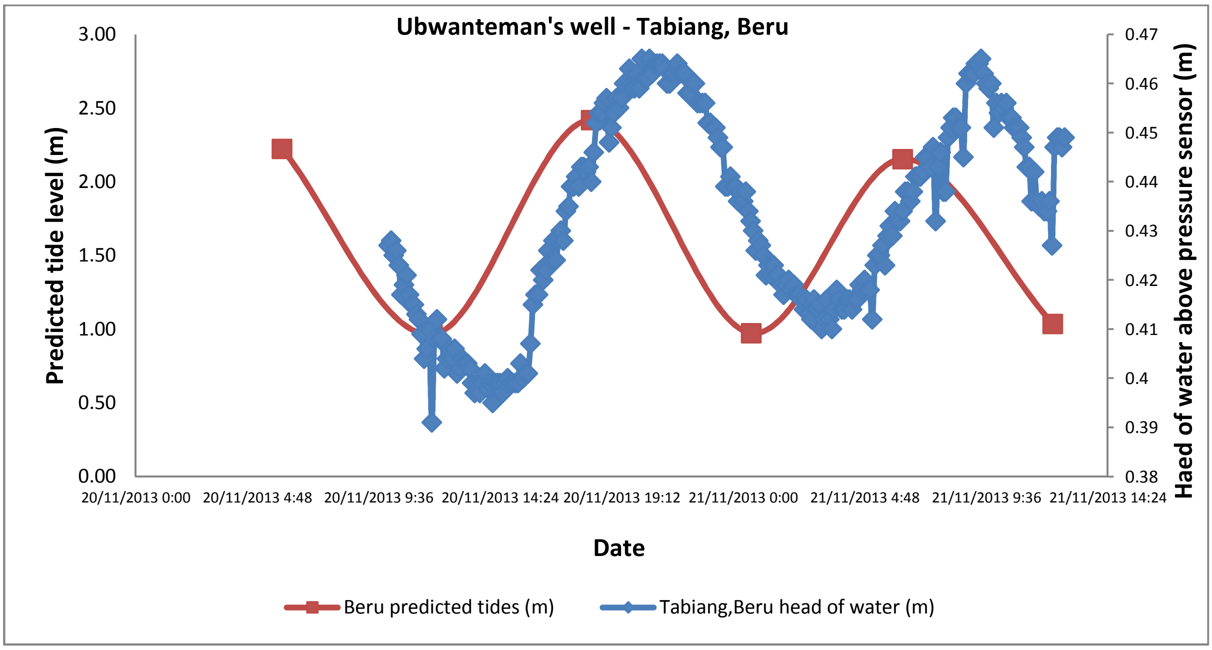


Figure A8-6. Groundwater level and predicted tidal data for Ubwanteman's household well in Tabiang Village.

Table A8-7. Summary of measured groundwater level and predicted tidal data at Rouben Nikaro's well in Autukia Village.

Beru predicted tides			Rouben Nikaro's well, Autukia, Beru				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
19/11/2013 5:17	2.29						
19/11/2013 11:14	0.90	-1.58	19/11/2013 13:06	0.27	-0.15	1:51	9%
19/11/2013 17:30	2.48	1.58	19/11/2013 19:48	0.42	0.11	2:17	7%
19/11/2013 23:47	0.90	-1.32	20/11/2013 2:06	0.30		2:18	
20/11/2013 5:47	2.22	1.26					
20/11/2013 11:43	0.96	-1.46					
20/11/2013 18:00	2.42	-1.46					
Mean						2:09	8%

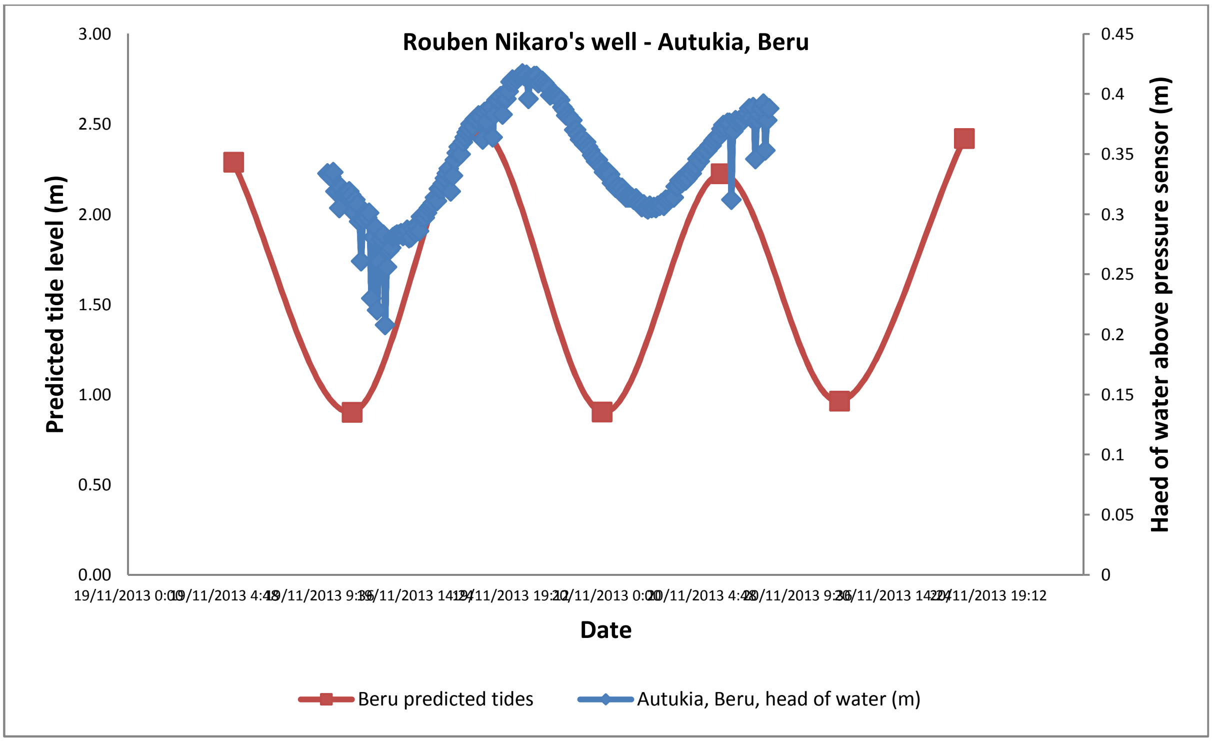


Figure A8-7. Groundwater level and predicted tidal data for Rouben Nikaro's household well in Autukia Village.

Table A8-8. Summary of Beru Island CTD monitoring records.

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
Autukia	Rouben Nikaro	K6813	130	19/11/2013 10:00	20/11/2013 8:12	22.2	2.09	8%
Tabiang	Kaireiti	K6813	40	20/11/2013 9:06	21/11/2013 8:18	23.2	3.11	7%
	Ubwanteman	P5144	60	20/11/2013 10:00	21/11/2013 12:42	26.7	2.38	4%
Nuka	Catholic Church	K6813	150	22/11/2013 8:30	25/11/2013 9:06	72.6	2.42	4%
	Rongorongo High School	P5144	170	22/11/2013 9:00	25/11/2013 8:48	71.8	2.02	7%
Teteirio	Village	K6813	90	25/11/2013 10:00	28/11/2013 14:30	76.5	2.15	7%
Taubukiniberu	Agriculture station	P5144	90	26/11/2013 10:00	28/11/2013 14:48	76.8	2.17	6%
Average						52.83	2.33	6%

Annex 9

Rainwater Harvesting Analysis Calculator & Beru Results

This annex presents the analysis of potential rainwater harvesting centres in each target village on Beru atoll. The analysis uses White's (2010) rainfall calculator spreadsheet (Table A9-2) and the historical monthly rainfall for Beru from January 1945 to June 2014.

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 = Tank Capacity/1000 (kL)
Roof Area (m^2)	A
% Guttering	Percentage of roof edge bordered by guttering
Collecting Roof Area (m^2)	A_{col} = (%Guttering x A)/100
Guttering Condition	Good Adequate Repair Replace
Capture Efficiency, C ($0 \le C \le 1$)	C = 0.75, C = 0.55, C = 0.35, C = 0.15
Effective Roof Area (m^2)	$A_{eff} = C \times A_{col}$

Furthermore, the rainfall calculator (White, 2010) was used to generate estimates of the available water for each selected building based on 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 populations.
- Effective roof area calculated incorporates guttering losses and runoff coefficient, with an input runoff parameter C equal to 1.
- An 84% satisfaction limit was assumed, whereby the rainwater harvesting system would be able to provide the calculated volume of water per person per day for 10 out of 12 months.

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

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

3. Existing building with fully improved roof catchment infrastructure, i.e. guttering and down pipes 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 of storage volume.

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

It should be noted that in using these rainwater harvesting projections, one needs to be aware of the following basic assumptions by White (2010):

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 instantaneous rainfall rate.
4. Monthly rainfall is used but the spread of rain over the month is not considered.

Table A9-2. Rainwater calculator created by White (2010) and using Beru long-term and discontinuous monthly rainfalls from January 1945 to June 2014.

INPUTS

catchment area	A	641	m^2
runoff C	C	1	0.95-0.7
tank vol	S	80,000	litres
demand	D	2.9	L/p/d
users	N	443	
month days	dt	30.4333	
initial tank volume		0	

RESULTS

186

length of record

months	723
years	60

overflow

average monthly overflow	38,342	litres

Reliability (at end of month t)

% (months) empty	25.7%
% of months demand met	74.3%
% tank full	40.4%

Satisfaction

	84%	of monthly demand met on average
longest	722	months in a row where less than 100% demand is met
dry spell	722	months in a row where less than 60% of demand is met

NB Enter inputs into yellow boxes only. Results displayed depend on catchment area, runoff coefficient, tank volume, demand per person, and number of users

DON'T TOUCH BELOW HERE - can enter a different rain series if needed.

if entering daily data change month days (see above) to 1

Beru rainfall Jan 1945 – Jun 2014					surplus/deficit	**Storage**								
month yr	rain	**Runoff** (L)	L + Vt-1	**Total D** (O)	L + Vt - O	0	**overflow**	**% of D**	100%met	run	60%met	run		
Jan-45	48	30768	30768	39098	-8330	0	0	79%	0	0	1	0		
Feb-45	7	4487	4487	39098	-34611	0	0	11%	0	1	0	1		
Mar-45	9	5769	5769	39098	-33329	0	0	15%	0	2	0	2		
Apr-45	62	39742	39742	39098	644	644	0	100%	1	3	1	3		

May-45	54	34614	35258	39098	-3839	0	0	90%	0	4	1	4		
Jun-45	99	63459	63459	39098	24361	24361	0	100%	1	5	1	5		
Jul-45	57	36537	60898	39098	21801	21801	0	100%	1	6	1	6		
Aug-45	60	38460	60261	39098	21163	21163	0	100%	1	7	1	7		
Sep-45	63	40383	61546	39098	22448	22448	0	100%	1	8	1	8		
Oct-45	72	46152	68600	39098	29503	29503	0	100%	1	9	1	9		
Nov-45	22	14102	43605	39098	4507	4507	0	100%	1	10	1	10		
Dec-45	108	69228	73735	39098	34637	34637	0	100%	1	11	1	11		
Jan-46	112	71792	106429	39098	67332	67332	0	100%	1	12	1	12		
Feb-46	39	24999	92331	39098	53233	53233	0	100%	1	13	1	13		
Mar-46	128	82048	135281	39098	96183	80000	16183	100%	1	14	1	14		
Apr-46	213	136533	216533	39098	177435	80000	97435	100%	1	15	1	15		
May-46	252	161532	241532	39098	202434	80000	122434	100%	1	16	1	16		
Jun-46	211	135251	215251	39098	176153	80000	96153	100%	1	17	1	17		
Jul-46	311	199351	279351	39098	240253	80000	160253	100%	1	18	1	18		
Aug-46	264	169224	249224	39098	210126	80000	130126	100%	1	19	1	19		
Sep-46	46	29486	109486	39098	70388	70388	0	100%	1	20	1	20		
Oct-46	84	53844	124232	39098	85135	80000	5135	100%	1	21	1	21		
Nov-46	89	57049	137049	39098	97951	80000	17951	100%	1	22	1	22		
Dec-46	241	154481	234481	39098	195383	80000	115383	100%	1	23	1	23		
Jan-47	452	289732	369732	39098	330634	80000	250634	100%	1	24	1	24		
Feb-47	65	41665	121665	39098	82567	80000	2567	100%	1	25	1	25		
Mar-47	4	2564	82564	39098	43466	43466	0	100%	1	26	1	26		
Apr-47	13	8333	51799	39098	12702	12702	0	100%	1	27	1	27		
May-47	12	7692	20394	39098	-18704	0	0	52%	0	28	0	28		
Jun-47	29	18589	18589	39098	-20509	0	0	48%	0	29	0	29		
Jul-47	44	28204	28204	39098	-10894	0	0	72%	0	30	1	30		
Aug-47	11	7051	7051	39098	-32047	0	0	18%	0	31	0	31		
Sep-47	9	5769	5769	39098	-33329	0	0	15%	0	32	0	32		

Oct-47	40	25640	25640	39098	-13458	0	0	66%	0	33	1	33		
Nov-47	80	51280	51280	39098	12182	12182	0	100%	1	34	1	34		
Dec-47	94	60254	72436	39098	33339	33339	0	100%	1	35	1	35		
Jan-48	850	544850	578189	39098	539091	80000	459091	100%	1	36	1	36		
Feb-48	262	167942	247942	39098	208844	80000	128844	100%	1	37	1	37		
Mar-48	60	38460	118460	39098	79362	79362	0	100%	1	38	1	38		
Apr-48	184	117944	197306	39098	158209	80000	78209	100%	1	39	1	39		
May-48	193	123713	203713	39098	164615	80000	84615	100%	1	40	1	40		
Jun-48	109	69869	149869	39098	110771	80000	30771	100%	1	41	1	41		
Jul-48	130	83330	163330	39098	124232	80000	44232	100%	1	42	1	42		
Aug-48	20	12820	92820	39098	53722	53722	0	100%	1	43	1	43		
Sep-48	38	24358	78080	39098	38983	38983	0	100%	1	44	1	44		
Oct-48	20	12820	51803	39098	12705	12705	0	100%	1	45	1	45		
Nov-48	80	51280	63985	39098	24887	24887	0	100%	1	46	1	46		
Dec-48	270	173070	197957	39098	158860	80000	78860	100%	1	47	1	47		
Jan-49	729	467289	547289	39098	508191	80000	428191	100%	1	48	1	48		
Feb-49	139	89099	169099	39098	130001	80000	50001	100%	1	49	1	49		
Mar-49	136	87176	167176	39098	128078	80000	48078	100%	1	50	1	50		
Apr-49	11	7051	87051	39098	47953	47953	0	100%	1	51	1	51		
May-49	62	39742	87695	39098	48598	48598	0	100%	1	52	1	52		
Jun-49	43	27563	76161	39098	37063	37063	0	100%	1	53	1	53		
Jul-49	31	19871	56934	39098	17836	17836	0	100%	1	54	1	54		
Aug-49	32	20512	38348	39098	-749	0	0	98%	0	55	1	55		
Sep-49	12	7692	7692	39098	-31406	0	0	20%	0	56	0	56		
Oct-49	25	16025	16025	39098	-23073	0	0	41%	0	57	0	57		
Nov-49	3	1923	1923	39098	-37175	0	0	5%	0	58	0	58		
Dec-49	3	1923	1923	39098	-37175	0	0	5%	0	59	0	59		
Jan-50	1	641	641	39098	-38457	0	0	2%	0	60	0	60		
Feb-50	0	0	0	39098	-39098	0	0	0%	0	61	0	61		

Mar-50	2	1282	1282	39098	-37816	0	0	3%	0	62	0	62		
Apr-50	2	1282	1282	39098	-37816	0	0	3%	0	63	0	63		
May-50	0	0	0	39098	-39098	0	0	0%	0	64	0	64		
Jun-50	8	5128	5128	39098	-33970	0	0	13%	0	65	0	65		
Jul-50	28	17948	17948	39098	-21150	0	0	46%	0	66	0	66		
Aug-50	68	43588	43588	39098	4490	4490	0	100%	1	67	1	67		
Sep-50	34	21794	26284	39098	-12813	0	0	67%	0	68	1	68		
Oct-50	31	19871	19871	39098	-19227	0	0	51%	0	69	0	69		
Nov-50	32	20512	20512	39098	-18586	0	0	52%	0	70	0	70		
Dec-50	41	26281	26281	39098	-12817	0	0	67%	0	71	1	71		
Jan-51	43	27563	27563	39098	-11535	0	0	70%	0	72	1	72		
Feb-51	7	4487	4487	39098	-34611	0	0	11%	0	73	0	73		
Mar-51	33	21153	21153	39098	-17945	0	0	54%	0	74	0	74		
Apr-51	105	67305	67305	39098	28207	28207	0	100%	1	75	1	75		
May-51	199	127559	155766	39098	116669	80000	36669	100%	1	76	1	76		
Jun-51	144	92304	172304	39098	133206	80000	53206	100%	1	77	1	77		
Jul-51	383	245503	325503	39098	286405	80000	206405	100%	1	78	1	78		
Aug-51	280	179480	259480	39098	220382	80000	140382	100%	1	79	1	79		
Sep-51	113	72433	152433	39098	113335	80000	33335	100%	1	80	1	80		
Oct-51	57	36537	116537	39098	77439	77439	0	100%	1	81	1	81		
Nov-51	35	22435	99874	39098	60777	60777	0	100%	1	82	1	82		
Dec-51	161	103201	163978	39098	124880	80000	44880	100%	1	83	1	83		
Jan-52	350	224350	304350	39098	265252	80000	185252	100%	1	84	1	84		
Feb-52	26	16666	96666	39098	57568	57568	0	100%	1	85	1	85		
Mar-52	73	46793	104361	39098	65264	65264	0	100%	1	86	1	86		
Apr-52	114	73074	138338	39098	99240	80000	19240	100%	1	87	1	87		
May-52	105	67305	147305	39098	108207	80000	28207	100%	1	88	1	88		
Jun-52	56	35896	115896	39098	76798	76798	0	100%	1	89	1	89		
Jul-52	94	60254	137052	39098	97955	80000	17955	100%	1	90	1	90		

Aug-52	82	52562	132562	39098	93464	80000	13464	100%	1	91	1	91		
Sep-52	69	44229	124229	39098	85131	80000	5131	100%	1	92	1	92		
Oct-52	91	58331	138331	39098	99233	80000	19233	100%	1	93	1	93		
Nov-52	25	16025	96025	39098	56927	56927	0	100%	1	94	1	94		
Dec-52	70	44870	101797	39098	62700	62700	0	100%	1	95	1	95		
Jan-53	176	112816	175516	39098	136418	80000	56418	100%	1	96	1	96		
Feb-53	157	100637	180637	39098	141539	80000	61539	100%	1	97	1	97		
Mar-53	101	64741	144741	39098	105643	80000	25643	100%	1	98	1	98		
Apr-53	140	89740	169740	39098	130642	80000	50642	100%	1	99	1	99		
May-53	129	82689	162689	39098	123591	80000	43591	100%	1	100	1	100		
Jun-53	119	76279	156279	39098	117181	80000	37181	100%	1	101	1	101		
Jul-53	162	103842	183842	39098	144744	80000	64744	100%	1	102	1	102		
Aug-53	152	97432	177432	39098	138334	80000	58334	100%	1	103	1	103		
Sep-53	162	103842	183842	39098	144744	80000	64744	100%	1	104	1	104		
Oct-53	30	19230	99230	39098	60132	60132	0	100%	1	105	1	105		
Nov-53	19	12179	72311	39098	33214	33214	0	100%	1	106	1	106		
Dec-53	216	138456	171670	39098	132572	80000	52572	100%	1	107	1	107		
Jan-54	99	63459	143459	39098	104361	80000	24361	100%	1	108	1	108		
Feb-54	6	3846	83846	39098	44748	44748	0	100%	1	109	1	109		
Mar-54	14	8974	53722	39098	14625	14625	0	100%	1	110	1	110		
Apr-54	8	5128	19753	39098	-19345	0	0	51%	0	111	0	111		
May-54	12	7692	7692	39098	-31406	0	0	20%	0	112	0	112		
Jun-54	9	5769	5769	39098	-33329	0	0	15%	0	113	0	113		
Jul-54	23	14743	14743	39098	-24355	0	0	38%	0	114	0	114		
Aug-54	47	30127	30127	39098	-8971	0	0	77%	0	115	1	115		
Sep-54	47	30127	30127	39098	-8971	0	0	77%	0	116	1	116		
Oct-54	5	3205	3205	39098	-35893	0	0	8%	0	117	0	117		
Nov-54	0	0	0	39098	-39098	0	0	0%	0	118	0	118		
Dec-54	38	24358	24358	39098	-14740	0	0	62%	0	119	1	119		

Jan-55	122	78202	78202	39098	39104	39104	0	100%	1	120	1	120		
Feb-55	0	0	39104	39098	7	7	0	100%	1	121	1	121		
Mar-55	45	28845	28852	39098	-10246	0	0	74%	0	122	1	122		
Apr-55	35	22435	22435	39098	-16663	0	0	57%	0	123	0	123		
May-55	15	9615	9615	39098	-29483	0	0	25%	0	124	0	124		
Jun-55	12	7692	7692	39098	-31406	0	0	20%	0	125	0	125		
Jul-55	24	15384	15384	39098	-23714	0	0	39%	0	126	0	126		
Aug-55	65	41665	41665	39098	2567	2567	0	100%	1	127	1	127		
Sep-55	36	23076	25643	39098	-13454	0	0	66%	0	128	1	128		
Oct-55	9	5769	5769	39098	-33329	0	0	15%	0	129	0	129		
Nov-55	4	2564	2564	39098	-36534	0	0	7%	0	130	0	130		
Dec-55	27	17307	17307	39098	-21791	0	0	44%	0	131	0	131		
Jan-56	53	33973	33973	39098	-5125	0	0	87%	0	132	1	132		
Feb-56	7	4487	4487	39098	-34611	0	0	11%	0	133	0	133		
Mar-56	18	11538	11538	39098	-27560	0	0	30%	0	134	0	134		
Apr-56	19	12179	12179	39098	-26919	0	0	31%	0	135	0	135		
May-56	54	34614	34614	39098	-4484	0	0	89%	0	136	1	136		
Jun-56	21	13461	13461	39098	-25637	0	0	34%	0	137	0	137		
Jul-56	153	98073	98073	39098	58975	58975	0	100%	1	138	1	138		
Aug-56	31	19871	78846	39098	39749	39749	0	100%	1	139	1	139		
Sep-56	11	7051	46800	39098	7702	7702	0	100%	1	140	1	140		
Oct-56	16	10256	17958	39098	-21140	0	0	46%	0	141	0	141		
Nov-56	60	38460	38460	39098	-638	0	0	98%	0	142	1	142		
Dec-56	4	2564	2564	39098	-36534	0	0	7%	0	143	0	143		
Jan-57	28	17948	17948	39098	-21150	0	0	46%	0	144	0	144		
Feb-57	46	29486	29486	39098	-9612	0	0	75%	0	145	1	145		
Mar-57	44	28204	28204	39098	-10894	0	0	72%	0	146	1	146		
Apr-57	22	14102	14102	39098	-24996	0	0	36%	0	147	0	147		
May-57	151	96791	96791	39098	57693	57693	0	100%	1	148	1	148		

Jun-57	161	103201	160894	39098	121797	80000	41797	100%	1	149	1	149		
Jul-57	255	163455	243455	39098	204357	80000	124357	100%	1	150	1	150		
Aug-57	85	54485	134485	39098	95387	80000	15387	100%	1	151	1	151		
Sep-57	179	114739	194739	39098	155641	80000	75641	100%	1	152	1	152		
Oct-57	216	138456	218456	39098	179358	80000	99358	100%	1	153	1	153		
Nov-57	383	245503	325503	39098	286405	80000	206405	100%	1	154	1	154		
Dec-57	291	186531	266531	39098	227433	80000	147433	100%	1	155	1	155		
Jan-58	338	216658	296658	39098	257560	80000	177560	100%	1	156	1	156		
Feb-58	197	126277	206277	39098	167179	80000	87179	100%	1	157	1	157		
Mar-58	315	201915	281915	39098	242817	80000	162817	100%	1	158	1	158		
Apr-58	582	373062	453062	39098	413964	80000	333964	100%	1	159	1	159		
May-58	246	157686	237686	39098	198588	80000	118588	100%	1	160	1	160		
Jun-58	66	42306	122306	39098	83208	80000	3208	100%	1	161	1	161		
Jul-58	117	74997	154997	39098	115899	80000	35899	100%	1	162	1	162		
Aug-58	28	17948	97948	39098	58850	58850	0	100%	1	163	1	163		
Sep-58	22	14102	72952	39098	33855	33855	0	100%	1	164	1	164		
Oct-58	33	21153	55008	39098	15910	15910	0	100%	1	165	1	165		
Nov-58	281	180121	196031	39098	156933	80000	76933	100%	1	166	1	166		
Dec-58	273	174993	254993	39098	215895	80000	135895	100%	1	167	1	167		
Jan-59	314	201274	281274	39098	242176	80000	162176	100%	1	168	1	168		
Feb-59	405	259605	339605	39098	300507	80000	220507	100%	1	169	1	169		
Mar-59	194	124354	204354	39098	165256	80000	85256	100%	1	170	1	170		
Apr-59	65	41665	121665	39098	82567	80000	2567	100%	1	171	1	171		
May-59	100	64100	144100	39098	105002	80000	25002	100%	1	172	1	172		
Jun-59	52	33332	113332	39098	74234	74234	0	100%	1	173	1	173		
Jul-59	72	46152	120386	39098	81289	80000	1289	100%	1	174	1	174		
Aug-59	30	19230	99230	39098	60132	60132	0	100%	1	175	1	175		
Sep-59	10	6410	66542	39098	27445	27445	0	100%	1	176	1	176		
Oct-59	19	12179	39624	39098	526	526	0	100%	1	177	1	177		

Nov-59	30	19230	19756	39098	-19342	0	0	51%	0	178	0	178		
Dec-59	9	5769	5769	39098	-33329	0	0	15%	0	179	0	179		
Jan-60	216	138456	138456	39098	99358	80000	19358	100%	1	180	1	180		
Feb-60	31	19871	99871	39098	60773	60773	0	100%	1	181	1	181		
Mar-60	19	12179	72952	39098	33855	33855	0	100%	1	182	1	182		
Apr-60	86	55126	88981	39098	49883	49883	0	100%	1	183	1	183		
May-60	53	33973	83856	39098	44758	44758	0	100%	1	184	1	184		
Jun-60	7	4487	49245	39098	10148	10148	0	100%	1	185	1	185		
Jul-60	93	59613	69761	39098	30663	30663	0	100%	1	186	1	186		
Aug-60	33	21153	51816	39098	12718	12718	0	100%	1	187	1	187		
Sep-60	57	36537	49255	39098	10158	10158	0	100%	1	188	1	188		
Oct-60	19	12179	22337	39098	-16761	0	0	57%	0	189	0	189		
Nov-60	11	7051	7051	39098	-32047	0	0	18%	0	190	0	190		
Dec-60	126	80766	80766	39098	41668	41668	0	100%	1	191	1	191		
Jan-61	106	67946	109614	39098	70517	70517	0	100%	1	192	1	192		
Feb-61	112	71792	142309	39098	103211	80000	23211	100%	1	193	1	193		
Mar-61	155	99355	179355	39098	140257	80000	60257	100%	1	194	1	194		
Apr-61	84	53844	133844	39098	94746	80000	14746	100%	1	195	1	195		
May-61	139	89099	169099	39098	130001	80000	50001	100%	1	196	1	196		
Jun-61	181	116021	196021	39098	156923	80000	76923	100%	1	197	1	197		
Jul-61	108	69228	149228	39098	110130	80000	30130	100%	1	198	1	198		
Aug-61	87	55767	135767	39098	96669	80000	16669	100%	1	199	1	199		
Sep-61	55	35255	115255	39098	76157	76157	0	100%	1	200	1	200		
Oct-61	61	39101	115258	39098	76161	76161	0	100%	1	201	1	201		
Nov-61	140	89740	165901	39098	126803	80000	46803	100%	1	202	1	202		
Dec-61	0	0	80000	39098	40902	40902	0	100%	1	203	1	203		
Jan-62	0	0	40902	39098	1805	1805	0	100%	1	204	1	204		
Feb-62	0	0	1805	39098	-37293	0	0	5%	0	205	0	205		
Mar-62	20	12820	12820	39098	-26278	0	0	33%	0	206	0	206		

Apr-62	42	26922	26922	39098	-12176	0	0	69%	0	207	1	207		
May-62	24	15384	15384	39098	-23714	0	0	39%	0	208	0	208		
Jun-62	25	16025	16025	39098	-23073	0	0	41%	0	209	0	209		
Jul-62	112	71792	71792	39098	32694	32694	0	100%	1	210	1	210		
Aug-62	78	49998	82692	39098	43595	43595	0	100%	1	211	1	211		
Sep-62	26	16666	60261	39098	21163	21163	0	100%	1	212	1	212		
Oct-62	38	24358	45521	39098	6423	6423	0	100%	1	213	1	213		
Nov-62	1	641	7064	39098	-32033	0	0	18%	0	214	0	214		
Dec-62	5	3205	3205	39098	-35893	0	0	8%	0	215	0	215		
Jan-63	15	9615	9615	39098	-29483	0	0	25%	0	216	0	216		
Feb-63	3	1923	1923	39098	-37175	0	0	5%	0	217	0	217		
Mar-63	27	17307	17307	39098	-21791	0	0	44%	0	218	0	218		
Apr-63	21	13461	13461	39098	-25637	0	0	34%	0	219	0	219		
May-63	6	3846	3846	39098	-35252	0	0	10%	0	220	0	220		
Jun-63	113	72433	72433	39098	33335	33335	0	100%	1	221	1	221		
Jul-63	76	48716	82051	39098	42954	42954	0	100%	1	222	1	222		
Aug-63	192	123072	166026	39098	126928	80000	46928	100%	1	223	1	223		
Sep-63	48	30768	110768	39098	71670	71670	0	100%	1	224	1	224		
Oct-63	77	49357	121027	39098	81930	80000	1930	100%	1	225	1	225		
Nov-63	352	225632	305632	39098	266534	80000	186534	100%	1	226	1	226		
Dec-63	360	230760	310760	39098	271662	80000	191662	100%	1	227	1	227		
Jan-64	519	332679	412679	39098	373581	80000	293581	100%	1	228	1	228		
Feb-64	535	342935	422935	39098	383837	80000	303837	100%	1	229	1	229		
Mar-64	24	15384	95384	39098	56286	56286	0	100%	1	230	1	230		
Apr-64	0	0	56286	39098	17189	17189	0	100%	1	231	1	231		
May-64	6	3846	21035	39098	-18063	0	0	54%	0	232	0	232		
Jun-64	23	14743	14743	39098	-24355	0	0	38%	0	233	0	233		
Jul-64	42	26922	26922	39098	-12176	0	0	69%	0	234	1	234		
Aug-64	93	59613	59613	39098	20515	20515	0	100%	1	235	1	235		

Sep-64	7	4487	25002	39098	-14095	0	0	64%	0	236	1	236		
Oct-64	2	1282	1282	39098	-37816	0	0	3%	0	237	0	237		
Nov-64	27	17307	17307	39098	-21791	0	0	44%	0	238	0	238		
Dec-64	81	51921	51921	39098	12823	12823	0	100%	1	239	1	239		
Jan-65	27	17307	30130	39098	-8967	0	0	77%	0	240	1	240		
Feb-65	188	120508	120508	39098	81410	80000	1410	100%	1	241	1	241		
Mar-65	89	57049	137049	39098	97951	80000	17951	100%	1	242	1	242		
Apr-65	105	67305	147305	39098	108207	80000	28207	100%	1	243	1	243		
May-65	119	76279	156279	39098	117181	80000	37181	100%	1	244	1	244		
Jun-65	141	90381	170381	39098	131283	80000	51283	100%	1	245	1	245		
Jul-65	287	183967	263967	39098	224869	80000	144869	100%	1	246	1	246		
Aug-65	370	237170	317170	39098	278072	80000	198072	100%	1	247	1	247		
Sep-65	293	187813	267813	39098	228715	80000	148715	100%	1	248	1	248		
Oct-65	384	246144	326144	39098	287046	80000	207046	100%	1	249	1	249		
Nov-65	307	196787	276787	39098	237689	80000	157689	100%	1	250	1	250		
Dec-65	49	31409	111409	39098	72311	72311	0	100%	1	251	1	251		
Jan-66	648	415368	487679	39098	448582	80000	368582	100%	1	252	1	252		
Feb-66	333	213453	293453	39098	254355	80000	174355	100%	1	253	1	253		
Mar-66	152	97432	177432	39098	138334	80000	58334	100%	1	254	1	254		
Apr-66	231	148071	228071	39098	188973	80000	108973	100%	1	255	1	255		
May-66	60	38460	118460	39098	79362	79362	0	100%	1	256	1	256		
Jun-66	30	19230	98592	39098	59495	59495	0	100%	1	257	1	257		
Jul-66	234	149994	209489	39098	170391	80000	90391	100%	1	258	1	258		
Aug-66	58	37178	117178	39098	78080	78080	0	100%	1	259	1	259		
Sep-66	57	36537	114617	39098	75520	75520	0	100%	1	260	1	260		
Oct-66	54	34614	110134	39098	71036	71036	0	100%	1	261	1	261		
Nov-66	63	40383	111419	39098	72321	72321	0	100%	1	262	1	262		
Dec-66	65	41665	113986	39098	74889	74889	0	100%	1	263	1	263		
Jan-67	98	62818	137707	39098	98609	80000	18609	100%	1	264	1	264		

Feb-67	0	0	80000	39098	40902	40902	0	100%	1	265	1	265		
Mar-67	48	30768	71670	39098	32573	32573	0	100%	1	266	1	266		
Apr-67	0	0	32573	39098	-6525	0	0	83%	0	267	1	267		
May-67	92	58972	58972	39098	19874	19874	0	100%	1	268	1	268		
Jun-67	53	33973	53847	39098	14750	14750	0	100%	1	269	1	269		
Jul-67	32	20512	35262	39098	-3836	0	0	90%	0	270	1	270		
Aug-67	41	26281	26281	39098	-12817	0	0	67%	0	271	1	271		
Sep-67	22	14102	14102	39098	-24996	0	0	36%	0	272	0	272		
Oct-67	8	5128	5128	39098	-33970	0	0	13%	0	273	0	273		
Nov-67	53	33973	33973	39098	-5125	0	0	87%	0	274	1	274		
Dec-67	169	108329	108329	39098	69231	69231	0	100%	1	275	1	275		
Jan-68	240	153840	223071	39098	183974	80000	103974	100%	1	276	1	276		
Feb-68	11	7051	87051	39098	47953	47953	0	100%	1	277	1	277		
Mar-68	0	0	47953	39098	8856	8856	0	100%	1	278	1	278		
Apr-68	30	19230	28086	39098	-11012	0	0	72%	0	279	1	279		
May-68	4	2564	2564	39098	-36534	0	0	7%	0	280	0	280		
Jun-68	2	1282	1282	39098	-37816	0	0	3%	0	281	0	281		
Jul-68	34	21794	21794	39098	-17304	0	0	56%	0	282	0	282		
Aug-68	23	14743	14743	39098	-24355	0	0	38%	0	283	0	283		
Sep-68	6	3846	3846	39098	-35252	0	0	10%	0	284	0	284		
Oct-68	86	55126	55126	39098	16028	16028	0	100%	1	285	1	285		
Nov-68	3	1923	17951	39098	-21146	0	0	46%	0	286	0	286		
Dec-68	182	116662	116662	39098	77564	77564	0	100%	1	287	1	287		
Jan-69	342	219222	296786	39098	257689	80000	177689	100%	1	288	1	288		
Feb-69	299	191659	271659	39098	232561	80000	152561	100%	1	289	1	289		
Mar-69	426	273066	353066	39098	313968	80000	233968	100%	1	290	1	290		
Apr-69	276	176916	256916	39098	217818	80000	137818	100%	1	291	1	291		
May-69	10	6410	86410	39098	47312	47312	0	100%	1	292	1	292		
Jun-69	46	29486	76798	39098	37701	37701	0	100%	1	293	1	293		

Jul-69	40	25640	63341	39098	24243	24243	0	100%	1	294	1	294		
Aug-69	29	18589	42832	39098	3734	3734	0	100%	1	295	1	295		
Sep-69	66	42306	46040	39098	6943	6943	0	100%	1	296	1	296		
Oct-69	61	39101	46044	39098	6946	6946	0	100%	1	297	1	297		
Nov-69	40	25640	32586	39098	-6512	0	0	83%	0	298	1	298		
Dec-69	302	193582	193582	39098	154484	80000	74484	100%	1	299	1	299		
Jan-70	278	178198	258198	39098	219100	80000	139100	100%	1	300	1	300		
Feb-70	58	37178	117178	39098	78080	78080	0	100%	1	301	1	301		
Mar-70	137	87817	165897	39098	126800	80000	46800	100%	1	302	1	302		
Apr-70	201	128841	208841	39098	169743	80000	89743	100%	1	303	1	303		
May-70	43	27563	107563	39098	68465	68465	0	100%	1	304	1	304		
Jun-70	132	84612	153077	39098	113980	80000	33980	100%	1	305	1	305		
Jul-70	76	48716	128716	39098	89618	80000	9618	100%	1	306	1	306		
Aug-70	43	27563	107563	39098	68465	68465	0	100%	1	307	1	307		
Sep-70	13	8333	76798	39098	37701	37701	0	100%	1	308	1	308		
Oct-70	2	1282	38983	39098	-115	0	0	100%	1	309	1	309		
Nov-70	5	3205	3205	39098	-35893	0	0	8%	0	310	0	310		
Dec-70	5	3205	3205	39098	-35893	0	0	8%	0	311	0	311		
Jan-71	6	3846	3846	39098	-35252	0	0	10%	0	312	0	312		
Feb-71	5	3205	3205	39098	-35893	0	0	8%	0	313	0	313		
Mar-71	1	641	641	39098	-38457	0	0	2%	0	314	0	314		
Apr-71	35	22435	22435	39098	-16663	0	0	57%	0	315	0	315		
May-71	77	49357	49357	39098	10259	10259	0	100%	1	316	1	316		
Jun-71	50	32050	42309	39098	3212	3212	0	100%	1	317	1	317		
Jul-71	52	33332	36544	39098	-2554	0	0	93%	0	318	1	318		
Aug-71	94	60254	60254	39098	21156	21156	0	100%	1	319	1	319		
Sep-71	7	4487	25643	39098	-13454	0	0	66%	0	320	1	320		
Oct-71	28	17948	17948	39098	-21150	0	0	46%	0	321	0	321		
Nov-71	11	7051	7051	39098	-32047	0	0	18%	0	322	0	322		

Dec-71	61	39101	39101	39098	3	3	0	100%	1	323	1	323		
Jan-72	132	84612	84615	39098	45518	45518	0	100%	1	324	1	324		
Feb-72	42	26922	72440	39098	33342	33342	0	100%	1	325	1	325		
Mar-72	16	10256	43598	39098	4500	4500	0	100%	1	326	1	326		
Apr-72	132	84612	89112	39098	50015	50015	0	100%	1	327	1	327		
May-72	366	234606	284621	39098	245523	80000	165523	100%	1	328	1	328		
Jun-72	277	177557	257557	39098	218459	80000	138459	100%	1	329	1	329		
Jul-72	245	157045	237045	39098	197947	80000	117947	100%	1	330	1	330		
Aug-72	231	148071	228071	39098	188973	80000	108973	100%	1	331	1	331		
Sep-72	436	279476	359476	39098	320378	80000	240378	100%	1	332	1	332		
Oct-72	292	187172	267172	39098	228074	80000	148074	100%	1	333	1	333		
Nov-72	345	221145	301145	39098	262047	80000	182047	100%	1	334	1	334		
Dec-72	571	366011	446011	39098	406913	80000	326913	100%	1	335	1	335		
Jan-73	651	417291	497291	39098	458193	80000	378193	100%	1	336	1	336		
Feb-73	474	303834	383834	39098	344736	80000	264736	100%	1	337	1	337		
Mar-73	242	155122	235122	39098	196024	80000	116024	100%	1	338	1	338		
Apr-73	22	14102	94102	39098	55004	55004	0	100%	1	339	1	339		
May-73	35	22435	77439	39098	38342	38342	0	100%	1	340	1	340		
Jun-73	13	8333	46675	39098	7577	7577	0	100%	1	341	1	341		
Jul-73	7	4487	12064	39098	-27034	0	0	31%	0	342	0	342		
Aug-73	83	53203	53203	39098	14105	14105	0	100%	1	343	1	343		
Sep-73	33	21153	35258	39098	-3839	0	0	90%	0	344	1	344		
Oct-73	2	1282	1282	39098	-37816	0	0	3%	0	345	0	345		
Nov-73	1	641	641	39098	-38457	0	0	2%	0	346	0	346		
Dec-73	19	12179	12179	39098	-26919	0	0	31%	0	347	0	347		
Jan-74	0	0	0	39098	-39098	0	0	0%	0	348	0	348		
Feb-74	0	0	0	39098	-39098	0	0	0%	0	349	0	349		
Mar-74	0	0	0	39098	-39098	0	0	0%	0	350	0	350		
Apr-74	22	14102	14102	39098	-24996	0	0	36%	0	351	0	351		

May-74	229	146789	146789	39098	107691	80000	27691	100%	1	352	1	352		
Jun-74	31	19871	99871	39098	60773	60773	0	100%	1	353	1	353		
Jul-74	20	12820	73593	39098	34496	34496	0	100%	1	354	1	354		
Aug-74	85	54485	88981	39098	49883	49883	0	100%	1	355	1	355		
Sep-74	25	16025	65908	39098	26810	26810	0	100%	1	356	1	356		
Oct-74	18	11538	38348	39098	-749	0	0	98%	0	357	1	357		
Nov-74	15	9615	9615	39098	-29483	0	0	25%	0	358	0	358		
Dec-74	276	176916	176916	39098	137818	80000	57818	100%	1	359	1	359		
Jan-75	332	212812	292812	39098	253714	80000	173714	100%	1	360	1	360		
Feb-75	52	33332	113332	39098	74234	74234	0	100%	1	361	1	361		
Mar-75	136	87176	161410	39098	122313	80000	42313	100%	1	362	1	362		
Apr-75	69	44229	124229	39098	85131	80000	5131	100%	1	363	1	363		
May-75	29	18589	98589	39098	59491	59491	0	100%	1	364	1	364		
Jun-75	115	73715	133206	39098	94109	80000	14109	100%	1	365	1	365		
Jul-75	30	19230	99230	39098	60132	60132	0	100%	1	366	1	366		
Aug-75	8	5128	65260	39098	26163	26163	0	100%	1	367	1	367		
Sep-75	23	14743	40906	39098	1808	1808	0	100%	1	368	1	368		
Oct-75	6	3846	5654	39098	-33444	0	0	14%	0	369	0	369		
Nov-75	3	1923	1923	39098	-37175	0	0	5%	0	370	0	370		
Dec-75	5	3205	3205	39098	-35893	0	0	8%	0	371	0	371		
Jan-76	91	58331	58331	39098	19233	19233	0	100%	1	372	1	372		
Feb-76	16	10256	29489	39098	-9608	0	0	75%	0	373	1	373		
Mar-76	23	14743	14743	39098	-24355	0	0	38%	0	374	0	374		
Apr-76	50	32050	32050	39098	-7048	0	0	82%	0	375	1	375		
May-76	191	122431	122431	39098	83333	80000	3333	100%	1	376	1	376		
Jun-76	346	221786	301786	39098	262688	80000	182688	100%	1	377	1	377		
Jul-76	357	228837	308837	39098	269739	80000	189739	100%	1	378	1	378		
Aug-76	344	220504	300504	39098	261406	80000	181406	100%	1	379	1	379		
Sep-76	144	92304	172304	39098	133206	80000	53206	100%	1	380	1	380		

Oct-76	118	75638	155638	39098	116540	80000	36540	100%	1	381	1	381		
Nov-76	30	19230	99230	39098	60132	60132	0	100%	1	382	1	382		
Dec-76	170	108970	169102	39098	130005	80000	50005	100%	1	383	1	383		
Jan-77	207	132687	212687	39098	173589	80000	93589	100%	1	384	1	384		
Feb-77	121	77561	157561	39098	118463	80000	38463	100%	1	385	1	385		
Mar-77	165	105765	185765	39098	146667	80000	66667	100%	1	386	1	386		
Apr-77	352	225632	305632	39098	266534	80000	186534	100%	1	387	1	387		
May-77	49	31409	111409	39098	72311	72311	0	100%	1	388	1	388		
Jun-77	29	18589	90900	39098	51803	51803	0	100%	1	389	1	389		
Jul-77	155	99355	151158	39098	112060	80000	32060	100%	1	390	1	390		
Aug-77	131	83971	163971	39098	124873	80000	44873	100%	1	391	1	391		
Sep-77	95	60895	140895	39098	101797	80000	21797	100%	1	392	1	392		
Oct-77	58	37178	117178	39098	78080	78080	0	100%	1	393	1	393		
Nov-77	90	57690	135770	39098	96673	80000	16673	100%	1	394	1	394		
Dec-77	411	263451	343451	39098	304353	80000	224353	100%	1	395	1	395		
Jan-78	358	229478	309478	39098	270380	80000	190380	100%	1	396	1	396		
Feb-78	324	207684	287684	39098	248586	80000	168586	100%	1	397	1	397		
Mar-78	320	205120	285120	39098	246022	80000	166022	100%	1	398	1	398		
Apr-78	50	32050	112050	39098	72952	72952	0	100%	1	399	1	399		
May-78	35	22435	95387	39098	56290	56290	0	100%	1	400	1	400		
Jun-78	75	48075	104365	39098	65267	65267	0	100%	1	401	1	401		
Jul-78	43	27563	92830	39098	53732	53732	0	100%	1	402	1	402		
Aug-78	48	30768	84500	39098	45403	45403	0	100%	1	403	1	403		
Sep-78	1	641	46044	39098	6946	6946	0	100%	1	404	1	404		
Oct-78	11	7051	13997	39098	-25101	0	0	36%	0	405	0	405		
Nov-78	16	10256	10256	39098	-28842	0	0	26%	0	406	0	406		
Dec-78	153	98073	98073	39098	58975	58975	0	100%	1	407	1	407		
Jan-79	267	171147	230122	39098	191025	80000	111025	100%	1	408	1	408		
Feb-79	259	166019	246019	39098	206921	80000	126921	100%	1	409	1	409		

Mar-79	66	42306	122306	39098	83208	80000	3208	100%	1	410	1	410		
Apr-79	11	7051	87051	39098	47953	47953	0	100%	1	411	1	411		
May-79	93	59613	107566	39098	68469	68469	0	100%	1	412	1	412		
Jun-79	104	66664	135133	39098	96035	80000	16035	100%	1	413	1	413		
Jul-79	42	26922	106922	39098	67824	67824	0	100%	1	414	1	414		
Aug-79	28	17948	85772	39098	46675	46675	0	100%	1	415	1	415		
Sep-79	29	18589	65264	39098	26166	26166	0	100%	1	416	1	416		
Oct-79	122	78202	104368	39098	65270	65270	0	100%	1	417	1	417		
Nov-79	84	53844	119114	39098	80017	80000	17	100%	1	418	1	418		
Dec-79	153	98073	178073	39098	138975	80000	58975	100%	1	419	1	419		
Jan-80	100	64100	144100	39098	105002	80000	25002	100%	1	420	1	420		
Feb-80	96	61536	141536	39098	102438	80000	22438	100%	1	421	1	421		
Mar-80	132	84612	164612	39098	125514	80000	45514	100%	1	422	1	422		
Apr-80	63	40383	120383	39098	81285	80000	1285	100%	1	423	1	423		
May-80	72	46152	126152	39098	87054	80000	7054	100%	1	424	1	424		
Jun-80	76	48716	128716	39098	89618	80000	9618	100%	1	425	1	425		
Jul-80	15	9615	89615	39098	50517	50517	0	100%	1	426	1	426		
Aug-80	104	66664	117181	39098	78084	78084	0	100%	1	427	1	427		
Sep-80	54	34614	112698	39098	73600	73600	0	100%	1	428	1	428		
Oct-80	108	69228	142828	39098	103730	80000	23730	100%	1	429	1	429		
Nov-80	65	41665	121665	39098	82567	80000	2567	100%	1	430	1	430		
Dec-80	157	100637	180637	39098	141539	80000	61539	100%	1	431	1	431		
Jan-81	62	39742	119742	39098	80644	80000	644	100%	1	432	1	432		
Feb-81	30	19230	99230	39098	60132	60132	0	100%	1	433	1	433		
Mar-81	150	96150	156282	39098	117185	80000	37185	100%	1	434	1	434		
Apr-81	295	189095	269095	39098	229997	80000	149997	100%	1	435	1	435		
May-81	62	39742	119742	39098	80644	80000	644	100%	1	436	1	436		
Jun-81	132	84612	164612	39098	125514	80000	45514	100%	1	437	1	437		
Jul-81	36	23076	103076	39098	63978	63978	0	100%	1	438	1	438		

Aug-81	30	19230	83208	39098	44111	44111	0	100%	1	439	1	439		
Sep-81	81	51921	96032	39098	56934	56934	0	100%	1	440	1	440		
Oct-81	16	10256	67190	39098	28092	28092	0	100%	1	441	1	441		
Nov-81	0	0	28092	39098	-11005	0	0	72%	0	442	1	442		
Dec-81	125	80125	80125	39098	41027	41027	0	100%	1	443	1	443		
Jan-82	4	2564	43591	39098	4494	4494	0	100%	1	444	1	444		
Feb-82	10	6410	10904	39098	-28194	0	0	28%	0	445	0	445		
Mar-82	12	7692	7692	39098	-31406	0	0	20%	0	446	0	446		
Apr-82	84	53844	53844	39098	14746	14746	0	100%	1	447	1	447		
May-82	64	41024	55770	39098	16673	16673	0	100%	1	448	1	448		
Jun-82	168	107688	124361	39098	85263	80000	5263	100%	1	449	1	449		
Jul-82	351	224991	304991	39098	265893	80000	185893	100%	1	450	1	450		
Aug-82	460	294860	374860	39098	335762	80000	255762	100%	1	451	1	451		
Sep-82	176	112816	192816	39098	153718	80000	73718	100%	1	452	1	452		
Oct-82	337	216017	296017	39098	256919	80000	176919	100%	1	453	1	453		
Nov-82	182	116662	196662	39098	157564	80000	77564	100%	1	454	1	454		
Dec-82	546	349986	429986	39098	390888	80000	310888	100%	1	455	1	455		
Jan-83	78	49998	129998	39098	90900	80000	10900	100%	1	456	1	456		
Feb-83	168	107688	187688	39098	148590	80000	68590	100%	1	457	1	457		
Mar-83	108	69228	149228	39098	110130	80000	30130	100%	1	458	1	458		
Apr-83	146	93586	173586	39098	134488	80000	54488	100%	1	459	1	459		
May-83	284	182044	262044	39098	222946	80000	142946	100%	1	460	1	460		
Jun-83	244	156404	236404	39098	197306	80000	117306	100%	1	461	1	461		
Jul-83	385	246785	326785	39098	287687	80000	207687	100%	1	462	1	462		
Aug-83	105	67305	147305	39098	108207	80000	28207	100%	1	463	1	463		
Sep-83	101	64741	144741	39098	105643	80000	25643	100%	1	464	1	464		
Oct-83	0	0	80000	39098	40902	40902	0	100%	1	465	1	465		
Nov-83	43	27563	68465	39098	29368	29368	0	100%	1	466	1	466		
Dec-83	61	39101	68469	39098	29371	29371	0	100%	1	467	1	467		

Jan-84	6	3846	33217	39098	-5881	0	0	85%	0	468	1	468		
Feb-84	8	5128	5128	39098	-33970	0	0	13%	0	469	0	469		
Mar-84	11	7051	7051	39098	-32047	0	0	18%	0	470	0	470		
Apr-84	92	58972	58972	39098	19874	19874	0	100%	1	471	1	471		
May-84	87	55767	75641	39098	36544	36544	0	100%	1	472	1	472		
Jun-84	40	25640	62184	39098	23086	23086	0	100%	1	473	1	473		
Jul-84	140	89740	112826	39098	73728	73728	0	100%	1	474	1	474		
Aug-84	28	17948	91676	39098	52579	52579	0	100%	1	475	1	475		
Sep-84	47	30127	82706	39098	43608	43608	0	100%	1	476	1	476		
Oct-84	37	23717	67325	39098	28227	28227	0	100%	1	477	1	477		
Nov-84	35	22435	50662	39098	11565	11565	0	100%	1	478	1	478		
Dec-84	24	15384	26949	39098	-12149	0	0	69%	0	479	1	479		
Jan-85	55	35255	35255	39098	-3843	0	0	90%	0	480	1	480		
Feb-85	10	6410	6410	39098	-32688	0	0	16%	0	481	0	481		
Mar-85	92	58972	58972	39098	19874	19874	0	100%	1	482	1	482		
Apr-85	0	0	19874	39098	-19223	0	0	51%	0	483	0	483		
May-85	34	21794	21794	39098	-17304	0	0	56%	0	484	0	484		
Jun-85	50	32050	32050	39098	-7048	0	0	82%	0	485	1	485		
Jul-85	21	13461	13461	39098	-25637	0	0	34%	0	486	0	486		
Aug-85	44	28204	28204	39098	-10894	0	0	72%	0	487	1	487		
Sep-85	20	12820	12820	39098	-26278	0	0	33%	0	488	0	488		
Oct-85	33	21153	21153	39098	-17945	0	0	54%	0	489	0	489		
Nov-85	129	82689	82689	39098	43591	43591	0	100%	1	490	1	490		
Dec-85	72	46152	89743	39098	50646	50646	0	100%	1	491	1	491		
Jan-86	30	19230	69876	39098	30778	30778	0	100%	1	492	1	492		
Feb-86	7	4487	35265	39098	-3833	0	0	90%	0	493	1	493		
Mar-86	8	5128	5128	39098	-33970	0	0	13%	0	494	0	494		
Apr-86	8	5128	5128	39098	-33970	0	0	13%	0	495	0	495		
May-86	16	10256	10256	39098	-28842	0	0	26%	0	496	0	496		

Jun-86	65	41665	41665	39098	2567	2567	0	100%	1	497	1	497		
Jul-86	148	94868	97435	39098	58338	58338	0	100%	1	498	1	498		
Aug-86	101	64741	123079	39098	83981	80000	3981	100%	1	499	1	499		
Sep-86	194	124354	204354	39098	165256	80000	85256	100%	1	500	1	500		
Oct-86	229	146789	226789	39098	187691	80000	107691	100%	1	501	1	501		
Nov-86	132	84612	164612	39098	125514	80000	45514	100%	1	502	1	502		
Dec-86	368	235888	315888	39098	276790	80000	196790	100%	1	503	1	503		
Jan-87	356	228196	308196	39098	269098	80000	189098	100%	1	504	1	504		
Feb-87	248	158968	238968	39098	199870	80000	119870	100%	1	505	1	505		
Mar-87	517	331397	411397	39098	372299	80000	292299	100%	1	506	1	506		
Apr-87	362	232042	312042	39098	272944	80000	192944	100%	1	507	1	507		
May-87	340	217940	297940	39098	258842	80000	178842	100%	1	508	1	508		
Jun-87	182	116662	196662	39098	157564	80000	77564	100%	1	509	1	509		
Jul-87	279	178839	258839	39098	219741	80000	139741	100%	1	510	1	510		
Aug-87	160	102560	182560	39098	143462	80000	63462	100%	1	511	1	511		
Sep-87	151	96791	176791	39098	137693	80000	57693	100%	1	512	1	512		
Oct-87	84	53844	133844	39098	94746	80000	14746	100%	1	513	1	513		
Nov-87	76	48716	128716	39098	89618	80000	9618	100%	1	514	1	514		
Dec-87	349	223709	303709	39098	264611	80000	184611	100%	1	515	1	515		
Jan-88	267	171147	251147	39098	212049	80000	132049	100%	1	516	1	516		
Feb-88	138	88458	168458	39098	129360	80000	49360	100%	1	517	1	517		
Mar-88	185	118585	198585	39098	159487	80000	79487	100%	1	518	1	518		
Apr-88	71	45511	125511	39098	86413	80000	6413	100%	1	519	1	519		
May-88	206	132046	212046	39098	172948	80000	92948	100%	1	520	1	520		
Jun-88	28	17948	97948	39098	58850	58850	0	100%	1	521	1	521		
Jul-88	49	31409	90259	39098	51162	51162	0	100%	1	522	1	522		
Aug-88	65	41665	92827	39098	53729	53729	0	100%	1	523	1	523		
Sep-88	20	12820	66549	39098	27451	27451	0	100%	1	524	1	524		
Oct-88	11	7051	34502	39098	-4595	0	0	88%	0	525	1	525		

Nov-88	13	8333	8333	39098	-30765	0	0	21%	0	526	0	526		
Dec-88	6	3846	3846	39098	-35252	0	0	10%	0	527	0	527		
Jan-89	0	0	0	39098	-39098	0	0	0%	0	528	0	528		
Feb-89	0	0	0	39098	-39098	0	0	0%	0	529	0	529		
Mar-89	2	1282	1282	39098	-37816	0	0	3%	0	530	0	530		
Apr-89	62	39742	39742	39098	644	644	0	100%	1	531	1	531		
May-89	33	21153	21797	39098	-17300	0	0	56%	0	532	0	532		
Jun-89	92	58972	58972	39098	19874	19874	0	100%	1	533	1	533		
Jul-89	18	11538	31412	39098	-7685	0	0	80%	0	534	1	534		
Aug-89	11	7051	7051	39098	-32047	0	0	18%	0	535	0	535		
Sep-89	24	15384	15384	39098	-23714	0	0	39%	0	536	0	536		
Oct-89	14	8974	8974	39098	-30124	0	0	23%	0	537	0	537		
Nov-89	30	19230	19230	39098	-19868	0	0	49%	0	538	0	538		
Dec-89	87	55767	55767	39098	16669	16669	0	100%	1	539	1	539		
Jan-90	483	309603	326272	39098	287175	80000	207175	100%	1	540	1	540		
Feb-90	288	184608	264608	39098	225510	80000	145510	100%	1	541	1	541		
Mar-90	242	155122	235122	39098	196024	80000	116024	100%	1	542	1	542		
Apr-90	188	120508	200508	39098	161410	80000	81410	100%	1	543	1	543		
May-90	97	62177	142177	39098	103079	80000	23079	100%	1	544	1	544		
Jun-90	72	46152	126152	39098	87054	80000	7054	100%	1	545	1	545		
Jul-90	0	0	80000	39098	40902	40902	0	100%	1	546	1	546		
Aug-90	171	109611	150513	39098	111416	80000	31416	100%	1	547	1	547		
Sep-90	180	115380	195380	39098	156282	80000	76282	100%	1	548	1	548		
Oct-90	62	39742	119742	39098	80644	80000	644	100%	1	549	1	549		
Nov-90	121	77561	157561	39098	118463	80000	38463	100%	1	550	1	550		
Dec-90	419	268579	348579	39098	309481	80000	229481	100%	1	551	1	551		
Jan-91	419	268579	348579	39098	309481	80000	229481	100%	1	552	1	552		
Feb-91	32	20512	100512	39098	61414	61414	0	100%	1	553	1	553		
Mar-91	26	16666	78080	39098	38983	38983	0	100%	1	554	1	554		

Apr-91	16	10256	49239	39098	10141	10141	0	100%	1	555	1	555		
May-91	7	4487	14628	39098	-24470	0	0	37%	0	556	0	556		
Jun-91	98	62818	62818	39098	23720	23720	0	100%	1	557	1	557		
Jul-91	66	42306	66026	39098	26929	26929	0	100%	1	558	1	558		
Aug-91	214	137174	164103	39098	125005	80000	45005	100%	1	559	1	559		
Sep-91	165	105765	185765	39098	146667	80000	66667	100%	1	560	1	560		
Oct-91	113	72433	152433	39098	113335	80000	33335	100%	1	561	1	561		
Nov-91	329	210889	290889	39098	251791	80000	171791	100%	1	562	1	562		
Dec-91	210	134610	214610	39098	175512	80000	95512	100%	1	563	1	563		
Jan-92	278	178198	258198	39098	219100	80000	139100	100%	1	564	1	564		
Feb-92	145	92945	172945	39098	133847	80000	53847	100%	1	565	1	565		
Mar-92	173	110893	190893	39098	151795	80000	71795	100%	1	566	1	566		
Apr-92	184	117944	197944	39098	158846	80000	78846	100%	1	567	1	567		
May-92	318	203838	283838	39098	244740	80000	164740	100%	1	568	1	568		
Jun-92	213	136533	216533	39098	177435	80000	97435	100%	1	569	1	569		
Jul-92	232	148712	228712	39098	189614	80000	109614	100%	1	570	1	570		
Aug-92	55	35255	115255	39098	76157	76157	0	100%	1	571	1	571		
Sep-92	35	22435	98592	39098	59495	59495	0	100%	1	572	1	572		
Oct-92	47	30127	89622	39098	50524	50524	0	100%	1	573	1	573		
Nov-92	167	107047	157571	39098	118473	80000	38473	100%	1	574	1	574		
Dec-92	406	260246	340246	39098	301148	80000	221148	100%	1	575	1	575		
Jan-93	198	126918	206918	39098	167820	80000	87820	100%	1	576	1	576		
Feb-93	196	125636	205636	39098	166538	80000	86538	100%	1	577	1	577		
Mar-93	150	96150	176150	39098	137052	80000	57052	100%	1	578	1	578		
Apr-93	0	0	80000	39098	40902	40902	0	100%	1	579	1	579		
May-93	236	151276	192178	39098	153081	80000	73081	100%	1	580	1	580		
Jun-93	96	61536	141536	39098	102438	80000	22438	100%	1	581	1	581		
Jul-93	0	0	80000	39098	40902	40902	0	100%	1	582	1	582		
Aug-93	0	0	40902	39098	1805	1805	0	100%	1	583	1	583		

Sep-93	197	126277	128082	39098	88984	80000	8984	100%	1	584	1	584		
Oct-93	203	130123	210123	39098	171025	80000	91025	100%	1	585	1	585		
Nov-93	2	1282	81282	39098	42184	42184	0	100%	1	586	1	586		
Dec-93	354	226914	269098	39098	230001	80000	150001	100%	1	587	1	587		
Jan-94	81	51921	131921	39098	92823	80000	12823	100%	1	588	1	588		
Feb-94	7	4487	84487	39098	45389	45389	0	100%	1	589	1	589		
Mar-94	19	12179	57568	39098	18471	18471	0	100%	1	590	1	590		
Apr-94	267	171147	189618	39098	150520	80000	70520	100%	1	591	1	591		
May-94	77	49357	129357	39098	90259	80000	10259	100%	1	592	1	592		
Jun-94	0	0	80000	39098	40902	40902	0	100%	1	593	1	593		
Jul-94	55	35255	76157	39098	37060	37060	0	100%	1	594	1	594		
Aug-94	79	50639	87699	39098	48601	48601	0	100%	1	595	1	595		
Sep-94	203	130123	178724	39098	139626	80000	59626	100%	1	596	1	596		
Oct-94	0	0	80000	39098	40902	40902	0	100%	1	597	1	597		
Nov-94	139	89099	130001	39098	90904	80000	10904	100%	1	598	1	598		
Dec-94	373	239093	319093	39098	279995	80000	199995	100%	1	599	1	599		
Jan-00		0	80000	39098	40902	40902	0	100%	1	600	1	600		
Feb-00	2.0	1295	42197	39098	3099	3099	0	100%	1	601	1	601		
Mar-00	10.0	6429	9529	39098	-29569	0	0	24%	0	602	0	602		
Apr-00	15.1	9660	9660	39098	-29438	0	0	25%	0	603	0	603		
May-00	18.2	11685	11685	39098	-27412	0	0	30%	0	604	0	604		
Jun-00	67.3	43114	43114	39098	4016	4016	0	100%	1	605	1	605		
Jul-00	122.1	78285	82301	39098	43204	43204	0	100%	1	606	1	606		
Aug-00	162.6	104246	147449	39098	108352	80000	28352	100%	1	607	1	607		
Sep-00	0.0	0	80000	39098	40902	40902	0	100%	1	608	1	608		
Oct-00	0.0	6	40909	39098	1811	1811	0	100%	1	609	1	609		
Nov-00	22.6	14487	16298	39098	-22800	0	0	42%	0	610	0	610		
Dec-00	38.6	24743	24743	39098	-14355	0	0	63%	0	611	1	611		
Jan-01	0.0	0	0	39098	-39098	0	0	0%	0	612	0	612		

Feb-01	0.0	0	0	39098	-39098	0	0	0%	0	613	0	613		
Mar-01	0.0	0	0	39098	-39098	0	0	0%	0	614	0	614		
Apr-01	26.0	16666	16666	39098	-22432	0	0	43%	0	615	0	615		
May-01	30.4	19486	19486	39098	-19611	0	0	50%	0	616	0	616		
Jun-01	77.7	49806	49806	39098	10708	10708	0	100%	1	617	1	617		
Jul-01	188.1	120572	131280	39098	92182	80000	12182	100%	1	618	1	618		
Aug-01	92.5	59293	139293	39098	100195	80000	20195	100%	1	619	1	619		
Sep-01	33.1	21217	101217	39098	62119	62119	0	100%	1	620	1	620		
Oct-01	0.6	385	62504	39098	23406	23406	0	100%	1	621	1	621		
Nov-01	74.6	47819	71225	39098	32127	32127	0	100%	1	622	1	622		
Dec-01	490.0	314090	346217	39098	307120	80000	227120	100%	1	623	1	623		
Jan-02	176.8	113329	193329	39098	154231	80000	74231	100%	1	624	1	624		
Feb-02	286.3	183518	263518	39098	224421	80000	144421	100%	1	625	1	625		
Mar-02	394.3	252746	332746	39098	293649	80000	213649	100%	1	626	1	626		
Apr-02	111.9	71728	151728	39098	112630	80000	32630	100%	1	627	1	627		
May-02	120.1	76984	156984	39098	117886	80000	37886	100%	1	628	1	628		
Jun-02	230.6	147815	227815	39098	188717	80000	108717	100%	1	629	1	629		
Jul-02	78.4	50254	130254	39098	91157	80000	11157	100%	1	630	1	630		
Aug-02	459.5	294540	374540	39098	335442	80000	255442	100%	1	631	1	631		
Sep-02	231.9	148648	228648	39098	189550	80000	109550	100%	1	632	1	632		
Oct-02	96.6	61921	141921	39098	102823	80000	22823	100%	1	633	1	633		
Nov-02	569.9	365306	445306	39098	406208	80000	326208	100%	1	634	1	634		
Dec-02	247.2	158455	238455	39098	199358	80000	119358	100%	1	635	1	635		
Jan-03	608.1	389792	469792	39098	430694	80000	350694	100%	1	636	1	636		
Feb-03	529	339089	419089	39098	379991	80000	299991	100%	1	637	1	637		
Mar-03	395.5	253516	333516	39098	294418	80000	214418	100%	1	638	1	638		
Apr-03	135.9	87112	167112	39098	128014	80000	48014	100%	1	639	1	639		
May-03	66.5	42627	122627	39098	83529	80000	3529	100%	1	640	1	640		
Jun-03	5.8	3718	83718	39098	44620	44620	0	100%	1	641	1	641		

Jul-03	0.0	0	44620	39098	5522	5522	0	100%	1	642	1	642		
Aug-03	62.6	40127	45649	39098	6551	6551	0	100%	1	643	1	643		
Sep-03	229.9	147366	153917	39098	114820	80000	34820	100%	1	644	1	644		
Oct-03	72.6	46537	126537	39098	87439	80000	7439	100%	1	645	1	645		
Nov-03	94.3	60446	140446	39098	101349	80000	21349	100%	1	646	1	646		
Dec-03	113.5	72754	152754	39098	113656	80000	33656	100%	1	647	1	647		
Jan-04	278.8	178730	258730	39098	219632	80000	139632	100%	1	648	1	648		
Feb-04	198.4	127187	207187	39098	168090	80000	88090	100%	1	649	1	649		
Mar-04	171.0	109624	189624	39098	150526	80000	70526	100%	1	650	1	650		
Apr-04	238.2	152693	232693	39098	193595	80000	113595	100%	1	651	1	651		
May-04	49.2	31537	111537	39098	72440	72440	0	100%	1	652	1	652		
Jun-04	145.8	93471	165910	39098	126812	80000	46812	100%	1	653	1	653		
Jul-04	149.6	95894	175894	39098	136796	80000	56796	100%	1	654	1	654		
Aug-04	262.2	168077	248077	39098	208979	80000	128979	100%	1	655	1	655		
Sep-04	257.6	165134	245134	39098	206037	80000	126037	100%	1	656	1	656		
Oct-04	111.8	71664	151664	39098	112566	80000	32566	100%	1	657	1	657		
Nov-04	0.0	0	80000	39098	40902	40902	0	100%	1	658	1	658		
Dec-04	0.0	0	40902	39098	1805	1805	0	100%	1	659	1	659		
Jan-05	102.6	65779	67584	39098	28486	28486	0	100%	1	660	1	660		
Feb-05	37.0	23723	52210	39098	13112	13112	0	100%	1	661	1	661		
Mar-05	135.8	87054	100166	39098	61069	61069	0	100%	1	662	1	662		
Apr-05	179.6	115136	176205	39098	137107	80000	57107	100%	1	663	1	663		
May-05	90.2	57837	137837	39098	98740	80000	18740	100%	1	664	1	664		
Jun-05	73.6	47203	127203	39098	88106	80000	8106	100%	1	665	1	665		
Jul-05	119.6	76689	156689	39098	117592	80000	37592	100%	1	666	1	666		
Aug-05	77.8	49883	129883	39098	90785	80000	10785	100%	1	667	1	667		
Sep-05	0.0	0	80000	39098	40902	40902	0	100%	1	668	1	668		
Oct-05	0.0	0	40902	39098	1805	1805	0	100%	1	669	1	669		
Nov-05	0.0	0	1805	39098	-37293	0	0	5%	0	670	0	670		

Dec-05	0.0	0	0	39098	-39098	0	0	0%	0	671	0	671		
Jan-10	261.0	167301	167301	39098	128203	80000	48203	100%	1	672	1	672		
Feb-10	211.0	135251	215251	39098	176153	80000	96153	100%	1	673	1	673		
Mar-10	273.3	175185	255185	39098	216088	80000	136088	100%	1	674	1	674		
Apr-10	211.1	135315	215315	39098	176217	80000	96217	100%	1	675	1	675		
May-10	95.1	60959	140959	39098	101861	80000	21861	100%	1	676	1	676		
Jun-10	18.8	12051	92051	39098	52953	52953	0	100%	1	677	1	677		
Jul-10	19.9	12756	65709	39098	26611	26611	0	100%	1	678	1	678		
Aug-10	17.0	10897	37508	39098	-1589	0	0	96%	0	679	1	679		
Sep-10	6.9	4423	4423	39098	-34675	0	0	11%	0	680	0	680		
Oct-10	18.9	12115	12115	39098	-26983	0	0	31%	0	681	0	681		
Nov-10	0.0	0	0	39098	-39098	0	0	0%	0	682	0	682		
Dec-10	68.4	43844	43844	39098	4747	4747	0	100%	1	683	1	683		
Jan-11	3.1	1987	6734	39098	-32364	0	0	17%	0	684	0	684		
Feb-11	2.2	1410	1410	39098	-37687	0	0	4%	0	685	0	685		
Mar-11	19.0	12179	12179	39098	-26919	0	0	31%	0	686	0	686		
Apr-11	54.6	34999	34999	39098	-4099	0	0	90%	0	687	1	687		
May-11	65.6	42050	42050	39098	2952	2952	0	100%	1	688	1	688		
Jun-11	75.5	48396	51347	39098	12250	12250	0	100%	1	689	1	689		
Jul-11	92.7	59421	71670	39098	32573	32573	0	100%	1	690	1	690		
Aug-11	133.7	85702	118275	39098	79177	79177	0	100%	1	691	1	691		
Sep-11	0.0	0	79177	39098	40079	40079	0	100%	1	692	1	692		
Oct-11	0.0	0	40079	39098	982	982	0	100%	1	693	1	693		
Nov-11	0.0	0	982	39098	-38116	0	0	3%	0	694	0	694		
Dec-11	0.0	0	0	39098	-39098	0	0	0%	0	695	0	695		
Jan-12	6.4	4102	4102	39098	-34995	0	0	10%	0	696	0	696		
Feb-12	10.0	6410	6410	39098	-32688	0	0	16%	0	697	0	697		
Mar-12	55.3	35447	35447	39098	-3650	0	0	91%	0	698	1	698		
Apr-12	111.0	71151	71151	39098	32053	32053	0	100%	1	699	1	699		

May-12	215.8	138328	170381	39098	131283	80000	51283	100%	1	700	1	700		
Jun-12	82.9	53139	133139	39098	94041	80000	14041	100%	1	701	1	701		
Jul-12	400.0	256400	336400	39098	297302	80000	217302	100%	1	702	1	702		
Aug-12	57.4	36793	116793	39098	77696	77696	0	100%	1	703	1	703		
Sep-12	47.4	30383	108079	39098	68981	68981	0	100%	1	704	1	704		
Oct-12	69.0	44229	113210	39098	74113	74113	0	100%	1	705	1	705		
Nov-12	57.2	36665	110778	39098	71680	71680	0	100%	1	706	1	706		
Dec-12	115.1	73779	145459	39098	106362	80000	26362	100%	1	707	1	707		
Jan-13	40.5	25961	105961	39098	66863	66863	0	100%	1	708	1	708		
Feb-13	50.1	32114	98977	39098	59879	59879	0	100%	1	709	1	709		
Mar-13	52.5	33653	93532	39098	54434	54434	0	100%	1	710	1	710		
Apr-13	51.4	32947	87382	39098	48284	48284	0	100%	1	711	1	711		
May-13	36.7	23525	71809	39098	32711	32711	0	100%	1	712	1	712		
Jun-13	148.8	95381	128092	39098	88994	80000	8994	100%	1	713	1	713		
Jul-13	17.3	11089	91089	39098	51992	51992	0	100%	1	714	1	714		
Aug-13	9.0	5769	57761	39098	18663	18663	0	100%	1	715	1	715		
Sep-13	83.7	53652	72315	39098	33217	33217	0	100%	1	716	1	716		
Oct-13	66.2	42434	75651	39098	36554	36554	0	100%	1	717	1	717		
Nov-13	47.3	30319	66873	39098	27775	27775	0	100%	1	718	1	718		
Dec-13	107.3	68779	96554	39098	57457	57457	0	100%	1	719	1	719		
Jan-14	9.4	6025	63482	39098	24385	24385	0	100%	1	720	1	720		
Feb-14	9.0	5769	30154	39098	-8944	0	0	77%	0	721	1	721		
Jun-14	90.5	58011	58011	39098	18913	18913	0	100%	1	722	1	722		

Table A9-3. Aggregate RWH potential of the target communal buildings of each target village in relation to meeting current and future village drinking water demands.

Village	Population	RWH capacity under current catchment conditions (L/p/d)	RWH capacity with roof improvements (L/p/d)	RWH with roof improvements with improved storage of 20,000 L at each building (L/p/d)
Aoniman	2010 (123)	0.6	5.3	8.4
	2030 (89)	0.84	7.5	11.5
Autukia	2010 (188)	0.31	1.85	3.4
	2030 (117)	0.57	3	3.8
Nuka	2010 (443)	0.44	2	2.9
	2030 (433)	0.45	2	3
Tabiang	2010 (399)	0.23	1.75	2.5
	2030 (328)	0.28	2.1	3.2
Teteirio	2010 (79)	0.81	1.7	2.5
	2030 (102)	0.63	1.3	1.9
Rongorongo	2010 (190)	0	0	9
	2030 (79)	0	0	21

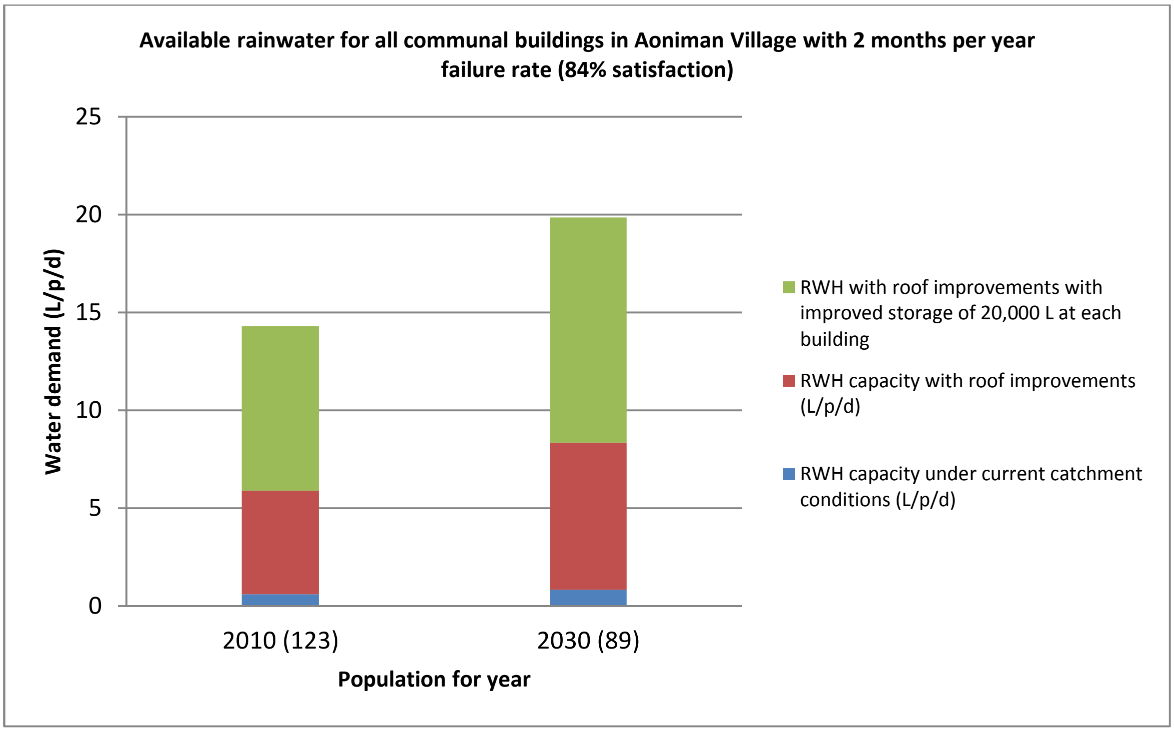


Figure A9-1. Available rainwater for the target communal buildings in Aoniman Village.

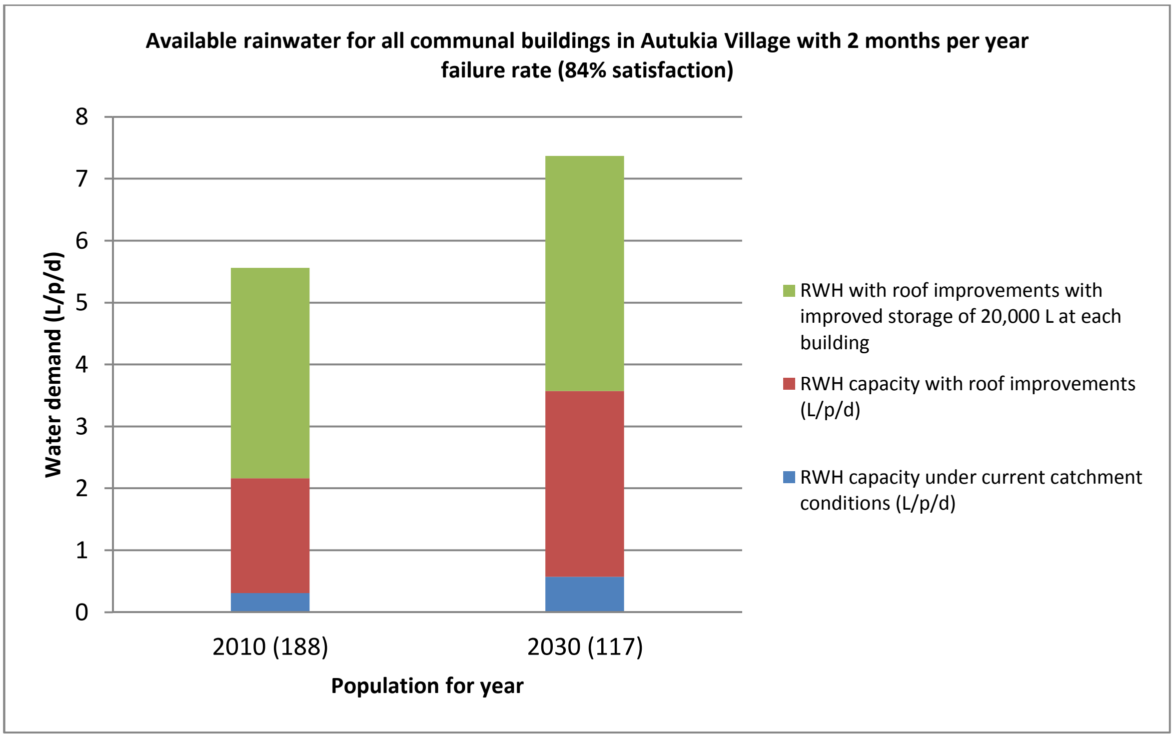


Figure A9-2. Available rainwater for the target communal buildings in Autukia Village.

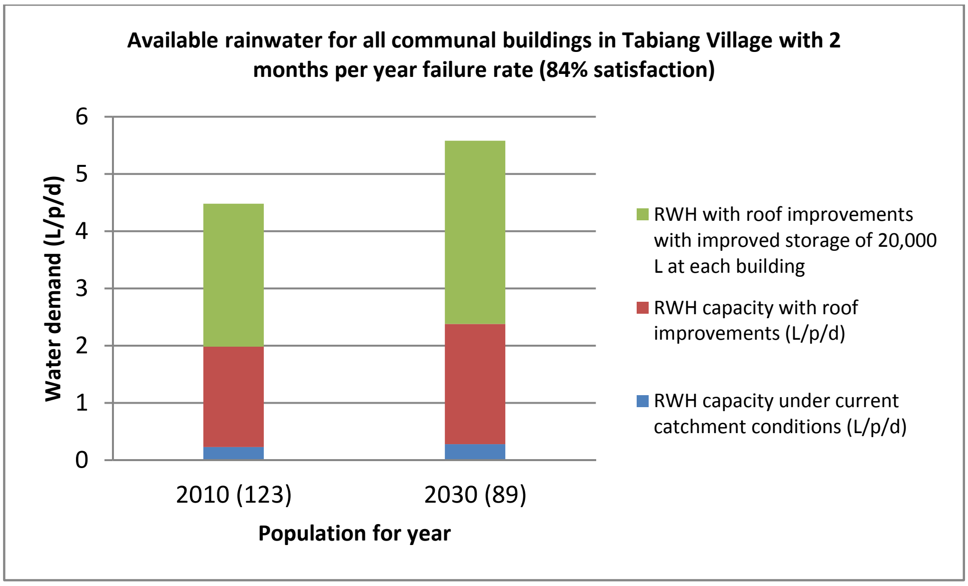


Figure A9-3. Available rainwater at the target communal building for Tabiang Village.

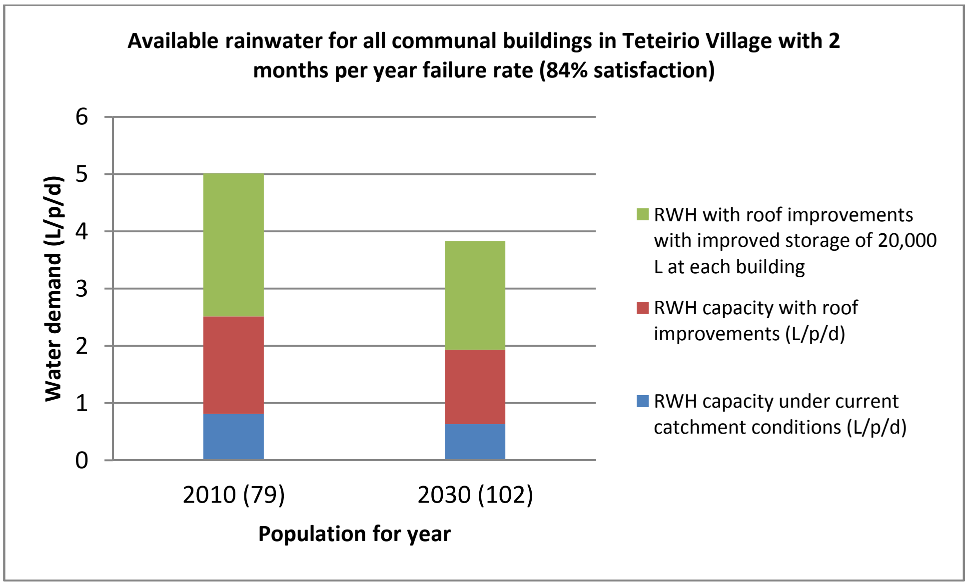


Figure A9-4. Available rainwater at the target communal building for Teteirio Village.

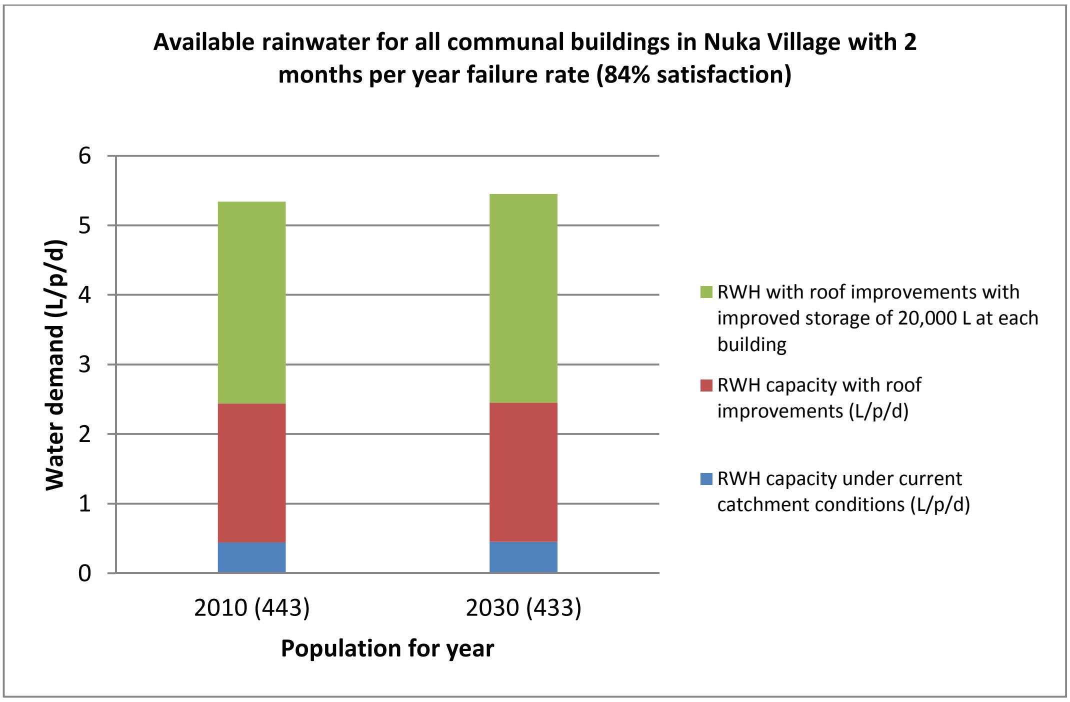


Figure A9-5. Available rainwater at the target communal buildings for Nuka Village.

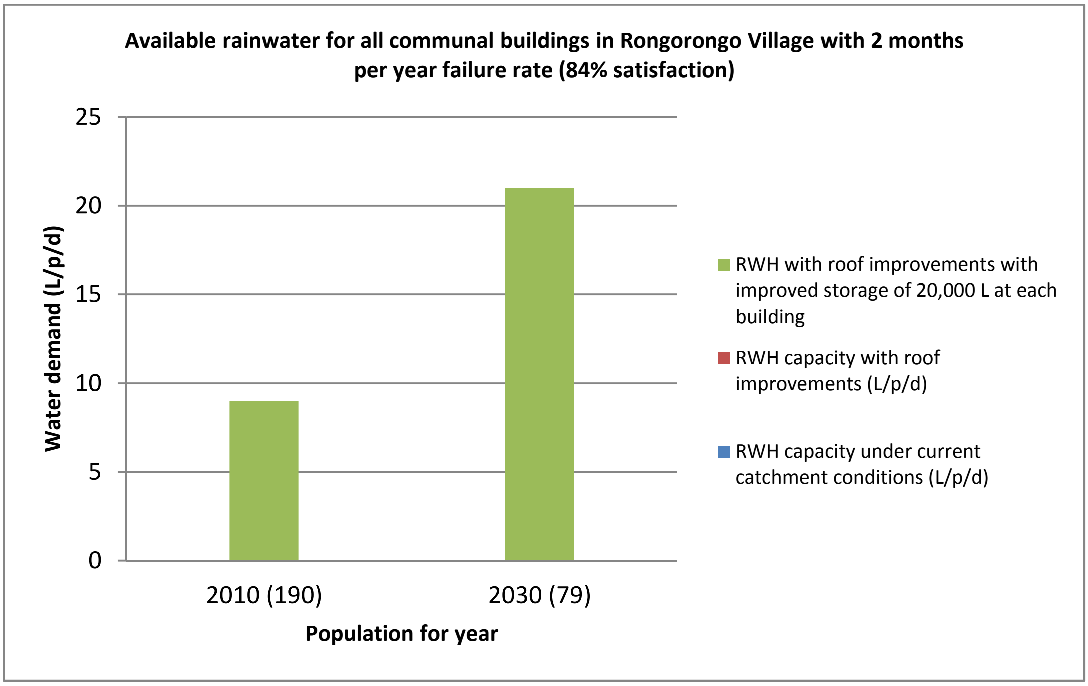


Figure A9-6. Available rainwater at the target communal buildings for Rongorongo Village.

Table A9-4. Analysis of varying roof catchment area (improved condition) with increasing storage volume (L) based on a fixed demand of 100 people at a 2-months per failure rate (or 84% satisfaction).

Roof Catchment	5000	10,000	15,000	20,000	25,000	30,000
50 metre squared catchment projected demand	0.95	1.14	1.25	1.4	1.5	1.55
100 metre squared catchment projected demand	1.55	1.9	2.1	2.25	2.4	2.5
150 metre squared catchment projected demand	2.1	2.5	2.8	3	3.2	3.35
200 metre squared catchment projected demand	2.6	3.1	3.5	3.8	4	4.2
250 metre squared catchment projected demand	3	3.6	4.1	4.5	4.7	5
300 metre squared catchment projected demand	3.5	4.1	4.7	5.1	5.4	5.6
350 metre squared catchment projected demand	4	4.6	5.2	5.6	5.9	6.2
400 metre squared catchment projected demand	4.4	5.2	5.8	6.3	6.7	6.9
450 metre squared catchment projected demand	4.9	5.7	6.3	6.8	7.2	7.5
500 metre squared catchment projected demand	5.3	6	6.6	7.3	7.8	8.1

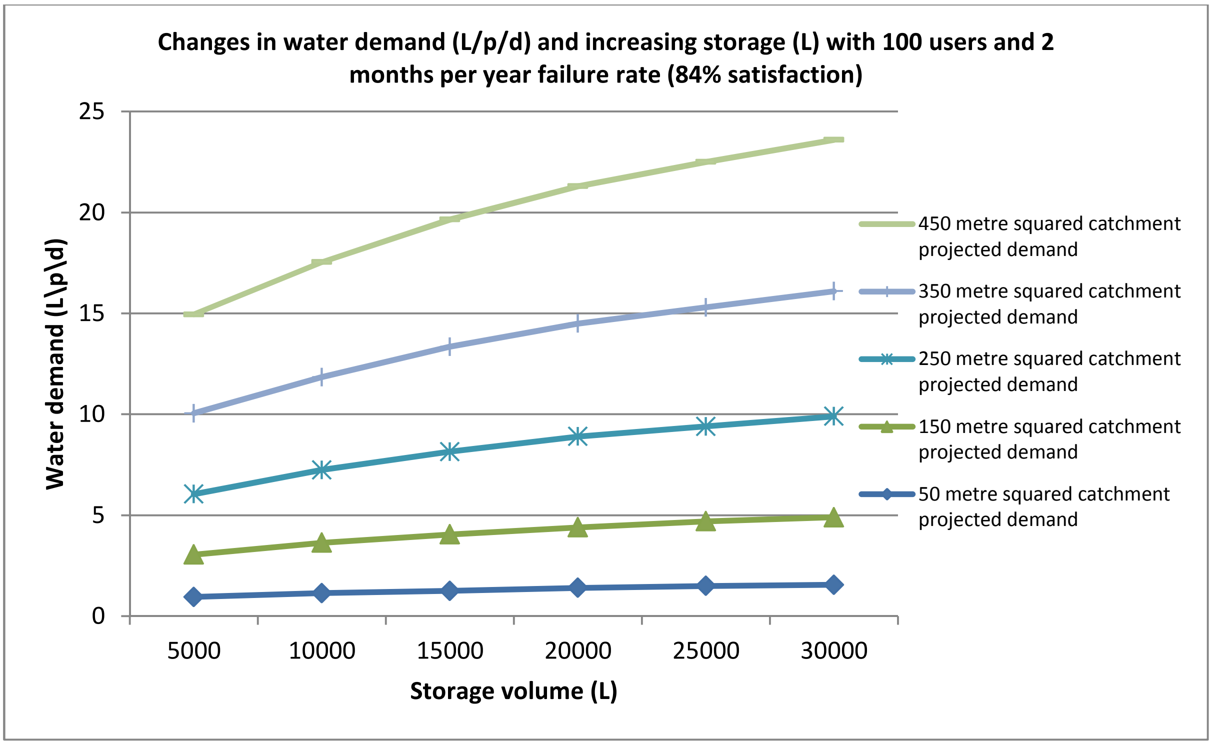


Figure A9-7. Analysis of changing water demand on varying roof catchment area based on a fixed number of users and 84% satisfaction.

Annex 10

Village Meeting Notes from Beru

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

Table A10-1. Summary of key discussion areas at consultation meetings at the target villages.

Village	Summary of discussion points
Autukia 29/11/2013	Village groups: • show concern with high E.coli contamination • agree with the need to have communally-owned system to address long-term operation and maintenance issues • assured of village support, in terms of land access and labour, during assistance stage • requested more distribution tanks and tap stands
Tabiang 29/11/2013	Village groups: • show concern with high E.coli contamination • agree with the need to have communally-owned system to address long-term operation and maintenance issues • assured of village support, in terms of land access and labour, during assistance stage • requested more distribution tanks and tap stands
Aoniman 29/11/2013	Village groups: • show concern with high E.coli contamination • acknowledged the limited groundwater potential underlying the village • if a communal source can be located near Nuka or Tabiang, the village prefers the use of solar pump for abstraction purpose • agree with the need to have communally-owned system to address long-term operation and maintenance issues • assured of village support, in terms of land access and labour, during assistance stage • requested more rainwater harvesting facilities and storage tanks
Nuka 30/11/2013	Village groups: • show concern with high E.coli contamination • agree with the need to have communally-owned system to address long-term operation and maintenance issues • assured of village support, in terms of land access and labour, during assistance stage • villages request three systems to cater for the northern, central and southern segments, with solar pump as the preferred abstraction method • requested more rainwater harvesting facilities and storage tanks for KPC church, Catholic church and adjacent schools
Teteirio 30/11/2013	Village groups: • show great concern with high E.coli contamination, particularly with the village well, which is closely located to a pit toilet • agree with the need to have communally-owned/managed system and are willing to relocate the current source towards the island's central • assured of village support, in terms of land access and labour, during assistance stage • requested more rainwater harvesting facilities and storage tanks for KPC church
Taubukiniberu 30/11/2013	Village groups: • show great concern with high E.coli contamination, particularly with the village well, which is closely located to a pit toilet • agree with the need to have communally-owned/managed system and are willing to relocate the current source towards the island's central • assured of village support, in terms of land access and labour, during assistance stage • requested more rainwater harvesting facilities and storage tanks for council buildings

Annex 11

Selected Survey Photos from Beru

This annex presents selected photos captured during the water resources assessment (WRA) and is intended to show the status and/or condition of water supply infrastructure in Beru at the time of the assessment (18 November to 2 December 2013).

Figure A11-1. A covered communal well, abstracted by hand pump, Autukia Village.

Figure A11-2. Well using both concrete rings and coral rocks as casing materials.

Figure A11-3. Multiple Tamana *pump distribution lines from a communal well.*

Figure A11-4. Example of an uncased well in Autukia Village.

Figure A11-5. **Tamana** ***pump used in Tabiang Village.***

Figure A11-6. A partially buried well accessed by **Tamana** ***pump and using PVC pipe***

Figure A11-7. Example of timber fencing to regulate access to wells.

Figure A11-8. Catholic Church in Aoniman Village – a potential RWH centre.

Figure A11-9. KPC* maneaba *in Aoniman Village, a target RWH communal building.

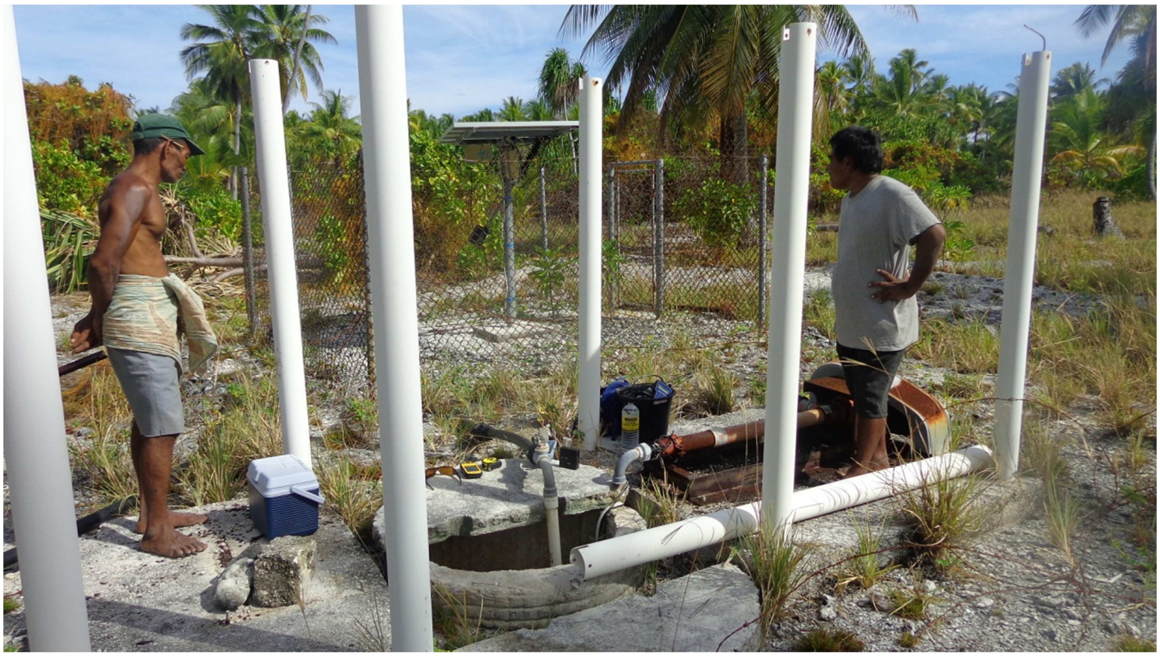


Figure A11-10. Solar pump system at Hiram Beigham High School serving the entire school and Rongorongo Village community. Note the new solar panel separately fenced in the background for security.

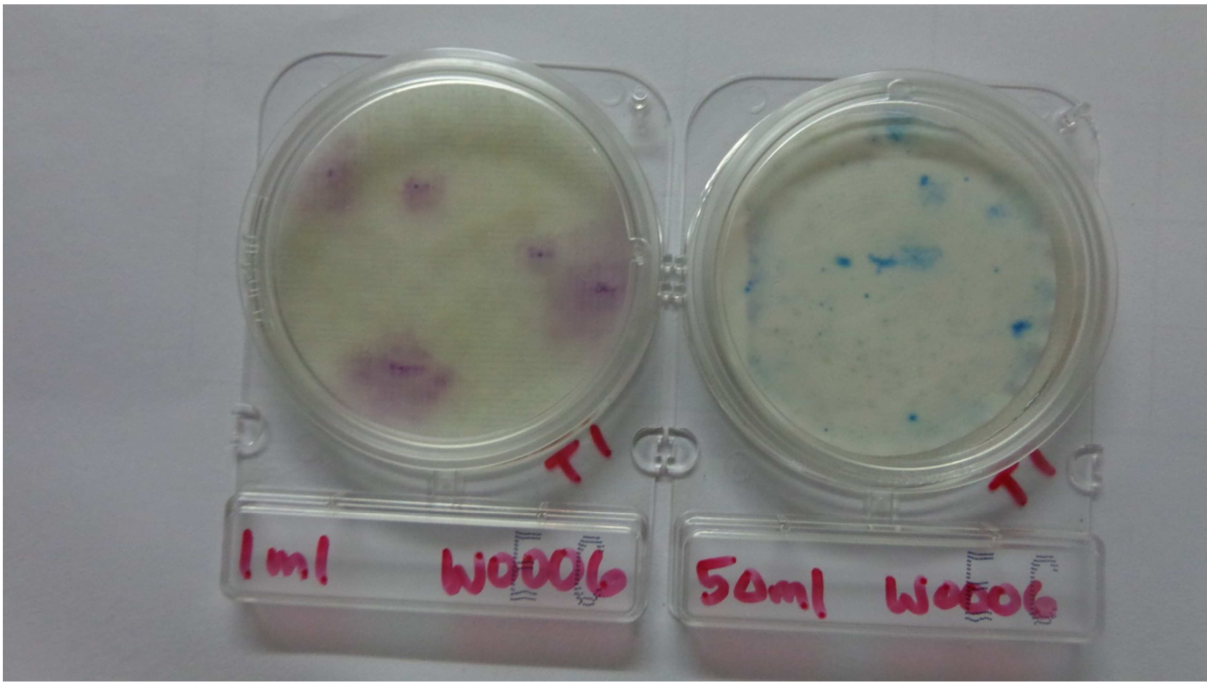


Figure A11-11. Example of compact dry plate of a groundwater well sample from Aoniman Village.

Figure A11-12. Villagers in Tabiang looking at WRA maps during the consultation meeting.

Figure A11-13. Villagers of Nuka listening to the survey team's presentation during the consultation meeting.

Figure A11-14. Villagers of Teteirio looking at images of the E.coli contamination of sampled well and rainwater tanks from around the village.

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