KIRIWATSAN Water Resources Assessment
Abaiang Island, Kiribati

Aminisitai Loco, Amit Singh, Martin Mataio, Eritateti Bwatio, Peter Sinclair

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KIRIWATSAN
Water Resources Assessment

ABAIANG ISLAND, KIRIBATI

Secretariat of the Pacific Community, Suva

February 2015

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Abbreviations and symbols

ADB	Asian Development Bank
AUD	Australian dollars
CV	Coefficient of Variation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EC	Electrical conductivity
EDF	European Development Fund
EM	electromagnetic
ENSO	El Niño – Southern Oscillation Index
GoK	Government of Kiribati
HYCOS	Hydrological Cycle Observation System
IC	Island Council
JSS	Junior Secondary School
KIRIWATSAN I	Kiribati Water and Sanitation Phase 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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- Ministry of Public Works and Utilities, particularly the Water Engineering Unit for permitting the use of its EM34 survey equipment and for providing staff support and ensuring that all cultural protocols on the island were followed.
- 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 Abaiang for allowing us access to their land and for their generous hospitality during our stay.

1.0 EXECUTIVE SUMMARY

As part of the EDF10 KIRIWATSAN I Project, Abaiang Island was visited between 8th and 22nd March, 2013 for water resources assessment. The survey was conducted at Ribono islet, Tebunginako, Aonobuaka, Ewena, Tuarabu and Taniau, 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.

One hundred and seventy (170) permanently roofed buildings were surveyed for rainwater harvesting potential and improvements. Of these, thirty seven (37) 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 ninety one (291) wells were assessed for infrastructural status and groundwater quality. The assessment of water table depth and salinity showed an average of 1.44 mbgl and 1.46 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 Colilert-18 presence and absence procedure, indicated the presence of E.coli bacteria in more than 90% of the sampled wells and rainwater tanks. Tests for nitrate indicated a low level of contamination. To ensure the protection of wells and improved groundwater quality in the short and medium term, the following are suggested:

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

- Use of 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. All the villages showed substantial freshwater lens thickness; with reserves capable of supporting the current population’s water demand during projected droughts in all but two villages. Ribono Islet is unlikely to support its water demand, whilst Ewena is likely to experience severe groundwater shortage due to its vulnerability to salinisation during dry periods.

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 Ewena, 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 Abaiang Island, under component 1 of the KIRIWATSAN Phase I Project.

- Field investigations for Abaiang Island were undertaken from 8th to 22nd March 2013. The assessment was conducted in 6 target villages: Ribono, Tebunginako, Aonobuaka, Ewena, Tuarabu and Taniau/Tebwanaga, and included: a survey of 170 buildings to assess the existing and potential rainwater harvesting systems.
- A survey of two hundred and ninety-one (291) 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 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 Abaiang Island.

2.2 Survey team and schedule

The survey team for Abaiang included Amini Loco and Amit Singh from the SOPAC Division of the Secretariat of the Pacific Community (SPC), Martin Mataio and Eretateti Bwatio from the Water Engineering Unit (WEU) of the Ministry of Public Works and Utilities (MPWU), and the Abaiang Island Water Technician, Matanterawa Tebaai. 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

Abaiang Island, located between longitudes 172°45'E and 173°05'E and latitudes 1°40'N and 1°60'N, is part of the Gilbert Group and situated immediately north of North Tarawa (Figure 1). The NW-SE trending atoll island has a land area of approximately 17.5 km^2 (National Statistics Office, 2012), with the island widths ranging from 150 to 800 m, and ground-surface elevation not exceeding a few metres. The island has several inhabited islets on the western and northern margin, including Ribono and Nuotaea.

Most villages are scattered in a linear pattern along the lagoon shoreline, while the islet villages have a compact village arrangements. Vegetation on the island includes coastal strand vegetation, mangroves, coastal marsh vegetation and inland atoll forests. Coconut palms and swamp taro *(bwabwai*) play important roles in agricultural activities mainly because copra is the major cash crop in the villages, whilst *bwabwai* has a special place as traditional food. The summary of the locations and additional descriptions of the 6 target villages are presented in Table 1. The target villages are: Ribono, Tebunginako, Aonobuaka, Ewena, Tuarabu and Taniau.

There are eighteen (18) villages on Abaiang Island, with two settlements Ribono and Nuotaea on islets. Two villages have changed their names in recent years: Kuria is now called Ewena, and Tebwanga is now called Taniau. Figure 2 is a map showing locations of the target villages.

Table 1. Summary of locations and descriptions of the target 6 villages. (Source: National Statistics Office)

Village	Population National Statistics Office (2012)	Population density pers/km^2	Land Area (m^2)	Description
Ribono	341	484	704,700	A NE-SW trending islet located north of Abaiang, with the village compacted on the SW end near the coast and on the lagoon side. The maximum islet width is ~ 600 m.
Tebunginako	424	409	1,035,700	The village is concentrated around the coastal area and is experiencing active coastal inundation on the west. The maximum island width around the village is ~ 700 m.
Aonobuaka	328	274	1,196,300	The village is concentrated on the coastal area of the lagoon, with a maximum island width of 500 m. Abaiang Junior Secondary and Wakaam Primary School are also located within the village boundary.
Ewena	166	379	437,500	The SE-NW trending village is the smallest target village located immediately north of the council area at Taburao and has the maximum island width of ~ 200 m.
Tuarabu	560	367	1,527, 300	The N-S trending village is the biggest of the surveyed villages and is located around Abaiang central. The village has a maximum width of ~ 700 m, with a number of schools and the island airstrip also located within the village boundary.
Taniau/ Tebwanga	310	350	884,700	The E-W trending village, concentrated on the coastal area of the lagoon, is located towards the south of Abaiang atoll. The maximum island width around the village is ~ 400 m.

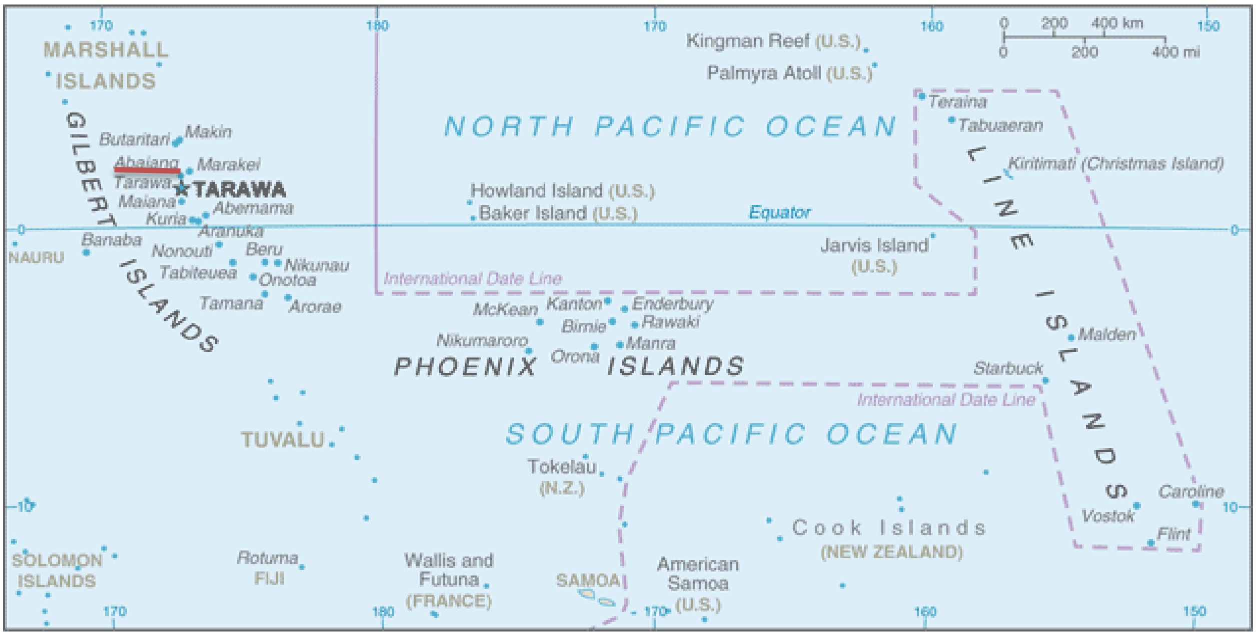

Figure 1. Location map of Abaiang Island in the Gilbert Islands Group.
Source: https://www.cia.gov/library/publications/the-world-factbook/geos/kr.html

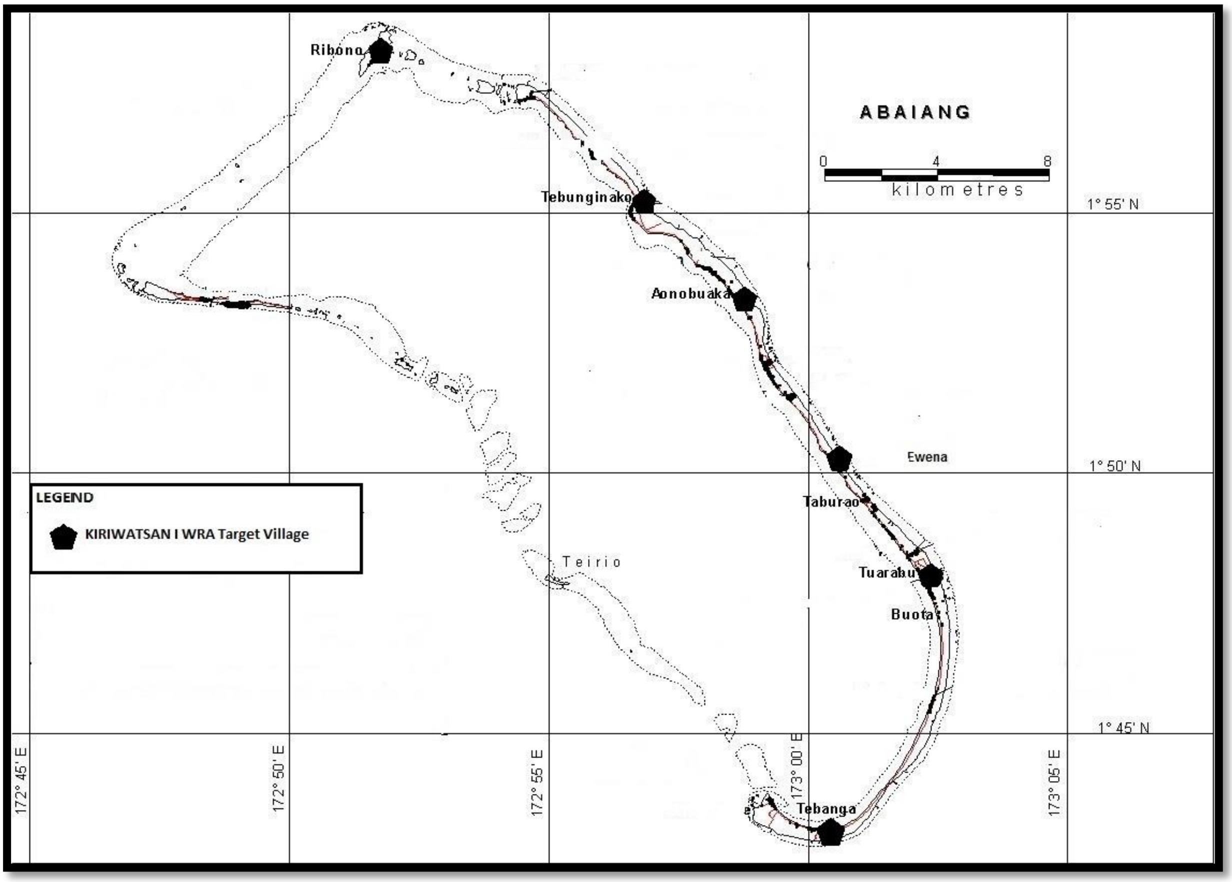

Figure 2. Locations of KIRIWATSAN 1 water resources assessment (WRA) target villages (Map Source: Abaiang Island profile, UNICEF 2012 profiling report).

Population on the island over the last two decades has, according to census data, fluctuated considerably between villages and over time. Significant population increase was recorded from 1990 to 1995, reaching a maximum population (6020) recorded in 1995. Since 1995 there has been a decline in island population, which has stabilised in recent years, with a total of 5502. 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.

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.

3.2 Rainfall Analysis

Monthly rainfall data for Abaiang is available from 1904 with gaps. The bulk of the complete rainfall (20 years) data is within the period from 1951 to 1973. Some records are available from 1974 until 1988 (14 years), with rainfall records mostly unavailable from 1989 to 2000 (11 years). Records were kept from 2000 - 2003 before records again ceased until 2011 when rainfall records were again kept until now. Daily rainfall records are mostly available from the manual rainfall stations installed under the joint support of the EU-funded Hydrological Observing Systems (HYCOS Project, 2006-2010) and the Kiribati Adaptation Program (KAP).

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

Table 2. Population data for Abaiang 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
Nuotaea	458	558	538	481	559	4.4%	-0.7%	-2.1%	3.2%	1.2%	692
Ribono	**286**	**299**	**265**	**271**	**341**	**0.9%**	**-2.3%**	**0.5%**	**5.2%**	**1.1%**	**414**
Takarano	350	360	322	300	348	0.6%	-2.1%	-1.4%	3.2%	0.1%	353
Ubanteman	116	142	119	112	126	4.5%	-3.2%	-1.2%	2.5%	0.6%	142
Tebunginako	**458**	**420**	**379**	**358**	**424**	**-1.7%**	**-2.0%**	**-1.1%**	**3.7%**	**-0.3%**	**402**
Borotiam	343	294	286	338	375	-2.9%	-0.5%	3.6%	2.2%	0.6%	420
Aonobuaka	**281**	**325**	**295**	**372**	**328**	**3.1%**	**-1.8%**	**5.2%**	**-2.4%**	**1.0%**	**396**
Koinawa	370	401	460	453	312	1.7%	2.9%	-0.3%	-6.2%	-0.5%	282
Morikao	247	534	546	400	233	23.2%	0.4%	-5.3%	-8.4%	2.5%	349
Ewena	**202**	**193**	**192**	**219**	**166**	**-0.9%**	**-0.1%**	**2.8%**	**-4.8%**	**-0.8%**	**141**
Taburao	207	185	91	221	322	-2.1%	-10.2%	28.6%	9.1%	6.4%	731
Tebero	132	149	197	167	157	2.6%	6.4%	-3.0%	-1.2%	1.2%	194
Tabwiroa	364	390	391	324	237	1.4%	0.1%	-3.4%	-5.4%	-1.8%	150
Tuarabu	**522**	**684**	**607**	**484**	**560**	**6.2%**	**-2.3%**	**-4.1%**	**3.1%**	**0.8%**	**645**
Tanimaiaki	207	251	239	276	274	4.3%	-1.0%	3.1%	-0.1%	1.6%	360
Taniau	**283**	**448**	**361**	**287**	**310**	**11.7%**	**-3.9%**	**-4.1%**	**1.6%**	**1.3%**	**392**
Aoneaba	128	56	81	48	51	-11.3%	8.9%	-8.1%	1.3%	-2.3%	27
Tabontebike	279	331	425	391	379	3.7%	5.7%	-1.6%	-0.6%	1.8%	515
Total	**5233**	**6020**	**5794**	**5502**	**5502**	**3.0%**	**-0.8%**	**-1.0%**	**0.0%**	**0.3%**	**5846**

The population trend from 1931 to 2010, indicates a steady growth recorded between 1963 and 1968, stabilising in the last 10 years (Figure 3).

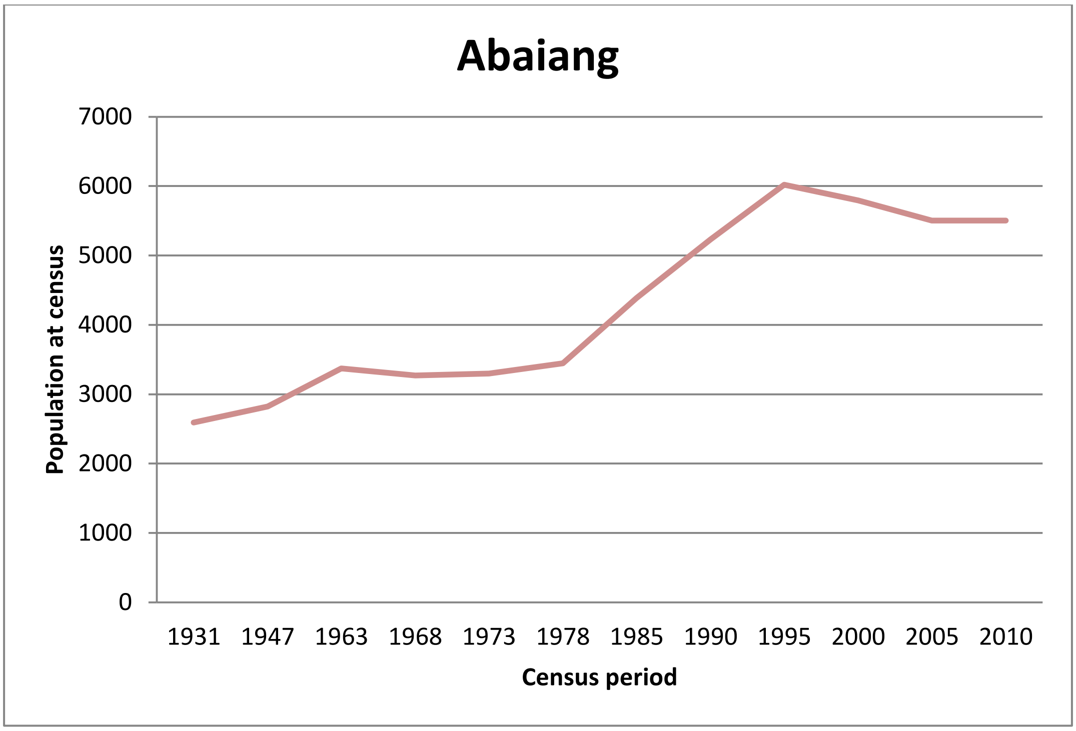

Figure 3. Population growth on Abaiang Island 1931 - 2010 (Source: National Statistics Office).

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

- Betio, South Tarawa
- Butaritari
- Beru

The available monthly rainfall data for Abaiang is compiled with data from the Kiribati Meteorological Service with some gaps filled by Taylor (1973), 'An Atlas of Pacific Islands Rainfall', and non-meteorological rainfall stations, from Morikao School. The climate data is summarised in Table 3 and the monthly records as Annex 2. The maximum monthly rainfall during this period occurred in January 1970, reading 761 mm; with zero monthly rainfall recorded for all months except for the months of April, May June and July. Abaiang, as with other islands within the Gilbert Group, have on average a 5-month 'wetter' December to April period, and higher mean rainfall, followed by a 7-month 'drier' May to November period, with lower mean rainfall. Comparison between the mean and the median values shows that the rainfall distribution is positively skewed towards higher rainfall. The variability of monthly rainfall is moderate between wet and dry seasons. It is noted that rainfall in July is on average slightly higher than surrounding months possibly due to some high rainfall events in 1958, 1965, 1969, 1982 and 1987 (Annex 2).

Table 3. Statistics of monthly rainfall in Abaiang for the period 1950-2014 (with gaps).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean	257	206	208	188	171	160	201	151	142	124	146	233	**2184**
Std Dev	202	176	174	126	116	114	142	118	127	113	123	139	**833**
CV*	0.79	0.85	0.84	0.67	0.68	0.71	0.71	0.78	0.89	0.92	0.84	0.60	**0.38**
Max	761	700	706	513	601	488	587	458	469	402	589	507	**4,568**
Min	0	0	0	5	6	12	14	0	0	0	0	0	**849**
Median	216	166	174.5	165	138.7	131	159.5	92	121	85.5	106	206.5	**2,003**
No. of years	45	47	50	49	48	44	42	43	43	46	47	42	**33**

CV*: Coefficient of variation = standard deviation/mean

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

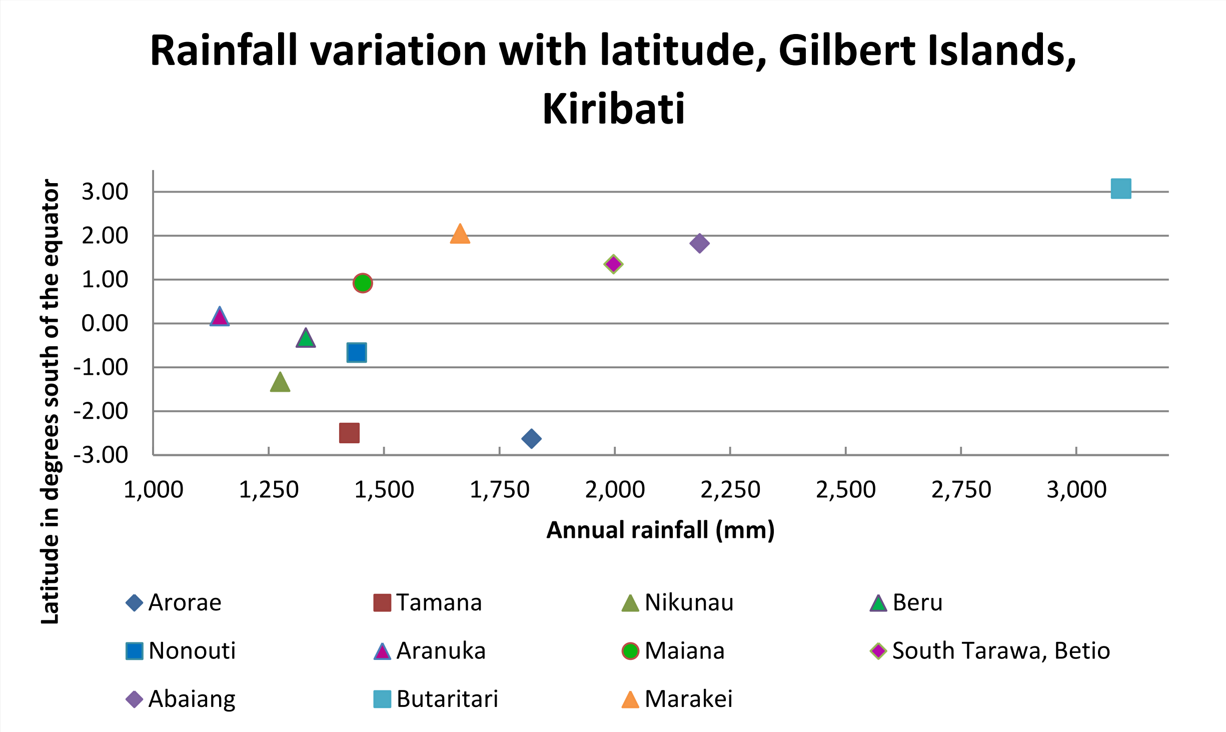

Figure 4. Mean annual rainfall (1950- 2014) variation with latitude for the Gilbert Islands group.

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

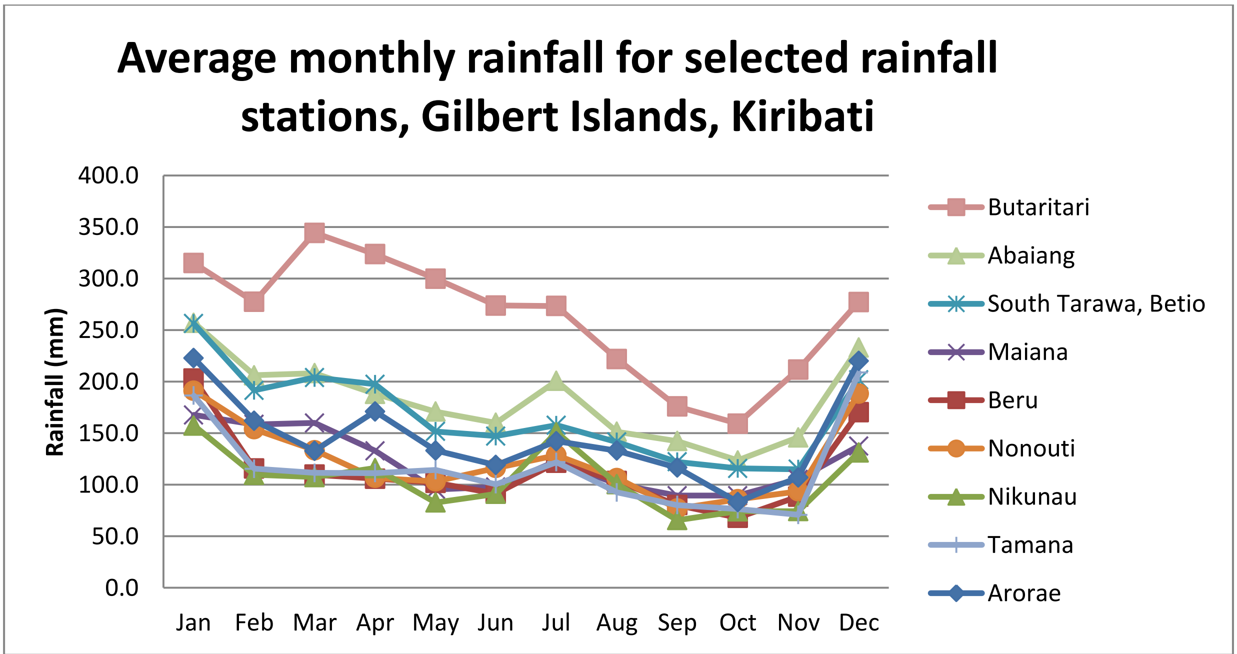

Figure 5. Variation in monthly rainfall for selected islands 1945-2014 (available records). Generally, the months from May to November are considered the driest months whilst the months from December to April, the wetter months, for Gilbert Islands.

Table 4. Annual rainfall (mm) 'drier' May to November (7 months) and 'wetter' December to April (5 months) seasonal rainfall statistics for Abaiang 1950 to 2014.

Statistic	Annual	May-Nov	Dec-Apr
Mean	2184	1114	1070
Std Dev	833	532	504
CV	0.38	0.48	0.47
Max	4568	2186	2382
Min	849	165	192.1
Median	2003	1099	1031
No. Years	33	33	33

It is noted that the 'drier' 7 months from May to November for Abaiang received slightly more rainfall than the 'wetter' 5 months from December to April for the period 1950-2014.

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 CV the greater the range of variability in rainfall and the greater the departure from the long-term annual average rainfall that can be expected. A lower CV indicates a lesser range of variability in rainfall and greater confidence in receiving a rainfall for any given year close to the long-term annual average. The CV of rainfall can be considered as an index of risk, the higher the CV, the higher the risk that rainfall will be less reliable. Because CV considers deviations from averages, it can be used for relative comparisons of variability within and between regions.

The CV for Abaiang is 0.38 indicating that rainfall in any one year, for about 68% of the time, can be expected to vary ±38% from the long-term annual average rainfall of 2,184 mm.

The Abaiang CV of 0.38 indicates a moderately 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 rainfall is even less reliable with consideration to any particular season. This is an important consideration in the assessment of water security especially with regard to reliance on rainwater harvesting.

The relatively large gaps in the Abaiang rainfall dataset precludes further analysis of the rainfall data. Tarawa is the closest station with good quality long-term data and a comparison between the two datasets indicates that rainfall is on average 12% higher than 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 Abaiang.

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

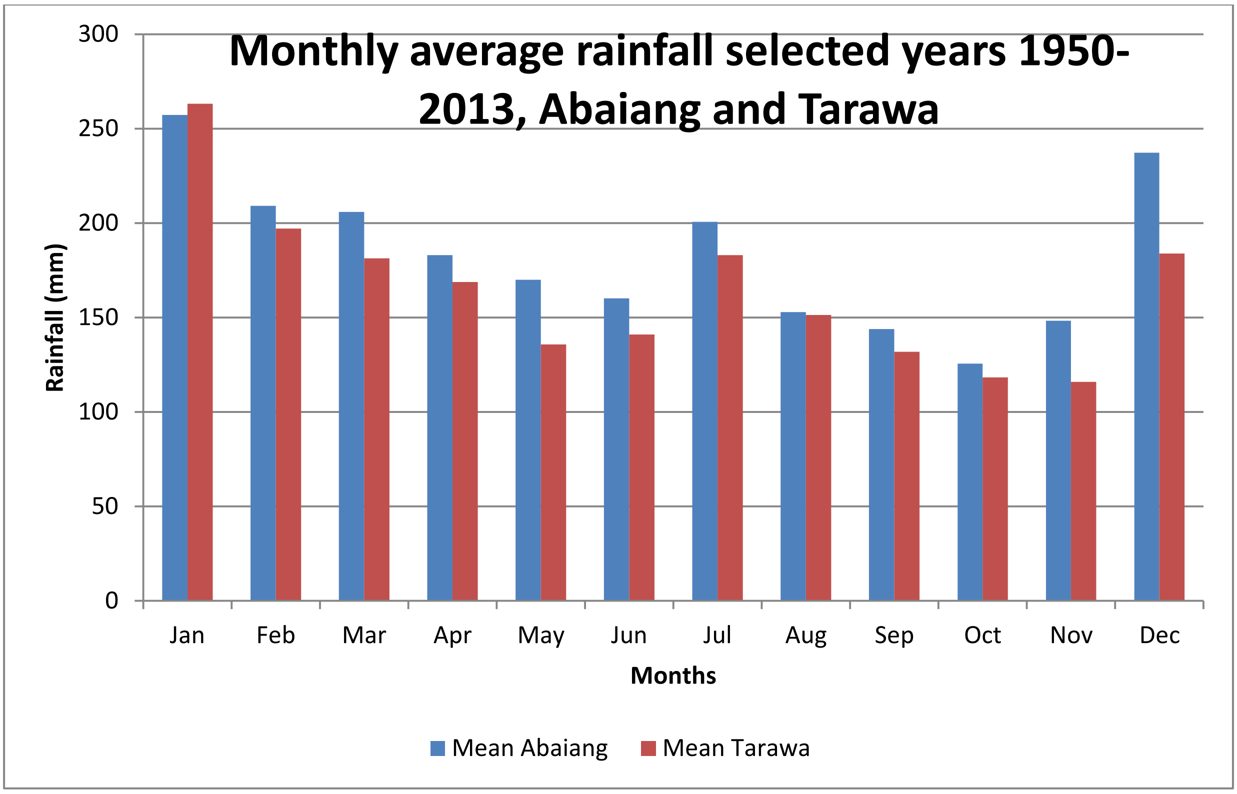

Figure 6. Average monthly rainfall for common years between Abaiang and Tarawa for the period 1950-2013.

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).

3.3 Geology and Hydrogeology

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

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

The occurrence of freshwater underlying atoll islands like Abaiang 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 (2004) 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.

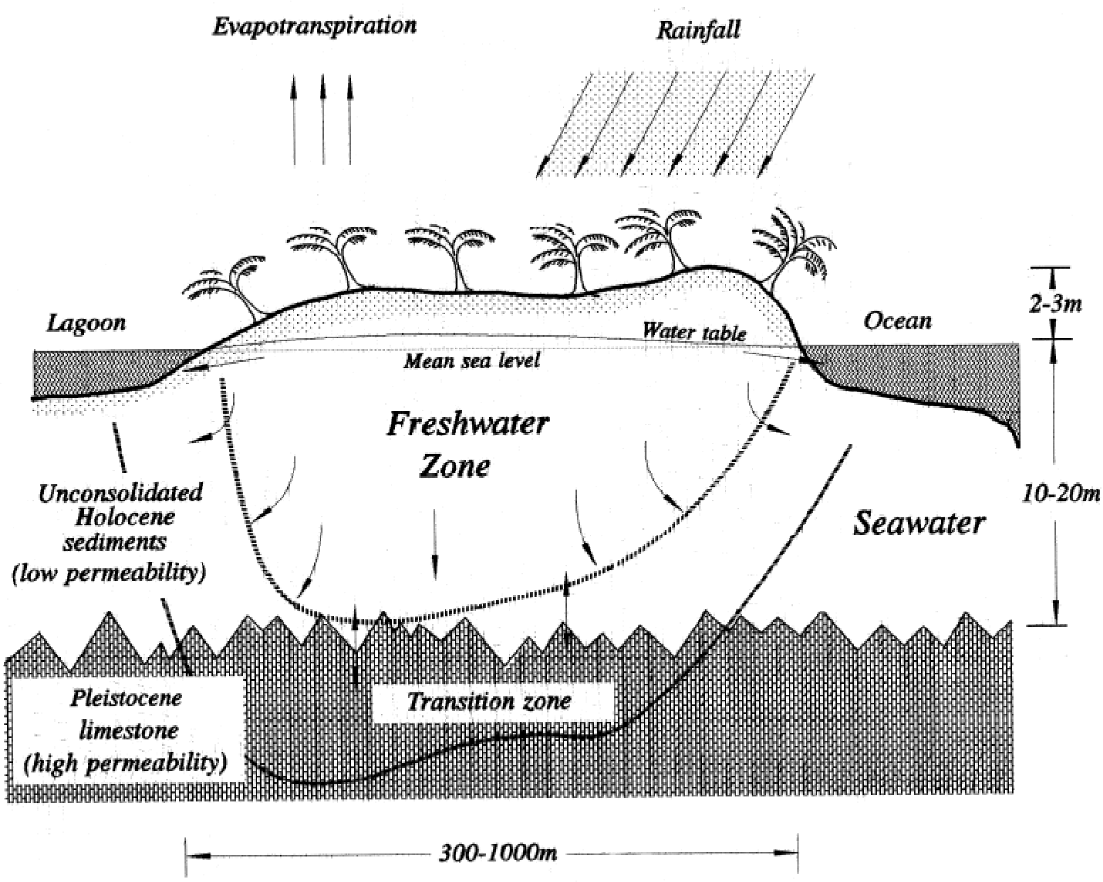

Figure 7. Freshwater lens configuration typical in atoll environments like Abaiang Island (Falkland 2003).

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 Abaiang (2184 mm), the estimated mean annual recharge for Abaiang was 808 mm, which accounted for an estimated 37% of annual rainfall.

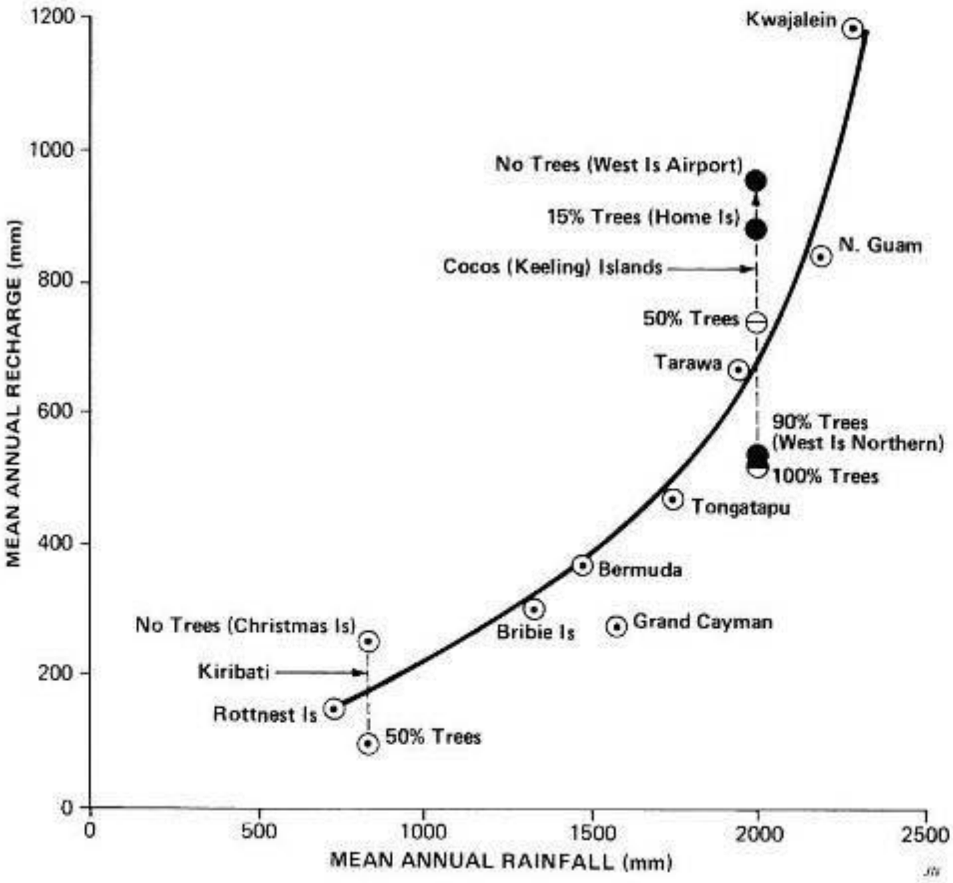

Figure 8. Annual rainfall – recharge relationship for a few studied small islands (UNESCO 1991).

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 Abaiang with a mean annual rainfall of approximately 2184 mm and an estimated mean annual recharge of 808 mm with 37% of rainfall; a conservative preliminary sustainable yield of 27% of annual recharge is determined which correlates with the estimated sustainable yield for Abaiang by Falkland (2003), of 28% 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.

3.4 Water supply and sanitation

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

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

Village	Main source of drinking water 2010					Total
	Rainwater tank	Pipe system (PUB)	Open well water	Protected well water	Other	
Nuotaea	1	0	33	49	2	**85**
Ribono	1	0	53	0	0	**54**
Takarano	0	0	59	3	0	**62**
Ubanteman	0	0	23	1	0	**24**
Tebunginako	1	0	68	1	0	**70**
Borotiam	1	0	60	0	0	**61**
Aonobuaka	0	0	42	11	0	**53**
Koinawa	4	0	22	27	0	**53**
Morikao	4	0	3	29	1	**37**
Ewena	2	0	25	5	0	**32**
Taburao	3	0	38	10	0	**51**
Tebero	1	0	23	6	0	**30**
Tabwiroa	3	0	15	14	0	**32**
Tuarabu	5	0	84	9	0	**98**
Tanimaiaki	0	0	44	1	0	**45**
Taniau/Tebwanga	1	0	30	33	0	**64**
Aoneaba	0	0	4	4	0	**8**
Tabontebike	6	0	31	30	0	**67**
Total	**33**	**0**	**657**	**233**	**3**	**926**

The 2010 census also indicates that **70% of households on Abaiang practice open defecation** – beach (631) and bush (14). Flush toilets (252), including pour-flush, is increasingly being used and account for 27% of households, whilst the sea (20) and pit latrines (8), are the least practised sanitation options accounting for 3% of the sanitation practices for households (Table 6).

Table 6. Sanitation systems in use on Abaiang. (National Statistics Office, 2012).

Census year	Flush PUB	Flush Own	Latrine	Atolette	Beach	Bush	Sea	No. Households
2005	0	37	162	19	687	413	380	853
2010	0	252	6	2	631	14	20	926

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

Falkland (2003) undertook an inspection of the water supply systems in most settlements in Abaiang, providing a summary of the status of the water supply systems at the time of that inspection. As part of the water resources assessment, an update of the status of the water supply systems for the target villages under KIRIWATSAN I has been undertaken and the original table updated for those systems inspected (Table 7).

Table 7. Updated water supply systems summary table (after Falkland 2003).

Village / School	General Description of the Water Supply System Falkland 2003	Condition of the Water Supply Falkland 2003	Condition of the Water Supply 2013
Nuotaea	Combination of private and communal wells. Communal system consists of a solar pump at a gallery away from the village and several hand pumps (5) on wells near houses. Distribution system consists of 63 mm PE pipe feeding two concrete tanks which feed communal taps (16). Private wells located in the village.	Original solar pump (1 Hp helical rotor) not working at start of visit but a new (centrifugal) pump was installed. All hand pumps broken. Low salinity water from solar pump.	Not surveyed.
Ribono	Communal system consists of 2 wells and 8 hand pumps.	All hand pumps reported to be broken. Water is sometimes brackish.	Thirty one wells surveyed. Two hand pumps operating, with a primary school solar pump reportedly damaged and panels stolen. Household wells reported to have elevated salinity during dry periods. Four exiting rainwater tanks, 2 attached to the health clinic and 2 attached to the Catholic church, were assessed. The Catholic church has potential for improved rainwater harvesting but may require some infrastructural assistance.
Takarano	Private wells. No communal system.	Low salinity water.	Not surveyed.
Ubanteman	Communal system consists of 2 wells and 7 hand pumps. Solar pump (0.125 hp diaphragm) for primary school at one well. Another non-pumped well. One tank and 6 taps.	All hand pumps broken and distribution pipe partially removed. Solar pump reinstalled at different well near school during visit. Water in wells is brackish in droughts (narrow part of island).	Not surveyed.
Tebunginako	Communal system consists of 2 wells and 7 hand pumps.	All hand pumps broken and distribution pipe partially removed. When working, the well water was reported to have low salinity (was pumped from wide part of island).	Thirty-six wells surveyed dominated by low salinity wells, most of which requiring infrastructural improvement. Catholic church has 3 rainwater tanks but need significant infrastructural improvements. Existing system is reported to be accessed by church members only.

Borotiam	**Private wells. No communal system.**	**Low salinity water.**	**Not surveyed.**
Aonobuaka	Communal system consists of a solar pump (0.125 Hp diaphragm) for primary school, several (9) hand pumps and 2 wells.	Solar pump not working (removed). Hand pumps not working and distribution pipes removed.	Fifty-five wells surveyed (including JSS and Primary School) dominated by low salinity wells, with most wells inadequately equipped. Several communal buildings have good roofing materials and catchment area but require significant infrastructural improvement
Koinawa	Communal system consists of 1 well, 9 hand pumps, 1 tank and 10 taps.	All hand pumps broken. Reported to be low salinity water.	Not surveyed.
Morikao	Communal system consists of 2 solar pumps (1 Hp and 0.33 Hp helical rotor) at one gallery location, 2 tanks and 28 taps.	System working.	Not surveyed.
Ewena	Communal system used to consist of a solar pump (1 Hp helical rotor) at a gallery at Tebero (south of Taburao), 2 tanks and 13 taps.	Solar pump removed due to high salinity and gallery abandoned. Site is too close to ocean beach (original site closer to lagoon not used due to land owner disallowing use of land).	Twenty-two (22) wells surveyed with 7 operational hand pumps. Wells salinity appeared to be moderate to high. Most wells were completely buried and abstracted though hand pumps. Six existing rainwater tanks, 2 for the Kiribati Protestant Church (KPC) church and 4 at the LDS shed, were assessed. The communal buildings show potential for improved rainwater harvesting but may require some infrastructural assistance.
Taburao	Communal system as for Ewena. Well in centre of village and another at hospital.	As for Ewena.	Not surveyed.
Tebero	Private wells. No communal system.	Generally low salinity water, except for one well measured near lagoon which indicated brackish water.	Not surveyed.
Tabwiroa	Communal system for secondary school consists of 3 solar pumps (1 Hp and 0.33 Hp Mono and centrifugal pumps) at one gallery.	System working. Operated by caretaker employed by the school. Low salinity water.	Not surveyed.

Tuarabu	Communal system for primary school consists of a solar pump (0.125 Hp diaphragm) at a well, head tank and 5 taps. Private wells in village.	System at primary school is working. Low salinity water.	Ninety-two (92) wells surveyed (including St Joseph College) with 21 operational hand pumps – most wells are inadequately equipped. Well and rainwater systems at St Joseph College, while operational, need to be rehabilitated due to highly deteriorated condition. Solar pump at secondary school is operational and there are reports of elevated salinity, possibly due to over-abstraction. Primary school solar panel is reported stolen. Forty-one existing tanks were assessed, with several buildings having potential for improved rainwater harvesting.
Tanimaiaki	Private wells. No communal system.	Low salinity water.	Not surveyed.
Tateta	Communal system consists of a solar pump (0.125 Hp diaphragm type) for primary school, 1 tank and 6 taps. One well in school compound.	Solar pump not working (removed as landowner disallowed use of land). Land is narrow and water may have been saline.	Not surveyed.
Taniau/Tebwanga	Private wells. No communal system.	Low salinity water.	Fifty-four (54) wells surveyed with 26 operational hand pumps. Low salinity wells with a handful of wells completely covered and accessed via *Tamana* pumps. Six existing rainwater tanks were assessed, together with the existing buildings. Communal buildings have good roof catchment but require significant infrastructural improvements.
Aoneaba	Private wells. No communal system.	Low salinity water.	Not surveyed.
Tabontebike	Communal system consists of 1 well with 3 suction lines to village, Nikuao guesthouse and KPC compound. Another well supplies water to Fisheries Ice Plant Private wells.	Hand pump to village not working. Low salinity water. Main well close to pig pen.	Not surveyed.

3.5 Previous work

The first of the previous studies undertaken in Abaiang was under the United Nations Capital Development Fund for Outer Islands Community Water Supply project in the 1990s. This entailed the installation of two (2) solar-powered infiltration galleries at Nuotaea Islet and around the council area. Mourits (1995) highlighted that the systems consisted of pumps, elevated storage tanks and distribution pipes and taps stands. It was identified that the success of the water system depended on the effectiveness of the Sanitarian Aide[1] in the island and the availability of spare parts for maintenance. Further, there was a general perception of Government ownership of these water systems and the transfer of these infrastructures to the island council could create conflicts between the council and the village communities, which in turn could result in system breakdowns.

Groundwater investigations were later conducted in 2003, under the Asian Development Bank (ADB) funded project referred to as the "Promotion of Effective Water Management Policies and Practices" (Falkland, 2003 & Falkland, 2004). The assessment, covering all villages except Ribono, included:

- groundwater salinity measurements;
- EM34 geophysical survey to provide freshwater lens estimates;
- water level and salinity data logging;
- sustainable yield estimates; and
- inspection of existing water supply systems.

Findings from the 2003 ADB project work included the following:

- Villages around the narrow part of the island, like Ubanteman, have less groundwater potential and are more likely affected by saline intrusion during droughts. The estimated groundwater thickness, approximately 15 m at Tabwiroa and 18 m at Nuotaea, should be treated with caution as it represents the ground condition at the time of the survey, and will vary, due to the dynamic nature of the lens based on climatic variations.
- EM34 − identified that current and disused galleries are not located at the most suitable sites.
- Groundwater is accessed by either shallow household wells or communal pumping systems. Many households obtain water either by the use of bailers (buckets and containers) or hand pumps
- Communal systems installed in the 1990s − small systems with Southern Cross hand pumps failed.
- Larger communal systems with solar pumps − had some specific problems:
  - Primary schools − diaphragm type pumps − blockages from fine sand.
  - Medium-size helical rotor pumps (Mono CP1600) − OK.
  - Large-size helical rotor pumps (Mono-bare shaft) − problems
- Rainwater, collected in some houses, represents a very small proportion of total water use, as most houses and *maneaba* are built from local materials and have thatched roofs.

[1] Sanitarian Aide was a position previously created for a person on the island who received some salary from the Public Works Department and undertook some training for the construction and maintenance of various component of the UNCDF Project (Mourits, 1995). The position is now absorbed into GoK and now known as the Island Water Technician.

- Many of the water supply systems on the island have failed due to lack of appropriate maintenance, linked back to lack of funding. Also, the current institutional arrangement is such that the operation and management of maintenance is viewed as the responsibility of the Island Council and National Government agencies in Tarawa.
- Current sanitation system, namely pit latrines, is believed to be causing direct contamination into the groundwater. Dry compost toilets are recommended.
- Water-related decisions on the islands include three institutions, namely the Ministry of Public Works and Utilities, the Island Council and the village headman (known as the *unimwane*).
- Women still perform the majority of water-related tasks at a household and community levels.
- The management and protection of water resources and water supply systems are hampered by a lack of:
  - water by-laws;
  - formal training/education of water technicians;
  - village water committees to address water-related matters;
  - communication facilities in the communities; and
  - understanding the interaction between groundwater contamination and sources of pollution.
- There was varied understanding for communal water supply systems, with supporters expecting improved water quality, whilst others oppose such arrangement due to limited control, responsibility and accountability.
- The allocation/arrangement of land for community water supply can be complicated as some –land owners reside outside of Kiribati.
- There is very little awareness on the need for land-use planning to safeguard water supply systems.
- There is mixed view within the community regarding who should be responsible for groundwater water supply maintenance and source protection.
- There is growing concern on climate change, based on frequent inundation events, and associated environmental threats, on vegetation, land resources and water resources.

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 the:

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

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

4.1 Survey methodologies

The assessment methods are as outlined below.

1. Assessment of existing rainwater harvesting infrastructure 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.[2]

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

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 173 buildings were surveyed in the target villages on Abaiang atoll, for assessment on the suitability and potential for rainwater harvesting and its improvements (Table 8). The assessment included:

- effective catchment area and condition;
- transmission type and efficiency;
- storage condition and dimensions; and
- an assessment of the contamination potential.

The main groups of buildings were:

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

   The following schools were surveyed:

   - Taiwan Primary School (near Tebunginako Village);
   - Wakaam Primary and Abaiang JSS (Aonobuaka Village); and
   - St Joseph College and St Paul Primary School (Tuarabu Village).

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

2. **Churches**

Both Kiribati Protestant Church (KPC) and Catholic Church (the main religious denominations) buildings were surveyed for their existing RWH status and potential. Sixteen (16) 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, guttering, down pipe, tanks and taps.

3. ***Maneaba***

Eighteen (18) *maneaba* (including 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.

4. Village clinics

The three newly constructed village health clinics at Ribono, Tebunginako, and Taniau 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 8. Summary of surveyed buildings in the target villages.

Village	Ribono	Tebunginako	Aonobuaka	Ewena	Tuarabu	Taniau
Number of buildings surveyed	4	12	26	9	108	14
Buildings with proper roofing materials	3	3	15	6	62	8
Buildings with no fascia board	1	9	15	4	55	7
Buildings with no guttering	1	9	12	3	43	7
Buildings with no down pipes	2	11	21	3	65	11
Buildings with overhanging vegetation	2	5	11	4	71	5
Buildings with tanks	2	2	7	5	28	3

It was assessed that:

- 56% of the buildings have good roof conditions – with the remaining 44% requiring minor repairs to total replacement of roofs.
- 53% of the suitably roofed buildings do not have fascia boards, 43% do not have guttering, and 65% do not have down pipes, demonstrating that the buildings are inadequately equipped for optimum rainwater collection, and transmission.
- 57% appear to be partially covered with vegetation – indicating that RWH on these buildings is obstructed by over-hanging vegetation, with potential of rainwater contamination, and guttering blockages and overflow.
- 27% of the buildings have storage tanks, suggesting that most buildings will require suitably sized rainwater tanks to be installed for secure and adequate storage/conservation.

It should be noted that inspections of roofing conditions are limited to what could be observed at the time of the survey from the ground. Experience 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 Abaiang, 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[3] with an estimated 68% 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 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 291 wells across 6 villages in Abaiang (Table 9). Standard water resource assessment techniques for the groundwater survey were used. These included surveying all wells in the target villages to help determine:

- well location;
- construction type;
- general condition;
- contamination risk;
- salinity; and
- 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 97% of all households in the target villages on Abaiang rely on groundwater for their potable and domestic water needs. This is reflected in the high percentage of well ownership for households, between 51% to 104%[4], depending on the village. Well ownership data indicates that:

[3] Presence of a casing, parapet, cover, fence, well apron, with increased distance from contamination source will improve well protection in most cases.
[4] 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 9. Typical bailer used for abstraction of groundwater from a local well, Aonobuaka, Abaiang.

Table 9. Summary of the state of groundwater wells surveyed within the target villages.

Village	Ribono	Tebunginako	Aonobuaka	Ewena	Tuarabu	Taniau	Total
Number of wells surveyed	31	36	55	22	92	55	291
INFRASTRUCTURE							
Unlined wells	0	3	0	0	7	3	13
Wells with coral rock casing	22	26	45	16	53	29	191
Wells with cement ring casing	9	7	6	2	22	4	50
Wells with no casing information recorded	0	0	0	1	7	18	26
Wells with no parapet	22	28	47	14	56	51	218
Wells with no proper cover	29	35	51	18	61	31	225
Wells with no apron	15	20	28	17	43	25	148
Wells with no fence	26	34	45	19	67	35	226
ABSTRACTION							Total
Wells using hand pumps	1	1	7	7	19	27	62
Wells using solar pumps	1	0	0	0	2	1	4
Wells using electrical pumps	0	0	0	0	4	0	4
Wells using bailers	28	35	45	15	60	27	210
Wells not used (Abandoned)	1	0	3	0	7	0	11
CONTAMINATION							Total
Wells located <= 20 m from contaminant sources	30	36	53	22	91	53	285
WATER QUALITY – PHYSICAL PROPERTIES							Average
Average total depth (m bgl)	1.44	1.66	2.16	2.31	2.50	2.09	2.03
Average depth to water table (m bgl)	1.12	1.27	1.76	1.79	2.02	1.67	1.60
Maximum salinity (mS/cm)	10.0	40.80	4.13	7.69	10.20	1.75	12.43
Minimum salinity (mS/cm)	0.47	0.34	0.50	0.71	0.36	0.56	0.49
Average salinity (mS/cm)	1.44	1.93	1.4	2.6	1.04	0.8	1.54
Median salinity (mS/cm)	1.02	0.84	1.15	2.15	0.83	0.77	0.95
Number of wells exceeding 2.5 mS/cm	2	4	6	9	2	0	23
WATER QUALITY – BACTERIOLOGICAL TESTS							Total
Number of E.coli samples taken	12	16	21	11	31	10	101
Number of samples showing E.coli presence	11	16	20	10	31	8	96
% of samples indicating contamination	92%	100%	95%	91%	100%	80%	95%

The well survey suggests that most wells (> 95%) 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, 4% were unlined, 66% use coral rocks, 17% use locally-made cement rings, 2% use cement blocks and 2% use other materials, such as polyethylene (PE) drums, tins and timber. The remaining 9% are completely covered with no information recorded on construction details.
- 75% of the wells do not have parapets and 51% do not have adequate aprons, suggesting that they are at greater risks of surface water ingresses and contamination.
- 77% of the wells do not have proper covers and 78% do not have fence, which are issues for both security and safety of the well and increased potential for algal growth.

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

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

4.3.2 Abstraction and usage

Abstraction of groundwater wells are characterised by:

- 21% use of the locally-made *Tamana* or hand pump (Figure 10) – the advantage of locally-made hand pumps includes:
  - the communities' familiarity with its operation and maintenance;
  - access to materials for repairs;
  - access to better quality water whereby the well can be located at a distant, more secure and better yielding source, away from contamination sources; and
  - low yield abstraction minimises up-coning and saline intrusion.
- 2% of wells using solar pumps, 2 of which were not working due to either damaged pumps or stolen solar panels.
- 2% of wells use electric-powered submersible pumps.
- 72% of wells use bailers, namely buckets, tins and containers – most bailers were found unprotected, lying on the ground, thereby increasing potential for contamination (Figure 9).
- 4% of wells were unused and abandoned due to poor water quality, particularly very high salinity.

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

Figure 10. Kiribati hand pump used for abstraction of groundwater from a distant local well, Ewena, Abaiang.

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 10.

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.[5]

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 10. Guide to salinity threshold values for consideration by the communities of Abaiang 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

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

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

- The median average EC value of the 291 wells at the time of the survey was 905 µS/cm.
- The average depth to the water table is 1.60 m bgl for all wells; and the maximum and minimum depths for the water table based on all sites is 3.79 – 0.12 m bgl.

A total of 23 (8%) of the surveyed wells, exhibited salinity levels in excess of the 2500 µS/cm adopted limit for freshwater resources. These higher salinity wells are likely to be attributed to close proximity to the coastline, or geological features such as higher permeability or preferential pathways allowing mixing with saline water. Given the low use of abstraction by solar or electric pumps, over pumping impacts 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 coast.

Bacteriological analysis – E.coli contamination

Groundwater is used for both drinking and domestic water needs in outer islands. Whilst boiling of all well water prior to drinking is recommended, treatment of water prior to consumption is not uniformly undertaken for household wells or village and communal wells in outer islands. In order to better understand the groundwater vulnerability and presence of bacteriological contamination, a standard presence/absence test was undertaken to determine the likelihood of contamination. The IDEXX Colilert-18 procedure, an E.coli presence/absence test, was used on samples collected from selected groundwater wells and rainwater storage tanks around the target villages. A sample preparation and analysis is provided in Annex 5, with village contamination maps shown in Annex 6.

Table 9 shows that approximately 90% of the wells or rainwater tanks sampled indicated the presence of E.coli bacteria. This can be attributed to:

- the close proximity of groundwater wells to numerous contaminant sources: pit toilets, poorly designed septic tanks, pig pens, *bwabwai* pits and general household point source contamination;
- wells and rainwater tanks not having adequate protection; including functioning covers and parapets to help prevent the entry of contaminated water or 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.

Presence/absence testing for indicator bacteria, E Coli, does not provide a quantitative appreciation of the extent of contamination of the water and is therefore limited in its usefulness. It is recommended that a quantitative sampling procedure, such as the compact-dry plate filtration membrane method, be used in the future should further microbiological sampling and analysis be conducted on the island. A fact sheet of this methodology and field procedure is provided as Annex 7.

4.3.4 Well-improvements

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

- Casing materials made from concrete rings ensuring structural integrity to the well and allowing improvements such as the introduction of hand pumps, well parapets, aprons and well covers.
- Construction of a parapet to prevent the ingress of surface runoff.
- Fitted well covers to prevent foreign matter from being introduced into the well and to reduce algae growth.
- Concrete aprons surrounding the wells to prevent the infiltration of surface water from the sides.
- Fencing to restrict access by animals and others trespassing into the well area.
- Hand pumps such as the *Tamana* pump, which reduces the need for activities to be centred around the well, thereby reducing the potential of contamination.
- Bailer stands to keep the bailers off the ground.
- Decommissioning of abandoned wells to reduce their use as waste disposal receptacles that potentially act as a pathway for groundwater contamination.

4.4 Electromagnetic SURVEYS – EM34

4.4.1 Introduction

The use of electromagnetic (EM) geophysical surveys to map the freshwater lens thickness in atoll environments is well established, being successfully used on Kiribati in recent times 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 Abaiang Island between the 9^{th} and the 20^{th} of March 2013, using the Ministry of Public Works and Utility owned Geonics EM34.

A standard approach to EM34 surveys was used to provide consistency between surveys, as outlined in Annex 8.

4.4.2 Survey location

Forty-three (43) EM34 survey lines were completed across the target villages. The focus for geophysical investigations was the areas within the immediate vicinity of the target villages, as these were the areas of most interest for the villages. It was considered that undertaking detailed investigations targeting the village area and surrounds would 'localise' the collective village ownership and responsibility for the water source and thereby help address issues over access and economic considerations to piping. It was generally observed that:

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

Time constraints, limited access to boats, and cultural activities taking place within the village during the available assessment time permitted only a limited geophysical survey to be undertaken on Ribono islet.

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

Traverse lines were undertaken between the lagoon and the ocean at 200 m spacing, using established paths where possible. Readings were taken every 30 m using the 10 m and 20 m cables in the horizontal dipole position (coils vertical). Some survey lines had to be slightly diverted or cut short 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 (Annex 8). Freshwater-thickness contours, based on the estimated freshwater thicknesses using 2.5 m contour intervals, were hand drawn in MapInfo GIS and presented in Annex 6.

Table 11: 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	39	87
2	32	71
4	26	56
6	22	47
8	19	41
10	17	36

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 12.

Table 12. Estimated freshwater lens area beneath the target village areas.

Village	Ribono	Tebunginako	Aonobuaka	Ewena	Tuarabu	Taniau
Surveyed village area (m^2)[1]	704,700	911,900	1,163,600	514,000	1,508,800	1,140,600
Freshwater lens area (m^2)[2]	117,258	649,380	570,921	15,758	1,142,352	579,187
FW lens/survey area ratio (%)	17%	71%	49%	3%	76%	51%
Groundwater potential	Low	High	Moderate	Poor	High	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 Ribono and Ewena villages, which are identified as having low to poor groundwater potential, the fresh groundwater potential for the other villages in Abaiang is moderate to high. The poor groundwater potential in Ewena is attributed to the reduced island width around the village. The EM34 survey of Ribono was restricted due to time limitations. The estimate of low groundwater potential is therefore conservative. Further EM34 investigations may conceivably extend the area of fresh groundwater potential currently identified.

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 was downloaded onsite.

4.5.1 Tidal lag and tidal efficiency

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

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

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

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

Due to 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 Bonriki water reserve is provided (Table 14) for comparison with the data collected from Abaiang. The monitoring records from all the selected wells in Abaiang are presented in Annex 9.

Table 13. A summary of the logger data records and calculated tidal lags and efficiencies for Abaiang. Note that "NA" represents datasets with did not show noticeable tidal influences, rendering no definite tidal lag and tidal efficiency to be calculated. (See also Annex 9)

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 (hrs)	Tidal efficiency
Tebunginako	Bwaatake	K6818	130	11/03/2013 11:00	12/03/2013 12:00	25	2.51	13%
	Etueti	K6813	40	11/03/2013 11:00	12/03/2013 12:15	25.25	2.31	7%
Aonobuaka	Amarereiti	K6818	130	13/03/2013 11:00	14/03/2013 14:00	27	3.28	2%
	Taake	K6813	105	13/03/2013 11:00	14/03/2013 13:30	26.5	2.58	6%
Ewena	Moarite	K6818	120	15/03/2013 9:30	16/03/2013 8:15	22.75	NA	NA
	Living Water AOG	K6813	40	15/03/2013 9:30	16/03/2013 8:30	23	2.43	11%
Tuarabu	Tingo	K6818	80	16/03/2013 10:00	19/03/2013 13:15	75.25	2.04	13%
	Tom	K6813	70	16/03/2013 10:30	19/03/2013 13:15	74.75	2.39	13%
Tebwanga	Rubeteiti	K6818	75	20/03/2013 9:30	21/03/2013 10:30	25	0.42	13%
	Primary School	K6813	40	20/03/2013 9:30	21/03/2013 12:45	27.25	NA	NA
Ribono	Councillor	K6813	20	8/03/2013 18:30	9/03/2013 15:15	20.75	NA	NA
	Itinimarawa	K6818	80	8/03/2013 18:30	9/03/2013 15:30	21	8.42	4%
Average						24.79	2.93	9%

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

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

Figures 11 and 12 below graph the monitoring wells at Aonobuaka and Tuarabu villages (~15 km apart).

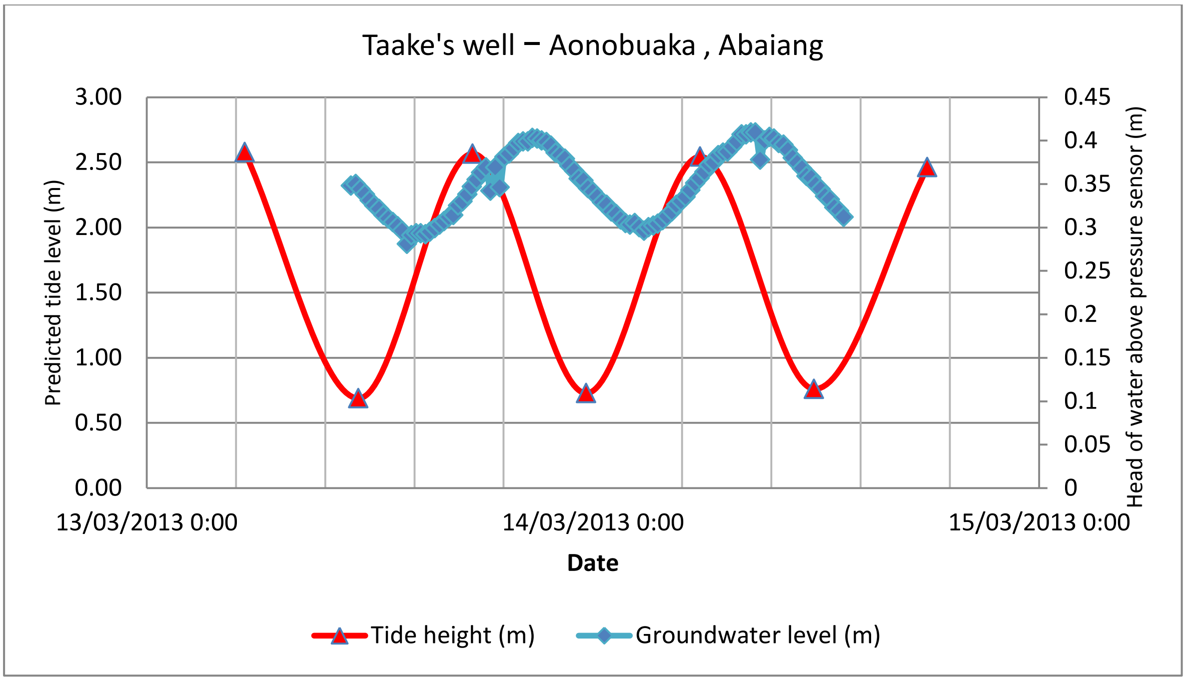

Figure 11. Predicted tidal height and measured groundwater level at Taake's well, at Aonobuaka Village and groundwater monitoring commencing at 11 am (13th March 2013) and terminated after 26.5 hours.

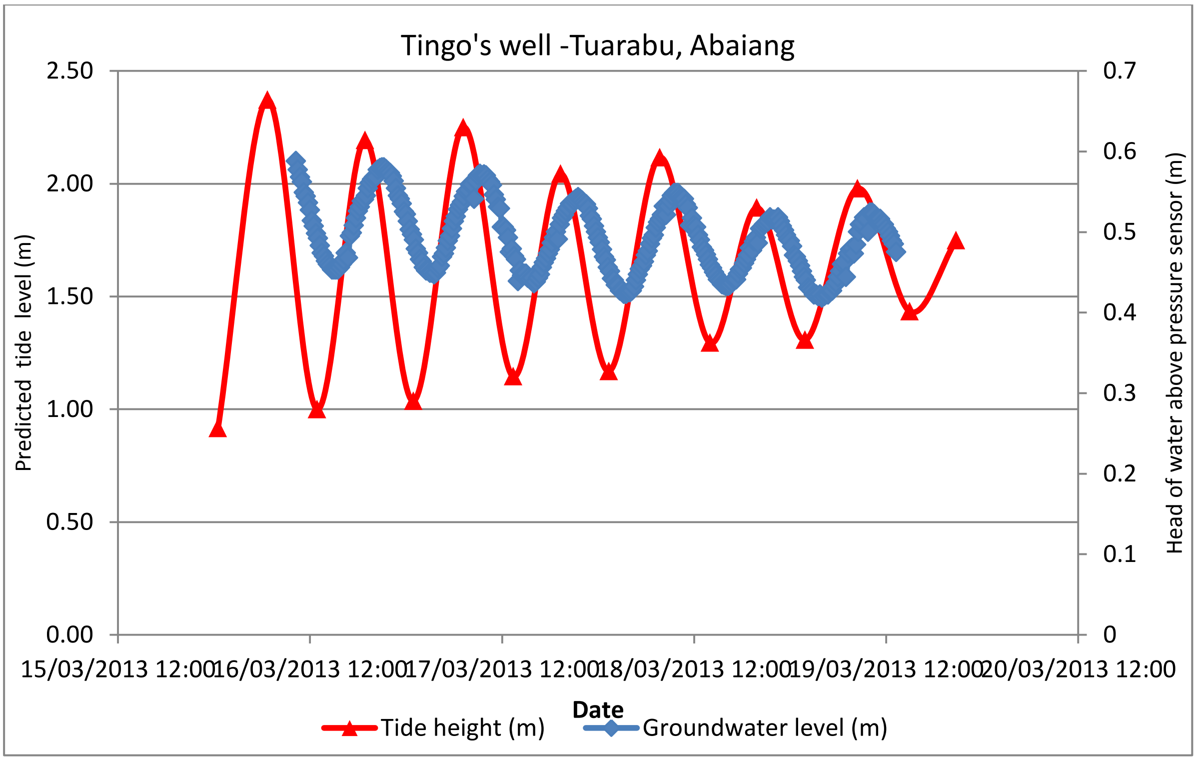

Figure 12. Predicted tidal height and measured groundwater level at Tingo's well, at Tuarabu Village with groundwater monitoring commencing at 10 am (16th March 2013) and terminated after 75.25 hours.

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

Compared with Tarawa, Abaiang has increased tidal lag values with generally higher tidal efficiency values, at closer distances from the ocean or lagoon influence. This difference between the two islands indicates probable differences in geology of the islands. It is suggested that sediments are likely to be less permeable for Abaiang than found in Bonriki, Tarawa; accounting for the increased tidal lag and with shallower depths to the Pleistocene limestone to account for the greater tidal efficiency values (Figure 13). Additional data is required to assess this suggested variation between the islands.

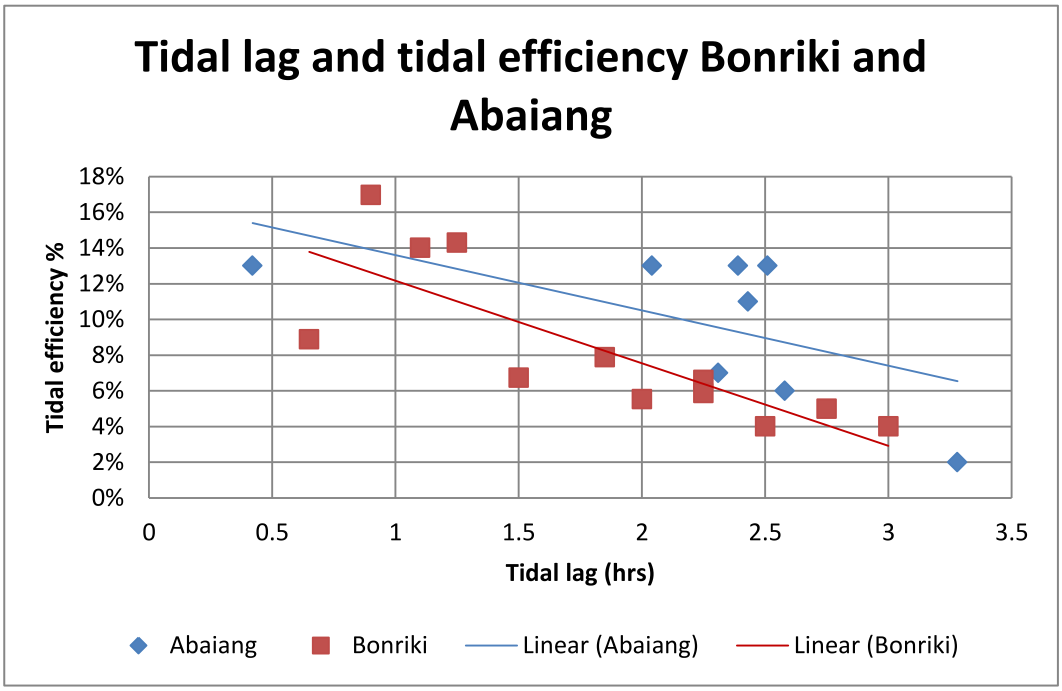

Figure 13. Tidal lag and tidal efficiency for Abaiang and Bonriki (Tarawa), with anomalous values removed.

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 due to 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 Abaiang monthly rainfall record (from November 1904 to May 2014), the rainwater harvesting potential in the communal buildings were assessed through White's (2010) rainwater calculator spreadsheet (Annex 10).

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

From Tables 15 and 16, it is clear that most communal buildings need substantial roof improvements to maximise the catchment area and to allow optimum rainwater collection. This implies the addition of various storage volumes to optimise water storage and availability for use. Clearly, the estimation of 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 demand to a fixed population will gradually decrease once the maximum roof area is reached. An analysis was conducted using the White's (2010) rainfall calculator to determine the ideal storage for a range of roof catchment areas in Abaiang (see Figure 14). 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 15. Summary of potential communal RWH centres. (See also Annex 10)

Village	Building Type	Owner	[1]Roof area (m^2)	Building ID	Percentage of roof covered by guttering	[2]Collecting Roof Area (m^2)	[3]Guttering Condition	[4]Guttering Efficiency	[5]Effective Roof Area (m^2)	[6]Improved Roof Area (m^2)	[7]Rain Tank Capacity (L)
Aonobuaka	*Maneaba*	Church	199.2	An1	50%	99.6	Adequate	0.55	55	149	5000
Aonobuaka	Church	KPC	70.55	An2	50%	35.275	Replace	0.15	5	53	5000
				Aonobuaka Total					60	202	10000
Ewena	Church	KPC church	219.35	Ew1	50%	109.675	Good	0.75	82	165	10000
Ewena	*Maneaba*	Church	220.8	Ew2	50%	110.4	Good	0.75	83	166	10000
Ewena	Church	Catholic church	154.84	Ew3	50%	77.42	Good	0.75	58	116	5000
				Ewena Total					223	446	25000
Ribono	Church	Catholic church	376.6	Ri1	50%	188.3	Good	0.75	141	282	10000
Taniau	Church	Catholic priest	126	Ta1	<25%	25.2	Adequate	0.55	14	95	5000
Taniau	*Maneaba*	Catholic church	140	Ta2	None	0	None	0	0	105	5000
Taniau	Church	KPC Church	65.32	Ta3	None	0	None	0	0	49	5000
				Taniau Total					155	531	25000
Tebunginako	*Maneaba*	*Maneaba*	508.26	Te1	50%	254.13	Good	0.75	191	381	10000
Tebunginako	Church	Old church	248.52	Te2	50%	124.26	Good	0.75	93	186	0
				Tebunginako Total					284	568	10000
Tuarabu	Church	LDS	161.5	Tu1	100%	161.5	Good	0.75	121	121	5000
Tuarabu	Government	Airport terminal	58.5	Tu2	None	0	None	0	0	44	0
Tuarabu	*Maneaba*	Catholic church	403	Tu3	50%	201.5	Adequate	0.55	111	302	1000
				Tuarabu Total					232	467	6000

Notes:

[1] Represents the product of the measured catchment length and width.

[2] The product of the roof catchment area and the current guttering coverage.

[3] Manually observed on-site guttering condition.

[4] Guttering efficiency values are derived from White (2010) shown in Table 16. This assigns 0.75 efficiency to "good" guttering – this also considers the runoff coefficient as specified in the White (2010) rainfall calculator spreadsheet.

[5] The product of collecting roof area and guttering efficiency.

[6] Assumes that an improved catchment, through the installation of good guttering material, will yield a 0.75 guttering efficiency; hence this is a product of the roof area * 0.75.

[7] Existing rainwater storage volume.

Table 16. 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 ($0 \le C \le 1$))	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}

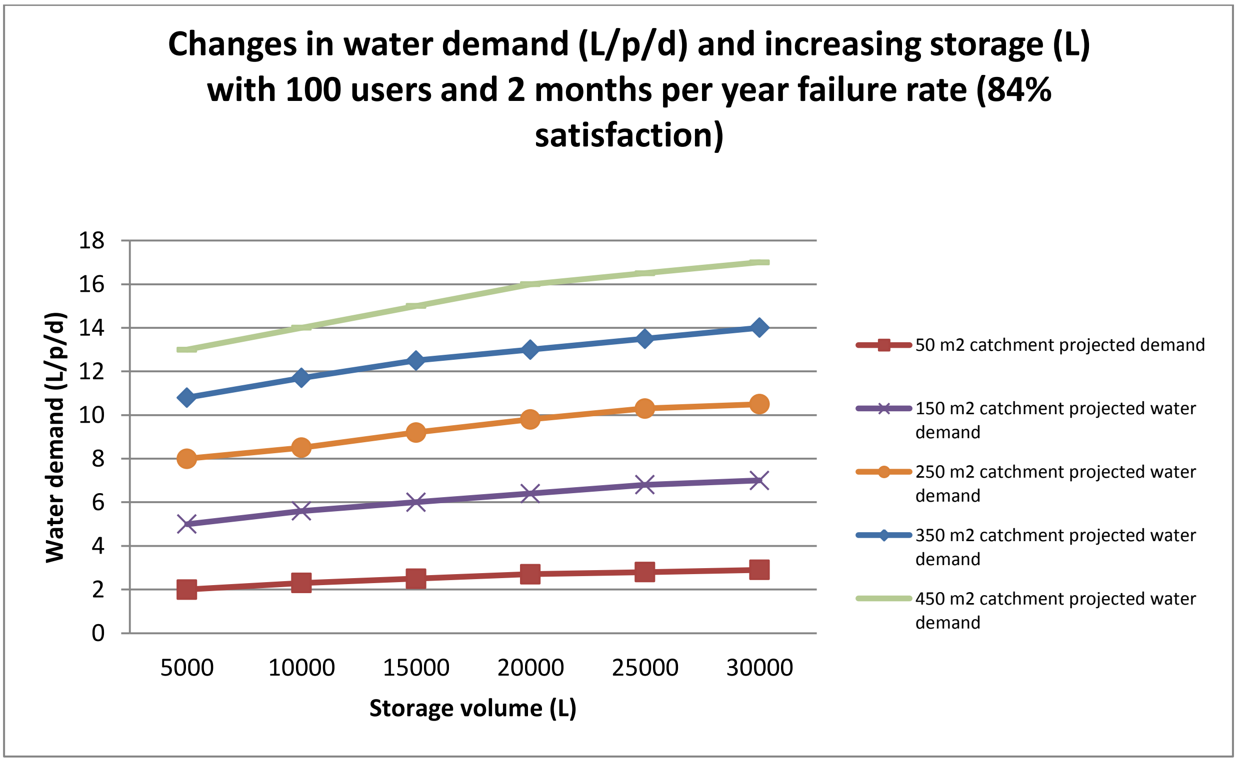

Figure 14. Changes in water demand (L/p/d) in relation to changing roof catchment and increasing storage volume based on 2 months failure rate in any one year (84% satisfaction).

Table 17, Figures 15 and 16 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.

Table 17. Analysis of combining all target communal buildings in each village to serving the current and future population.

Village	Population	[1]RWH capacity under current catchment conditions (L/p/d)	[2]RWH capacity under current and improved catchment conditions	[3]RWH capacity with roof improvements and increased storage 20,000 L
Aonobuaka	2010 (328)	0.83	2.2	3
	2030 (396)	0.69	1.8	2.5
Ewena	2010 (166)	5.7	10	12.6
	2030 (141)	6.7	11.8	14.8
Ribono	2010 (341)	1.55	2.8	3.4
	2030 (414)	1.3	2.3	2.8
Taniau	2010 (310)	2.2	6.2	7.7
	2030 (392)	1.75	4.9	6.1
Tebunginako	2010 (424)	2.3	4.2	5.4
	2030 (402)	2.4	4.4	5.6
Tuarabu	2010 (560)	1.35	2.5	3.6
	2030 (645)	1.15	2.2	3.2

Note:

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

[2] Water demand under improved conditions, uses the improved roof catchment from Table 15, the 2010 and 2030 populations and considers a 2 months per year failure rate (84% satisfaction) using White (2010) rainfall calculator.

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

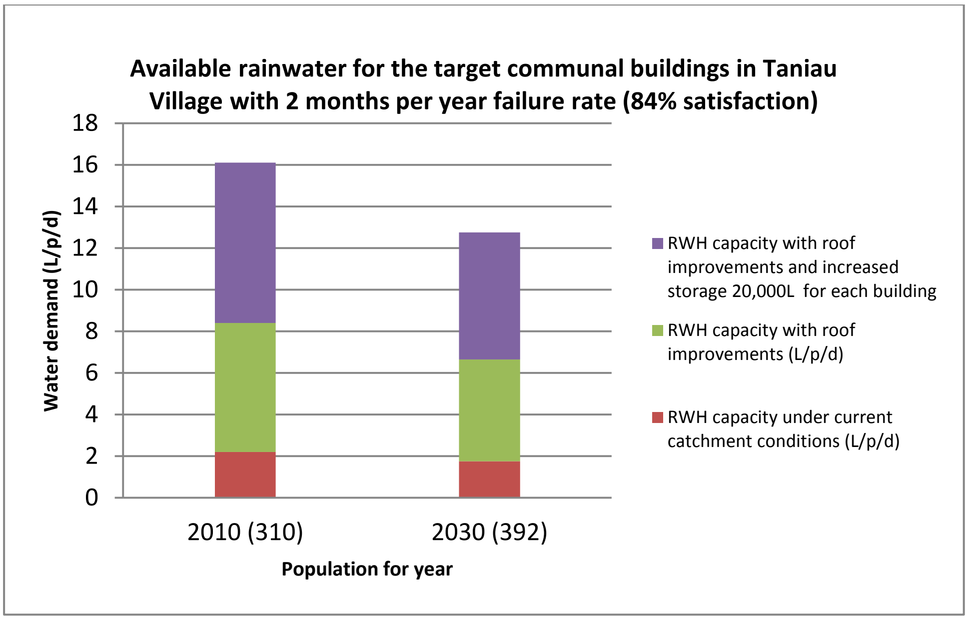

Figure 15. Water demand analysis of all target communal buildings in Taniau village on 2 months per year failure rate (84% satisfaction).

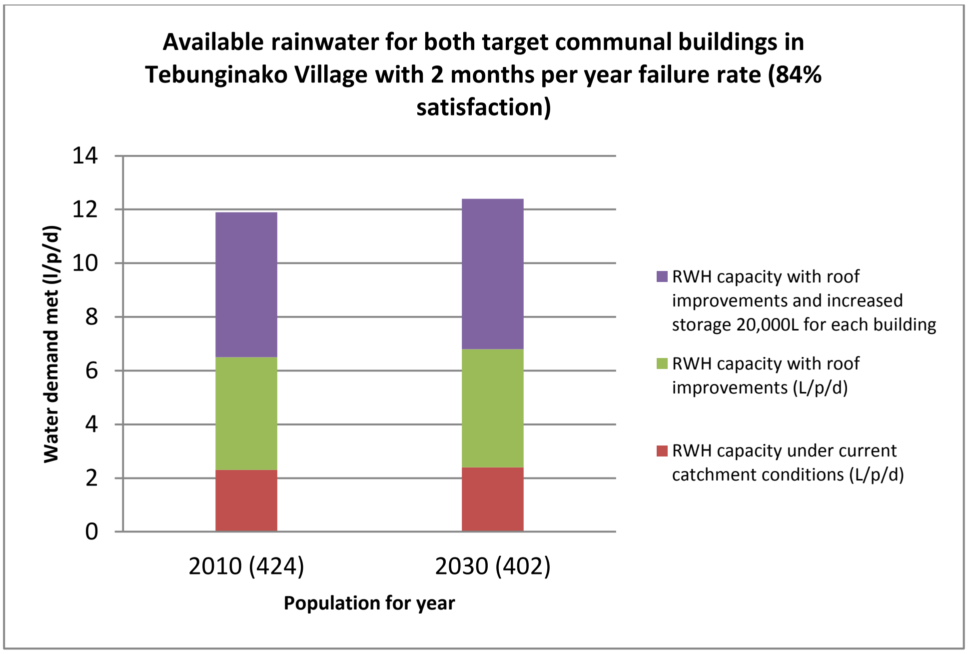

Figure 16. Water demand analysis of all target communal buildings in Tebunginako Village on 2 months per year failure rate (84% satisfaction).

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

Whilst rainwater often has lower salinity than groundwater, it has limited drought reserve potential and unless 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 8, 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 18.

Table 18. Summary of estimated groundwater resources underlying each village.

Village	Ribono	Tebunginako	Aonobuaka	Ewena	Tuarabu	Taniau
Total land area (m^2)[1]	704,700	911,900	1,163,600	514,000	1,508,800	1,140,600
Maximum island width (m)[2]	480	700	500	280	650	450
RAINFALL RECHARGE[3]						
Average annual rainfall recharge (m/yr)	0.81	0.81	0.81	0.81	0.81	0.81
Minimum recorded annual rainfall recharge (m/yr)	0.31	0.31	0.31	0.31	0.31	0.31
2030 predicted annual rainfall recharge (m/yr)	0.85	0.85	0.85	0.85	0.85	0.85
FRESHWATER LENS[4]						
Freshwater lens area (m^2)	117,258	649,380	570,921	15,758	1,142,352	579,187
Average freshwater lens thickness (m)	10.8	16.4	9.8	4.9	7.8	11.7
Lens/Total land ratio	17%	71%	49%	3%	76%	51%
Freshwater lens area > 6 m thick (m^2)	83,300	506,400	278,840	0	524,000	337,300
Average freshwater lens thickness (m)	11.9	17.7	12.9	0.0	9.1	13.1
Lens/total land ratio freshwater lens > 6 m thick	12%	56%	24%	0%	35%	30%
AVAILABLE FRESHWATER ESTIMATION[5]						
Freshwater lens volume (m^3)	1,261,696	10,656,326	5,600,735	77,687	8,876,075	6,753,320
Available groundwater (m^3)	378,509	3,196,898	1,680,221	23,306	2,662,823	2,025,996
Freshwater lens volume > 6 m thick (m^3)	991,270	8,963,280	3,597,036	0	4,773,640	4,418,630
Available groundwater for lens > 6 m thick (m^3)	297,381	2,688,984	1,079,111	0	1,432,092	1,325,589

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]areas having lens thickness equal or greater than 2.5 m, after KAPII (GWP, 2011), rainfall recharge considers Falkland's rainfall/recharge ratio of 27% (Section 3.3) 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] freshwater lens is delineated by selecting all estimated freshwater thicknesses greater than or equal to 2.5 m, whereas a proposed drought resilient zone is mapped around areas having estimated freshwater thickness of 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 represents the usable groundwater based on the assumed specific yield of 0.3 for coral sands (Falkland, 2003)

It appears that the variability in lens extent for villages is greatly influenced by island width at village locations. Note that Ewena 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.

The freshwater lens thickness and areal extent and associated calculations in Table 18 are based on the survey and ground conditions present at the time of the investigation. The freshwater lens thickness will vary over time; and according to prevailing climatic conditions e.g. freshwater lens thickness during wet periods is not the same as in dry periods.

Unlike Tarawa, there are no dedicated monitoring wells on Abaiang Island, 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. The residence time is estimated to be from about 2 to 6 years for the villages in this study, depending on the estimated freshwater thicknesses as determined from the EM34 survey.

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, so as to ensure water supply was 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, such as drinking, washing, cooking and for household animals. Agriculture and irrigation is limited and little has been done on the needs and considerations of groundwater dependent environments on atolls. As a first estimate, sustainable yield can be calculated as a percentage of the recharge for the lens area. According to the Falkland (2003) relationship of sustainable yield to percentage recharge (see Section 3.3, rainfall recharge for Abaiang was calculated at 37% indicating that the sustainable yield is estimated to be 27% of the average annual recharge.

The estimated sustainable yield (m^3/day) for each village and theoretical sustainable yield per capita in 2010 are summarised in Table 19.

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

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 a large extent 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 drought conditions from 1998-2000 observations, predicted a lens reduction in thickness by between 5 m and 5.5 m (Falkland, 2003). These suggest that, areas with a freshwater thickness of 6 m or more provides some drought resilience.

The drier season for rainfall is generally from May to November, with an average dry season rainfall being 1050 mm, based on monthly rainfall from 1950-2014. The lowest recorded annual rainfall was recorded in 1955, with 849 mm.

Using these dry periods' parameters, the average recharge will reduce to 389 mm (37 % of rainfall) and 314 mm for the dry months and for the lowest annual rainfall, respectively.

Observations that can be made from Table 18 are as follows:

- Significant reduction to available groundwater is observed in all target villages, restricting available groundwater to those areas with a freshwater lens thickness of > 6 m.
- Ewena is the only village estimated to be unable to support the approximate daily water demand of 65 L/p/d of the current population.
- Groundwater underneath Ewena Village is likely to experience impacts to water quality, which may require water conservation strategies.

The above estimates are a guide only and would require validation and monitoring of well water quality and rainfall to improve minimising the negative impact to the lens during extended dry periods.

c) Population growth

Tables 18 and 19, show that all target villages will not be subject to the same pressures of population growth. The following are worth noting:

- Even though Ribono, Aonobuaka, Tuarabu and Taniau would register population growth, this will not significantly affect the capacity of the underlying freshwater lens to meet the estimated water demand of 65 L/p/d (Falkland & White, 2009).
- Tebunginako with reduced population indicates significant freshwater resources for projected population up to 2030.
- Ewena Village, due to hydrogeological constraints is expected to have salinity issues even though a negative population growth is projected. Alternative water conservation strategies may be required, such as the installation of additional rainwater harvesting systems or improvements to existing systems, to meet drinking water needs during extended periods of drought.

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 19.

Table 19. Estimated sustainable yield considering the current and future populations and projected climatic conditions.

Village	Ribono	Tebunginako	Aonobuaka	Ewena	Tuarabu	Taniau
POPULATION DATA						
2010 population	341	424	328	166	560	310
2030 projected population	414	402	396	141	645	392
RAINFALL RECHARGE						
Average annual recharge (m/yr)	0.81	0.81	0.81	0.81	0.81	0.81
Minimum recorded annual recharge (m/yr)	0.31	0.31	0.31	0.31	0.31	0.32
2030 predicted annual recharge (m/yr)	0.85	0.85	0.85	0.85	0.85	0.85
FRESHWATER LENS						
Freshwater lens area (m^2)	117,258	649,380	570,921	15,758	1,142,352	579,187
Average freshwater lens thickness (m)	10.8	16.4	9.8	4.9	7.8	11.7
RESIDENCE TIME[1]						
Average residence time for freshwater lens (yrs)[1]	4.0	6.1	3.6	1.8	2.9	4.3
SUSTAINABLE YIELD RANGE[2]						
Sustainable yield range current (m^3/yr)[2]	10,309 - 26,528	57,093 - 146,916	50,195 - 129,165	1,385 - 3,565	100,436 - 258,446	50,992 - 131,035
Sustainable yield range 2030 (m^3/yr)	21,223 - 27,855	117,533 - 154,262	103,332 - 135,623	2,852 - 3,743	206,757 - 271,368	104,828 - 137,587
Sustainable yield range current per capita (L/p/d)	83 - 213	369 - 949	419 - 1079	23 – 59	275 - 708	450 - 1158
Sustainable yield range 2030 per capita (L/p/d)	140 - 184	801 - 1051	715 - 938	55 – 73	566 - 708	733 - 962

Notes:

[1] Residence time estimate = average freshwater lens thickness x specific yield x the annual rainfall recharge.

[2] Sustainable yield estimates m^3/day = estimated lens area x the calculated sustainable yield (after Falkland 2003)/ 365 days. Sustainable yield considers the measured freshwater lens area, the long-term annual average rainfall and minimum rainfall recharge, the recharge/sustainable yield ratio of 16%, whilst the projected future yield utilises the predicted 5% increase in rainfall (BOM, 2011) and the estimated 20% reduced rainfall – the per capita sustainable yield estimates for the current and future periods utilise the 2010 and 2030 populations, respectively.

These indicate that in all, but one village, water needs can be supported by their respective drought resilient zones. Again, Ewena is not considered for the latter analysis due to the relatively thin freshwater lens thickness, i.e. not having estimated lens thickness above the 6 m limit; and its potential for saline intrusion as a result of sea level rise.

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 subsequent population growth.

5.3 Community Awareness and Consultation

Community consultation and awareness was planned for all the target communities to establish the major water and sanitation problems and/or identify appropriate preferences from the perspectives of the villagers. Attempts to conduct this meeting at four villagers, namely Ribono, Tebunginako, Aonobuaka and Ewena, proved difficult. Villagers of Ribono were engaged in several pre-arranged functions, whilst the members of the other villages did not attend the scheduled meetings. Information provided by householders during the water resources assessment (WRA) household interviews in all the villages would provide insight into the needs and preferences of villagers.

The common issues raised at target village meetings included the following:

- Replacement of several damaged solar pumps and panels, (several solar panels were reported damaged or stolen, with pumps no longer in operation).
- Rainwater harvesting systems needs to be improved to all “properly roofed” churches and *maneaba*.
- Limited accessibility of some churches due to strong segregation between denominations.
- More rainwater tanks need to be installed at the church, as the current system is deemed inadequate during prolonged dry periods.
- Household wells needs improvement, with emphasis on the installation of *Tamana* pumps.

The following observations on the community meetings were made:

- Poor attendance by villagers

The limited attendance by community members was a concern. Formal communication processes and protocols were followed using the council clerk and village councillor, with adequate time given for information delivery to community members. This was interpreted as villagers placing higher priority on their other engagements, poor communications, or general lack of interest by villagers for these meetings due to the numerous recent meetings that the community have been asked to attend for different projects.

- Poor representation of women and youths

More than 95% of people who attended the Tuarabu and Taniau meetings were elderly males (Annex 12), indicating a poor turnout for youths and women. This was a concern when women are recognised as playing a critical role in water management for households. While a handful of women assisted, and appeared interested, during the survey work, none of them attended the scheduled meeting. More efforts should be taken to ensure that women are better represented at the community level, and are part of the decision making process, so that their practical approach to water resource use, needs, and protection are better included. Similarly youths, regarded as potential agents of behavioural change for the awareness, protection, management and operation of water and sanitation systems, should be included to safeguard the long-term operation and maintenance of any proposed water and sanitation improvement.

- Infrastructure-oriented needs/preferences

The community needs and preferences by the villagers are infrastructure-focussed with minimal concern for operation, maintenance and longer term management needs.

Promoting an environment that fosters awareness for the management and operation of water supply and sanitation facilities should be a focus of future community interaction and water supply and sanitation infrastructure improvements in Abaiang.

See also Annex 11 for village meeting notes.

6.0 WATER RESOURCES DEVELOPMENT OPTIONS

6.1 Existing Water Supplies

A survey of existing water supplies status was undertaken by Falkland in 2003. This was reviewed at the time of this survey and an updated status of the water supply systems is provided in Table 7 for the 6 target villages in this study.

As previously described, the surveyed villages rely upon groundwater for drinking and potable purposes. 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, some of which appeared to be non-operational due to either pump failures or stolen solar panel. Electric pumps are installed mainly in medical clinics, some of which were not operating due to electrical faults.

Rainwater harvesting is not widely practised around Abaiang. The reasons for poor rainwater harvesting uptake include:

- buildings with suitable permanent roofs being limited;
- settlements being 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; and
- compact villages, such as on Ribono islet, while having suitable roof buildings with significant RWH potential – needs significant infrastructural improvements.

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 15 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 (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 standard household wells are provided in the KIRIWATSAN Technical Notes on Water Supply Design Principles (Sinclair et al., 2015). In general, there is a preference for promoting and developing communal water supply systems that are more cost efficient; however, in some cases it may be preferable to consider improving individual household wells. The current designs are promoted for general uptake by the individual. It is recommended that the individual households, as the beneficiaries of the water supply infrastructure, would contribute towards the cost of improvements.

Note that it is recommended that all water used for 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 is the preferred option for Ribono, Tebunginako and Aonobuaka 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 Ribono, Aonobuaka, Tebunginako, Tuarabu and Taniau. 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. 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. Tuarabu is a community 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 & 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 95% 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 (70%) 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.
- 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 Abaiang 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 fund-raising 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 Abaiang, 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 7) 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 program.

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 Abaiang 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 Abaiang 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 SPC (2015b). 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)

ABAIANG ATOLL, KIRIBATI

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Annex 1

Survey Schedule around Abaiang Island

Table A1-1. Survey schedule around Abaiang Island between 8th and 22nd March 2013.

Date	Villages	Activities
8/2/2013		• Team travelled to Abaiang Island. • Met with the Island Council OIC and arranged logistics. • Team travelled to Ribono islet (team was not permitted to conduct assessment work as the entire village was engaged in International Women's Day celebration).
9/2/2013	Ribono islet	• A briefing was convened by the village elders to select the casual workers. • Conduct WRA survey in the village with EM34 survey conducted. • Attempts to hold community meetings were unsuccessful due to the engagement of village members in traditional functions.
10/2/2013		• Sunday – team prepared equipment for next day's survey.
11/2/2013	Aonobuaka	• Conducted WRA and EM34 in the northern segment of the village. • Arranged with village councillor to organise a community meeting for the next day.
12/2/2013	Aonobuaka	• Conducted WRA and EM34 in the southern segment of the village. • Very poor attendance for the scheduled community meeting with people engaged in other businesses.
13/2/2013	Tebunginako	• Conducted WRA and EM34 in the northern segment of the village. • Arranged with village councillor to organise a community meeting the next day.
14/2/2013	Tebunginako	• Conducted WRA and EM34 in the southern segment of the village. • Very poor attendances at community meetings as people were engaged in other business.
15/2/2013	Ewena	• Team met all the casual labourers at the village *maneaba* and arranged for community meeting to be held in the afternoon. • Conduct WRA and EM34 survey in the village. • Very poor attendance to the agreed community meeting.
16/2/2013	Tuarabu	• Team picked up all casual workers and conducted WRA and EM34 survey in the village.
17/2/2013		• Sunday – team prepared equipment for next day's survey.
18/2/2013	Tuarabu	• Arrange for community meeting in the afternoon. • WRA and EM34 survey in the village and high school. • Conducted community meeting.
19/2/2013	Taniau/Tebwanga	• WRA and EM34 survey in the village. • Arranged for community meeting.
20/2/2013	Taniau/Tebwanga	• Completed WRA survey.
21/2/2013	Taniau/Tebwanga	• Data compilation. • Conducted community meeting.
22/2/2013		• Team returned to Tarawa.

Annex 2

Historical Monthly Rainfall Data, Abaiang

Table A2-1. Historical monthly rainfall data on Abaiang Island from 1950 – 2014 (with gaps).

ABAIANG J60700 LAT 01 49N LONG 173 01E HT 3M												
RAINFALL MILLIMETRES												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
1950								90	84	35	36	65	
1951	105	44	96	78	229	336	327	291	227	95	106	283	2217
1952	675	232	274	113	180	134	74	130	33	32	204	421	2502
1953	323	560	218	399	241	137	217		469	115	180	507	
1954	379	217	235	198	48	16	99	321	70	23	49	151	1806
1955	104	10	47	165	53	60	68	31	121	10	7	173	849
1956	94	112	55	167	89	100	198	56	55	66	74	188	1254
1957	172	176	411	242	218	270	266	71	203	341	289	185	2844
1958	65	107	318	513	171	213	421	183	11	55	222	233	2512
1959	234	471	203	320	269	104	193	217	56	204	56	216	2543
1960	474	369	183	179	125	144	93	80	61	0	80	193	1981
1961	290	291	113	155	212	157	213	279	34	93	50	135	2022
1962	153	27	171	228	110	124	311	178	165	17	32	284	1800
1963	196	25	125	63	145	142	156	200	157	310	300	345	2164
1964	514	375	178	68	10	114	55	91	31	3	89	17	1545
1965	348	425	39	345	62	458	532	56	186	372	249	502	3574
1966	416	388	384	384	380	15	350	28	125	229	257	165	3121
1967	334	132	137	204	33	106	156	42	119	66	24	224	1577
1968	212	262	21	9	6	12	129	73	421	78	125	267	1615
1969	339	700	500	350	324	488	587	351	51	0	92		
1970	761	286	305	284	111	128	128	0	0	0	0	0	2003
1971	0	17	0	93	109	114				123	95	225	
1972	241	53	61	49	237	202	263	291	345	237	142	436	2557
1973	306	346	315	87	90	33	14	1	3	24	0	13	1232
1974	0	25	0	5	83								
1975	25	370	45	60									
1976	0	0	36	95	99			229	268	73	150	378	
1977	525	183	182	160	118	59		77	308	199	589		
1978		241	706	187	91	74	59	70	10	4	66	231	
1979	215	458	534	99	214	251	141	170	50	143	286	404	2965
1980	376	120	474	245	234	203	272	305	183	295	218	397	3322
1981			77	324	275	183	68	32	59	17	160	417	
1982	26	146	131	224	118	83	401	274	132	220	253	197	2205
1983	47	77	55	63	601	319	200	92	0	70	6	33	1563
1984	72	49	71	98	106	104	88	37	0	103	17	105	850
1985	11	35	80	66	44	62	57	65		60	54	147	
1986	216	78	31	112	25	73	125	80	141	246	301	415	1843
1987	263	356	401	411	388	257	436	344	181	152	153	193	3535
1988	400	338	421	106	219	122	15	34	8	19	3		
1989		11	26	49	108	69	47	53	28	24	102	176	

1990			206										
1991			183	79	205	270	120	344	418	243	379	315	
1992	230	333	330	418	200								
1993													
1994										402	218		
1995													
1996													
1997													
1998													
1999													
2000	180	41	152	105	149	94	187	114	85	149	195	109	1560
2001	167	166	259	208	386	183	381	253	143	77	269	381	2873
2002	705	491	542	279	189	420	163	458	260	353	343	365	4568
2003	720	353	549	125	125	184	153						
2004													
2005													
2006													
2007													
2008													
2009													
2010											76		
2011	20	9	0	114	299	246	381	110	343	93	44	48	1710
2012	208	21	113	188	132	159	221	255	249	64	173	178	1962
2013	175	89	98	269	127	24	64	53	238	150	46	74	1400
2014	251	74	317	441	216								

Table A2-2. Basic statistical analysis of discontinuous 1950 – 2014 monthly rainfall.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean	257	206	208	188	171	160	201	151	142	124	146	233	**2184**
Std Dev	202	176	174	126	116	114	142	118	127	113	123	139	**833**
CV*	0.79	0.85	0.84	0.67	0.68	0.71	0.71	0.78	0.89	0.92	0.84	0.60	**0.38**
Max	761	700	706	513	601	488	587	458	469	402	589	507	**4,568**
Min	0	0	0	5	6	12	14	0	0	0	0	0	**849**
Median	216	166	174.5	165	138.7	131	159.5	92	121	85.5	106	206.5	**2,003**
No. of years	45	47	50	49	48	44	42	43	43	46	47	42	**33**

NOTES

Annex 3

Groundwater Well Field Survey Sheet

NOTES

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

NOTES

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 Analysis Procedures & Abaiang Survey Results

NOTES

IDEXX Colilert-18 Microbiology Sampling and Preparation and Analysis

INTRODUCTION

This is a relatively rapid procedure to determine the presence and/or absence of E.coli and total coliforms in any water source as per the WHO guidelines for drinking water.

SAMPLE PREPARATION PROCEDURES

Selected wells and rainwater tanks were sampled for E.coli bacteria assessment. Samples, collected in screw-cap 100 ml bottles, were abstracted using plastic flasks, attached to stainless steel holders, and onto which nylon ropes are tied. Samples were kept in storage before the pre-arranged analysis facility, which was the Island Council guesthouse, was reached. Colilert re-agent capsules were then added to the samples, and subsequently mixed to dissolve. The samples were placed in a controlled storage environment (i.e. 34 °C ± 0.5) for at least 18 hours. After adequate storage time, the absence/presences analyses of coliforms were conducted through the observation of color changes in the samples. A color change from pale yellow to dark yellow signified the presence of total coliform in the samples. The presence of E.coli bacteria was determined by exposure under the UV light. E.coli bacteria is deemed present when a sample fluoresced under the UV light, otherwise, the tested bacteria is absent.

Quality Assurance & Quality Control

To guarantee the compliance of this sampling procedure and to avoid secondary contamination, the steps listed below were followed:

1. Avoid placing bailers on the ground to prevent any possible contamination.
2. Holding the bailer via the designated steel handle to avoid touching the bailer, during the sampling abstraction to prevent any possible contamination.
3. Adequately rinsing the bailers with sampled water, prior to filling to sample bottles.
4. Keeping the storage containers as dry as possible.
5. Proper labeling of the sampling bottles to avoid any ambiguity.

RESULTS

The results are presented in Table A5-1 below with the locations of the sampled water sources shown in Annex 6.

Table A5-1. E.coli & total coliform analyses results from the target villages on Abaiang Island.

VILLAGE	Well/TankNumber	Well/Tank Owner	Type	Date	E.coli	Total coliform
Ribono	T0001	Catholic Church	T	9/03/2013	Positive	Positive
Ribono	T0002	Medical Clinic	T	9/03/2013	Positive	Positive
Ribono	W0009	Tien	W	9/03/2013	Positive	Positive
Ribono	W0017	Teweia	W	9/03/2013	Positive	Positive
Ribono	W0009	Bwanoia	W	9/03/2013	Positive	Positive
Ribono	W0014	Tabutoa	W	9/03/2013	Positive	Positive
Ribono	W0002	Ribono Primary School	W	9/03/2013	Positive	Positive
Ribono	W0008	Rabuna	W	9/03/2013	Positive	Positive
Ribono	W0011	Borauea	W	9/03/2013	Negative	Positive
Ribono	W0003	Teinoamata	W	9/03/2013	Positive	Positive
Ribono	W0006	Keketi	W	9/03/2013	Positive	Positive
Ribono	W0004	Menetake	W	9/03/2013	Positive	Positive
Ribono	W0001	Councillor's House	W	9/03/2013	Positive	Positive
Ribono	W0001	Naronteral	W	9/03/2013	Positive	Positive
Tebunginako	W0011	Tabokai	W	11/03/2013	Positive	Positive
Tebunginako	W0003	Timi	W	11/03/2013	Positive	Positive
Tebunginako	W0005	Bitamone	W	11/03/2013	Positive	Positive
Tebunginako	T0001	*Maneaba*	T	11/03/2013	Positive	Positive
Tebunginako	W0004	Bwatika	W	11/03/2013	Positive	Positive
Tebunginako	W0012	Teburea	W	11/03/2013	Positive	Positive
Tebunginako	W0010	Tawita	W	11/03/2013	Positive	Positive
Tebunginako	W0006	Etueti	W	11/03/2013	Positive	Positive
Tebunginako	W0001	Bataak	W	11/03/2013	Positive	Positive
Tebunginako	W0010	Kokoria	W	11/03/2013	Positive	Positive
Tebunginako	W0001	Kanrawa	W	11/03/2013	Positive	Positive
Tebunginako	W0012	Pureeci	W	11/03/2013	Positive	Positive

Tebunginako	W0003	Totii	W	11/03/2013	Positive	Positive
Tebunginako	W0018	Taukoriri	W	11/03/2013	Positive	Positive
Tebunginako	W0015	Taake	W	12/03/2013	Positive	Positive
Tebunginako	W0016	Tekei	W	12/03/2013	Positive	Positive
Tebunginako	W0017	Tiakenibia	W	12/03/2013	Positive	Positive
Aonobuaka	W0024	Raman	W	13/03/2013	Positive	Positive
Aonobuaka	W0025	Ariteti	W	13/03/2013	Positive	Positive
Aonobuaka	W0012	Tauntang	W	13/03/2013	Positive	Positive
Aonobuaka	W0013	Taakei	W	13/03/2013	Positive	Positive
Aonobuaka	W0010	Katama	W	13/03/2013	Positive	Positive
Aonobuaka	W0016	Teaua	W	13/03/2013	Positive	Positive
Aonobuaka	W0009	Tone	W	13/03/2013	Positive	Positive
Aonobuaka	W0014	Neitiri	W	13/03/2013	Positive	Positive
Aonobuaka	W0001	Tamori	W	13/03/2013	Positive	Positive
Aonobuaka	W0018	Arikitau	W	13/03/2013	Positive	Positive
Aonobuaka	W0011	Bwenatewa	W	13/03/2013	Positive	Positive
Aonobuaka	W0006	Catholic Church	W	13/03/2013	Positive	Positive
Aonobuaka	W0008	Rea	W	13/03/2013	Positive	Positive
Aonobuaka	W0005	Iaonta	W	13/03/2013	Positive	Positive
Aonobuaka	W0028	Braia	W	13/03/2013	Positive	Positive
Aonobuaka	T0001	Church	T	13/03/2013	Negative	Positive
Aonobuaka	W0018	Abandoned Primary School Well	W	14/03/2013	Negative	Positive
Aonobuaka	W0016	Bwebwerai	W	14/03/2013	Positive	Positive
Aonobuaka	W0020	Tinnata	W	14/03/2013	Positive	Positive
Aonobuaka	W0019	Kokoa	W	14/03/2013	Positive	Positive
Aonobuaka	W0015	Nauoku	W	14/03/2013	Positive	Positive
Aonobuaka	W0017	Teata	W	11/03/2013	Positive	Positive
Ewena	W0001	Moarite	W	15/03/2013	Positive	Positive
Ewena	W0004	Yanu	W	15/03/2013	Positive	Positive

Ewena	W0001	Teariki	W	15/03/2013	Positive	Positive
Ewena	W0008	Tauri	W	15/03/2013	Positive	Positive
Ewena	W0005	Reinarua	W	15/03/2013	Positive	Positive
Ewena	W0007	Moote	W	15/03/2013	Negative	Positive
Ewena	W0002	Living Water AOG	W	15/03/2013	Positive	Positive
Ewena	W0008	Reene	W	15/03/2013	Positive	Positive
Ewena	W0012	Kaure	W	15/03/2013	Positive	Positive
Ewena	W0003	Kitabu	W	15/03/2013	Positive	Positive
Ewena	T0002	KPC Church	T	15/03/2013	Negative	Positive
Ewena	T0001	*Maneaba*	T	15/03/2013	Positive	Positive
Ewena	W0004	Ioane	W	15/03/2013	Positive	Positive
Ewena	T0001	Moote	T	15/03/2013	Positive	Positive
Tuarabu	W0009	Terameta	W	16/03/2013	Positive	Positive
Tuarabu	T0001	Bentara	T	16/03/2013	Positive	Positive
Tuarabu	W0002	Takam	W	16/03/2013	Positive	Positive
Tuarabu	W0001	Tebweka	W	16/03/2013	Positive	Positive
Tuarabu	W0001	Tom	W	16/03/2013	Positive	Positive
Tuarabu	T0002	Tebwera	T	16/03/2013	Positive	Positive
Tuarabu	W0015	St Paul Primary School	W	16/03/2013	Positive	Positive
Tuarabu	W0014	Tingo	W	16/03/2013	Positive	Positive
Tuarabu	W0003	Tororo	W	16/03/2013	Positive	Positive
Tuarabu	W0006	Metarua	W	16/03/2013	Positive	Positive
Tuarabu	W0017	Taake	W	16/03/2013	Positive	Positive
Tuarabu	W0012	Kaueata	W	16/03/2013	Positive	Positive
Tuarabu	W0013	Tobarau	W	16/03/2013	Positive	Positive
Tuarabu	W0004	Taikin	W	16/03/2013	Positive	Positive
Tuarabu	W0004	Bentara	W	16/03/2013	Positive	Positive
Tuarabu	T0001	Catholic *Maneaba* Tank	T	18/03/2013	Positive	Positive
Tuarabu	W0016	Taloa	W	18/03/2013	Positive	Positive

Tuarabu	W0001	Takabea	W	18/03/2013	Positive	Positive
Tuarabu	W0006	Secondary School Well	W	18/03/2013	Positive	Positive
Tuarabu	W0025	Pokati	W	18/03/2013	Positive	Positive
Tuarabu	W0014	Tekimwa	W	18/03/2013	Positive	Positive
Tuarabu	W0018	Bauro	W	18/03/2013	Positive	Positive
Tuarabu	T0003	School Tank	T	18/03/2013	Positive	Positive
Tuarabu	W0029	Kaiaba	W	18/03/2013	Positive	Positive
Tuarabu	W0035	Buto	W	18/03/2013	Positive	Positive
Tuarabu	W0014	Saint Joseph College School	W	18/03/2013	Positive	Positive
Tuarabu	W0015	Pauro	W	18/03/2013	Positive	Positive
Tuarabu	W0012	Saint Joseph College	W	18/03/2013	Positive	Positive
Tuarabu	T0003	Saint Joseph College	T	18/03/2013	Negative	Positive
Tuarabu	W0002	Paulo	W	18/03/2013	Positive	Positive
Tuarabu	T0013	Saint Joseph College	W	18/03/2013	Positive	Positive
Tuarabu	W0007	Saint Joseph College Church	W	18/03/2013	Positive	Positive
Tuarabu	T0014	School Guesthouse	T	18/03/2013	Positive	Positive
Tuarabu	T0001	Saint Joseph College	T	18/03/2013	Positive	Positive
Tuarabu	W0010	Saint Joseph College	W	18/03/2013	Positive	Positive
Tuarabu	W0002	Saint Joseph College Quarters 5	W	19/03/2013	Positive	Positive
Tuarabu	T0001	Matron	T	19/03/2013	Positive	Positive
Tuarabu	W0004	Pwereka	W	19/03/2013	Positive	Positive
Tuarabu	W0001	Matron	W	19/03/2013	Positive	Positive
Taniau	T0001	Aubike Clinic	T	20/03/2013	Positive	Positive
Taniau	W0015	Teraing	W	20/03/2013	Positive	Positive
Taniau	W0005	Tutu	T	20/03/2013	Positive	Positive
Taniau	W0004	Catholic Priest	W	20/03/2013	Positive	Positive
Taniau	W0009	Tetaake	W	20/03/2013	Positive	Positive
Taniau	W0007	Nabure	W	20/03/2013	Positive	Positive
Taniau	W0006	Nami	W	20/03/2013	Negative	Positive

Taniau	W0002	Primary School Well	W	20/03/2013	Positive	Positive
Taniau	W0011	Teman	W	20/03/2013	Positive	Positive
Taniau	W0025	Karowe	W	20/03/2013	Positive	Positive
Taniau	W0001	Rubetaiti	W	20/03/2013	Positive	Positive
Taniau	W0030	Arikata	W	20/03/2013	Negative	Positive

Annex 6

Abaiang Village Water Resources Assessment Maps

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

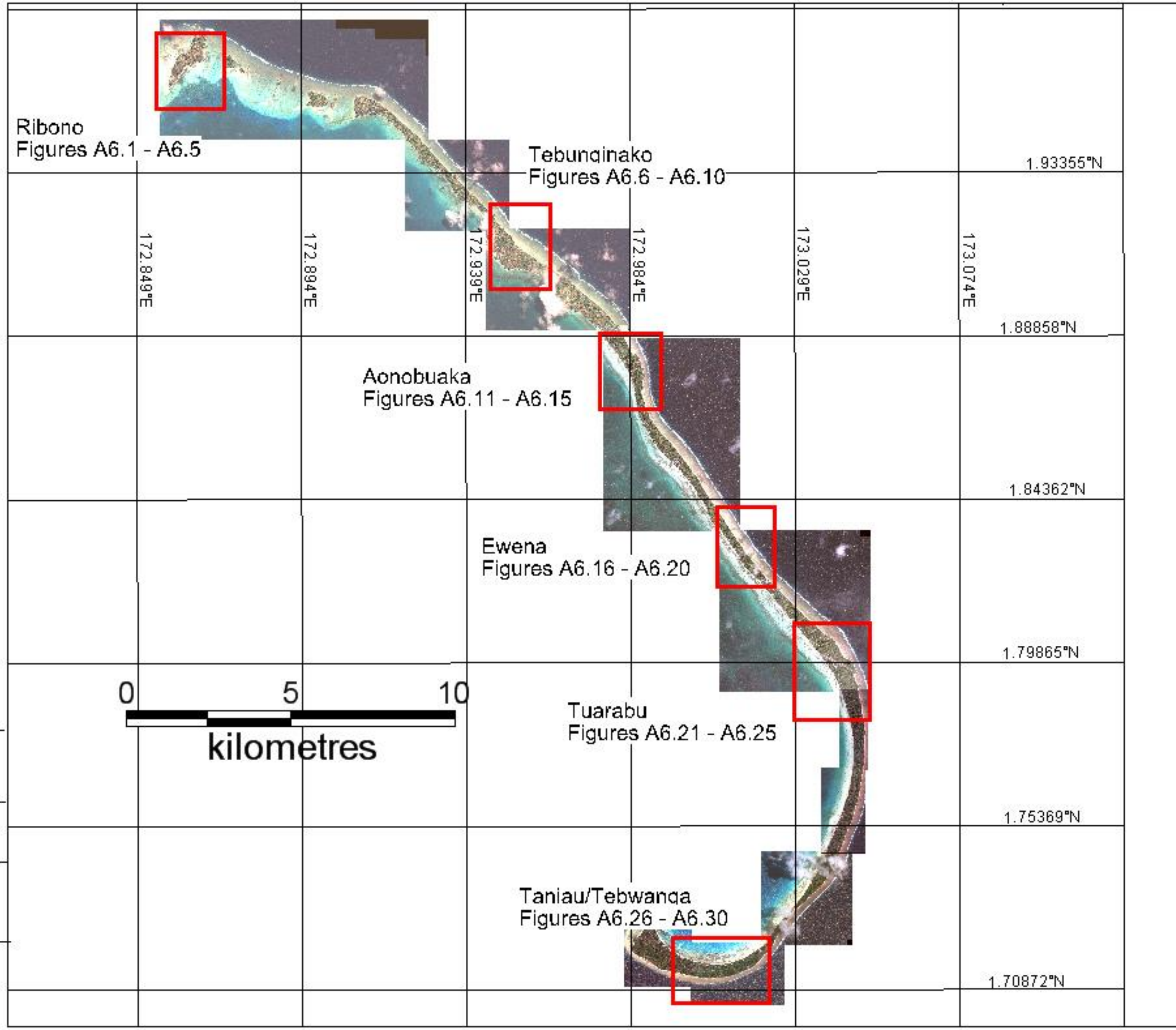
- a survey map, showing the locations of buildings, storage tanks, EM34 traverse lines and household wells within the target village area – a distinction is made between freshwater and saline wells based on the 2.5 mS/cm cut-off limit.
- Target rainwater harvesting buildings map showing communal buildings which have potential for rainwater harvesting.
- CTD diver location map showing selected wells in the villages where the data loggers were installed for water level, conductivity and temperature monitoring.
- Freshwater lens map showing the 2.5 m-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 tested wells and rainwater tanks (using IDEXX Colilert 18 presence/absence 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 – ABAIANG ATOLL INDEX MAP

GILBERT GROUP



LEGEND:

- Abaiang Atoll
- WRA target villages

NOTES

* index of target village maps

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Abaiang Atoll Index Map

Figure A6.1 – RIBONO, ABAIANG – WATER RESOURCES SURVEY MAP

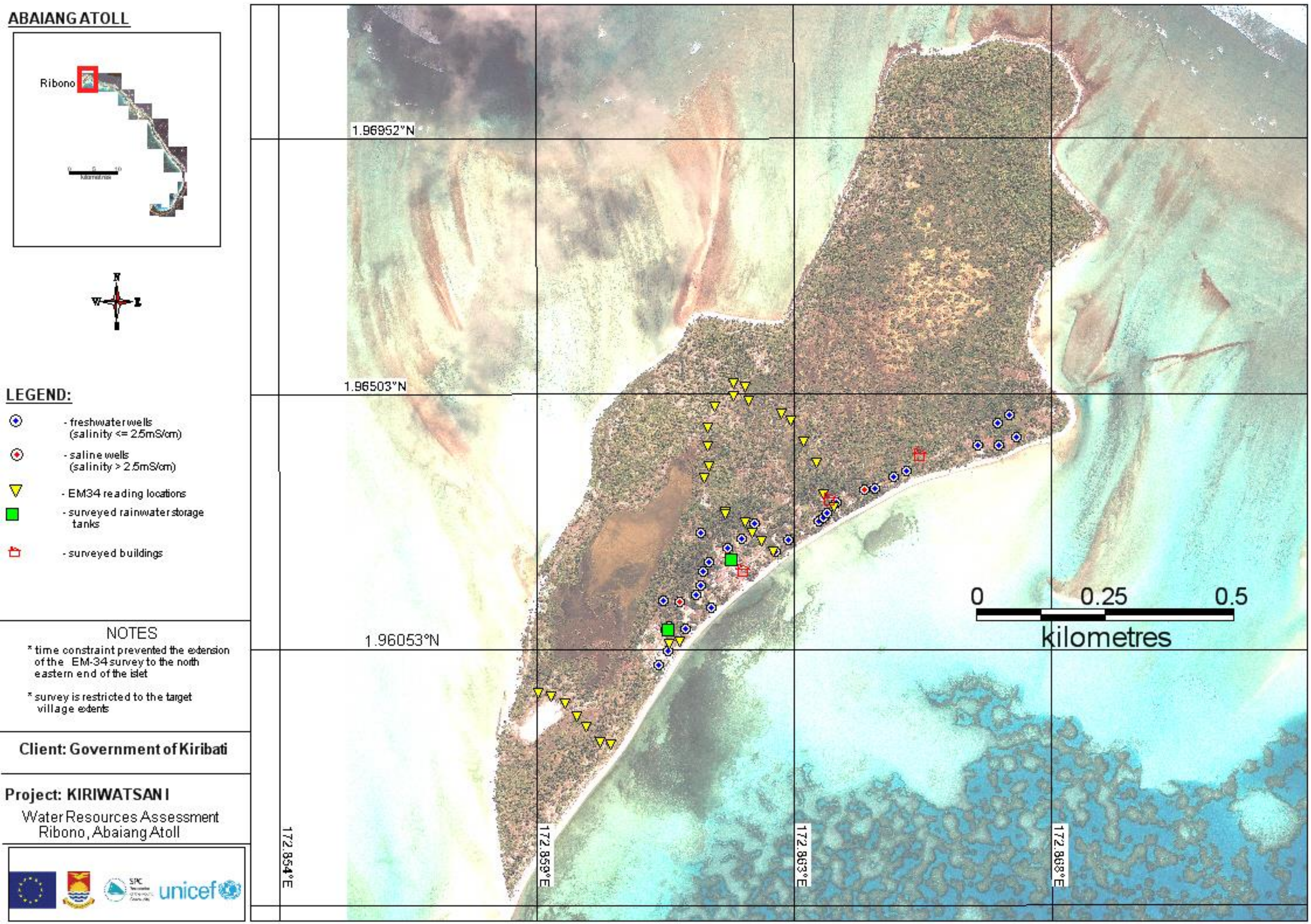


Figure A6.2 – RIBONO, ABAIANG – TARGET COMMUNAL BUILDING FOR RWH

ABAIANG ATOLL

LEGEND:

- surveyed buildings

NOTES

- Communal buildings with existing permanent roof materials selected for rainwater harvesting support
- Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Ribono, Abaiang Atoll

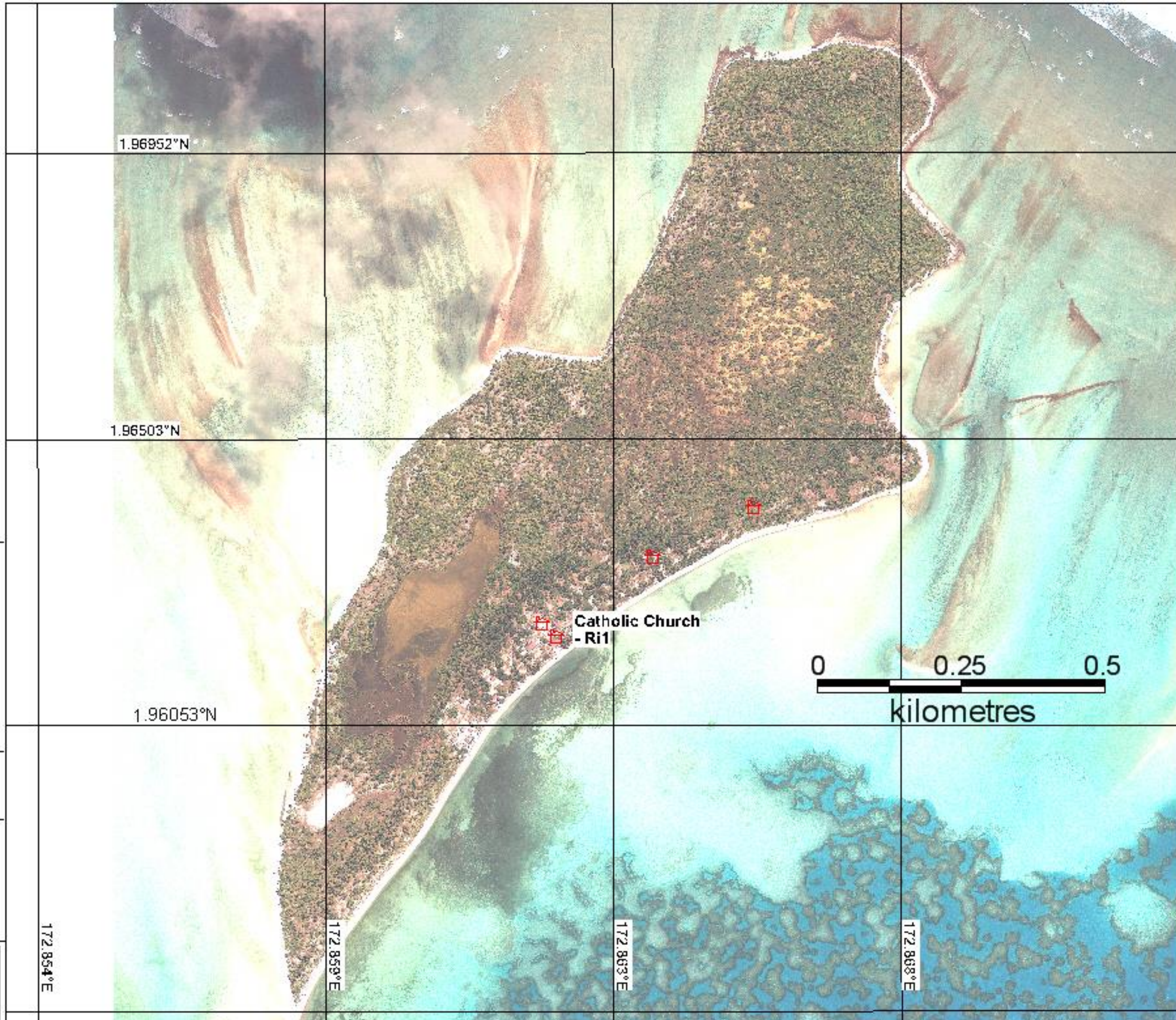


Figure A6.3 – RIBONO, ABAIANG – CTD DIVER LOCATIONS

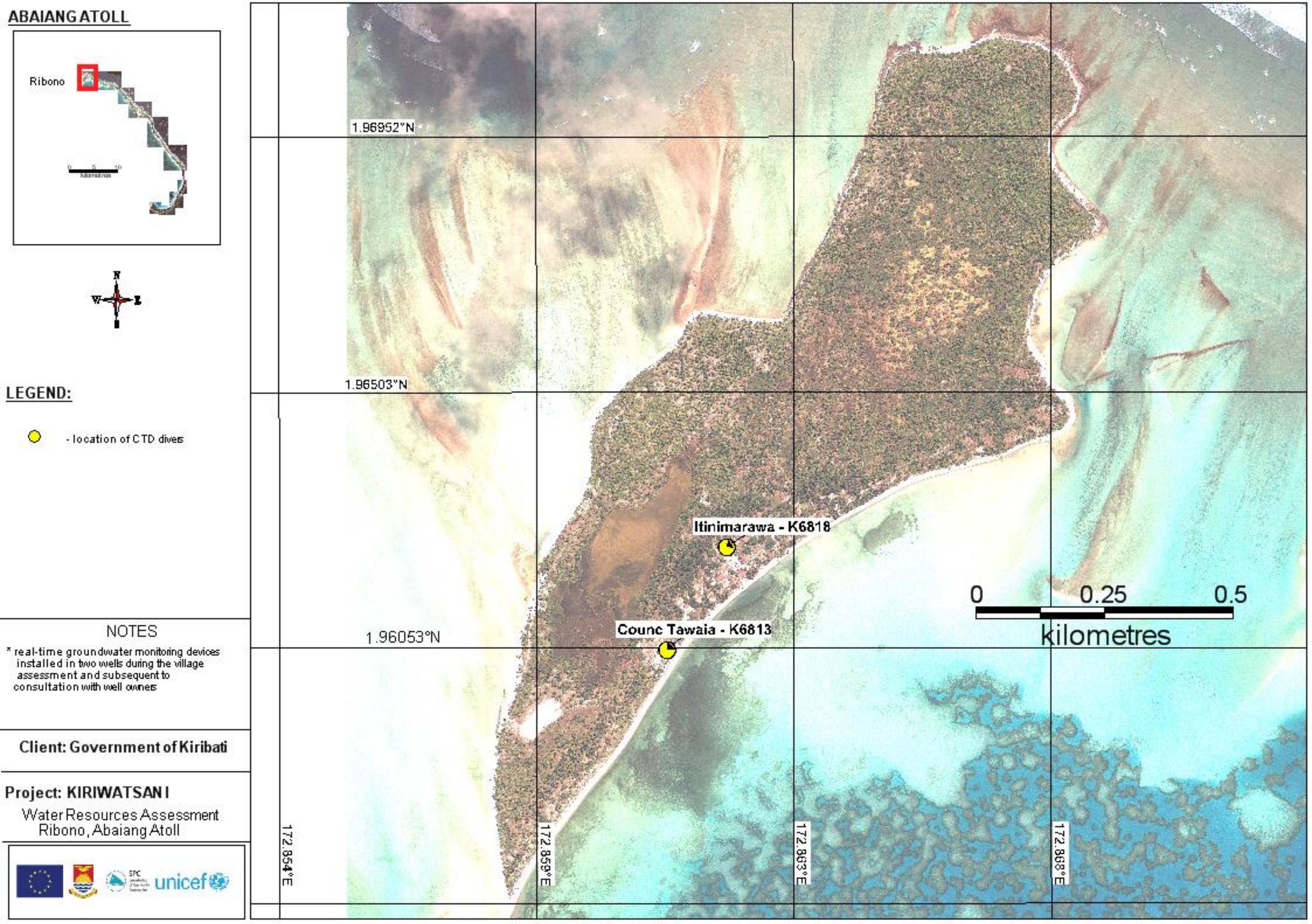


Figure A6.4 – RIBONO, ABAIANG – FRESH GROUNDWATER LENS POTENTIAL

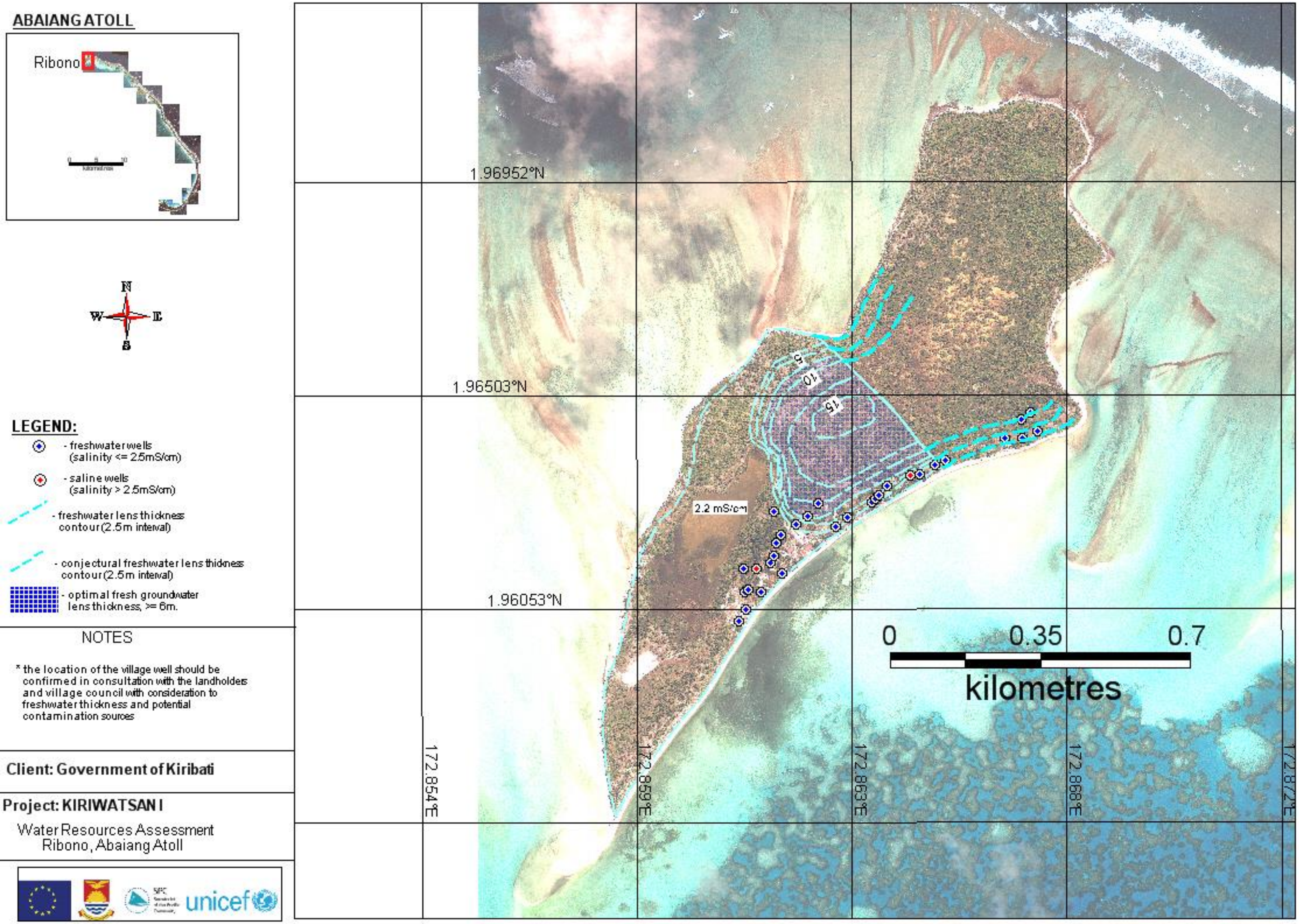


Figure A6.5 – RIBONO, ABAIANG – BACTERIOLOGICAL SAMPLING

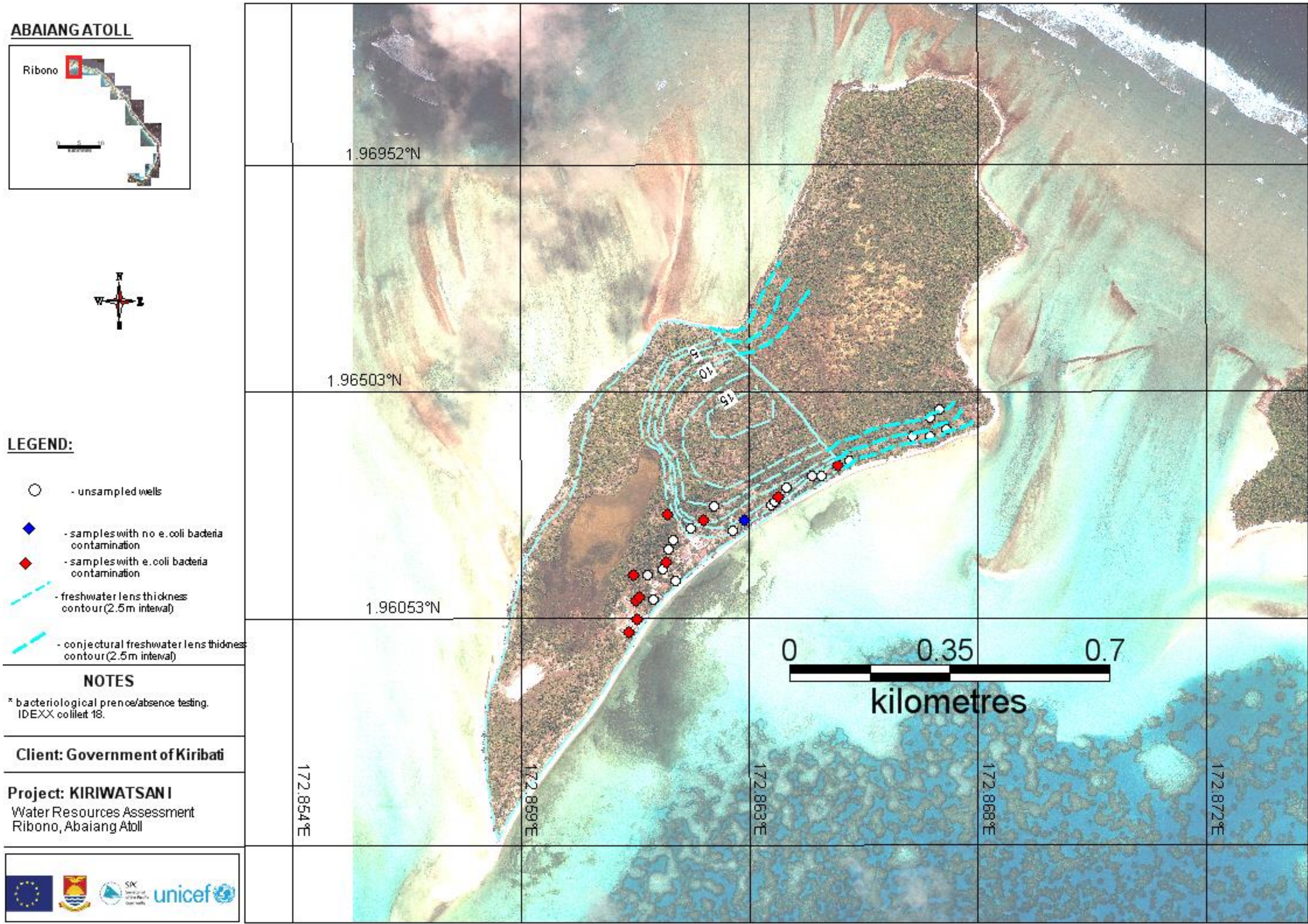


Figure A6.6 – TEBUNGINAKO, ABAIANG WATER RESOURCES SURVEY MAP

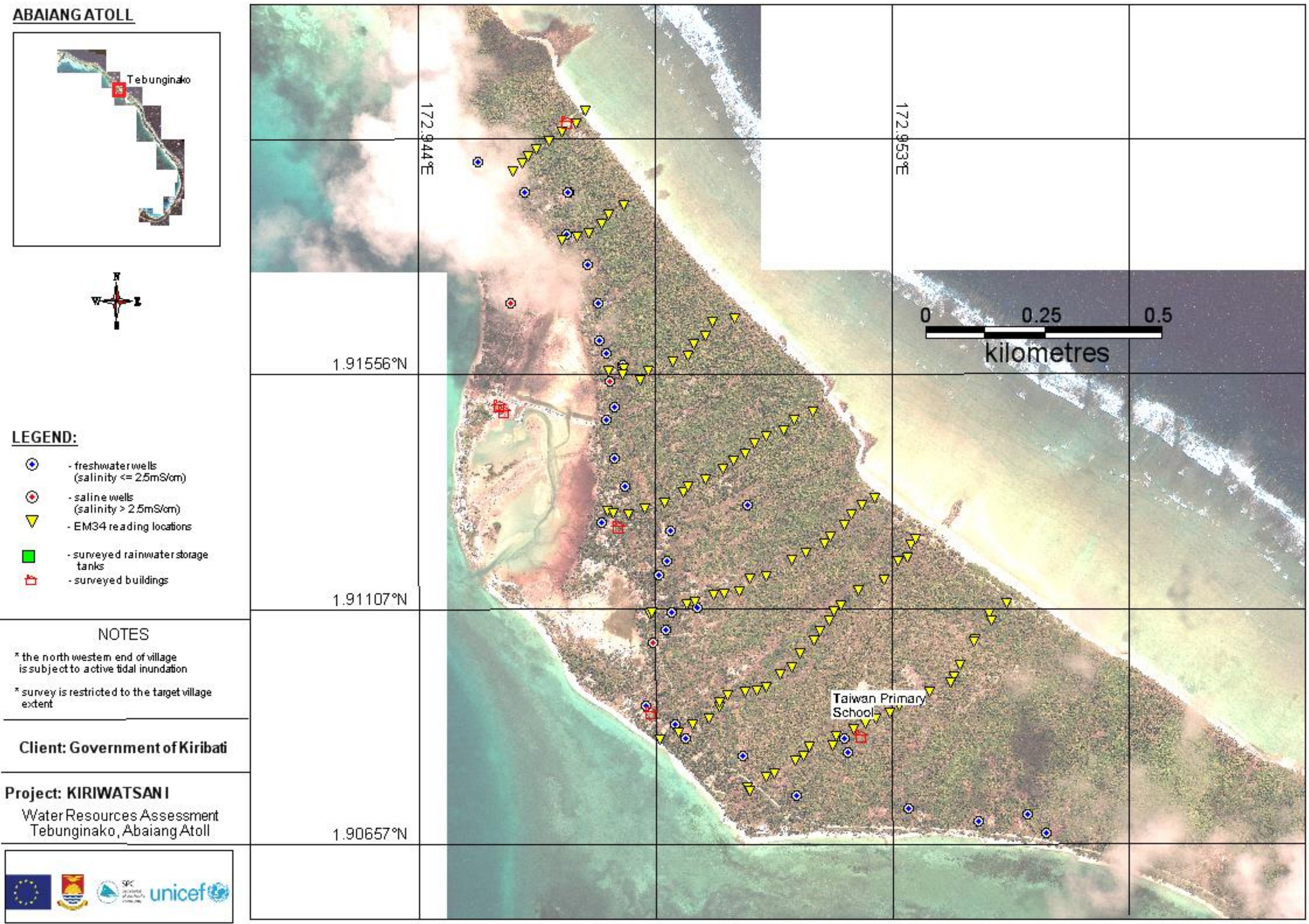
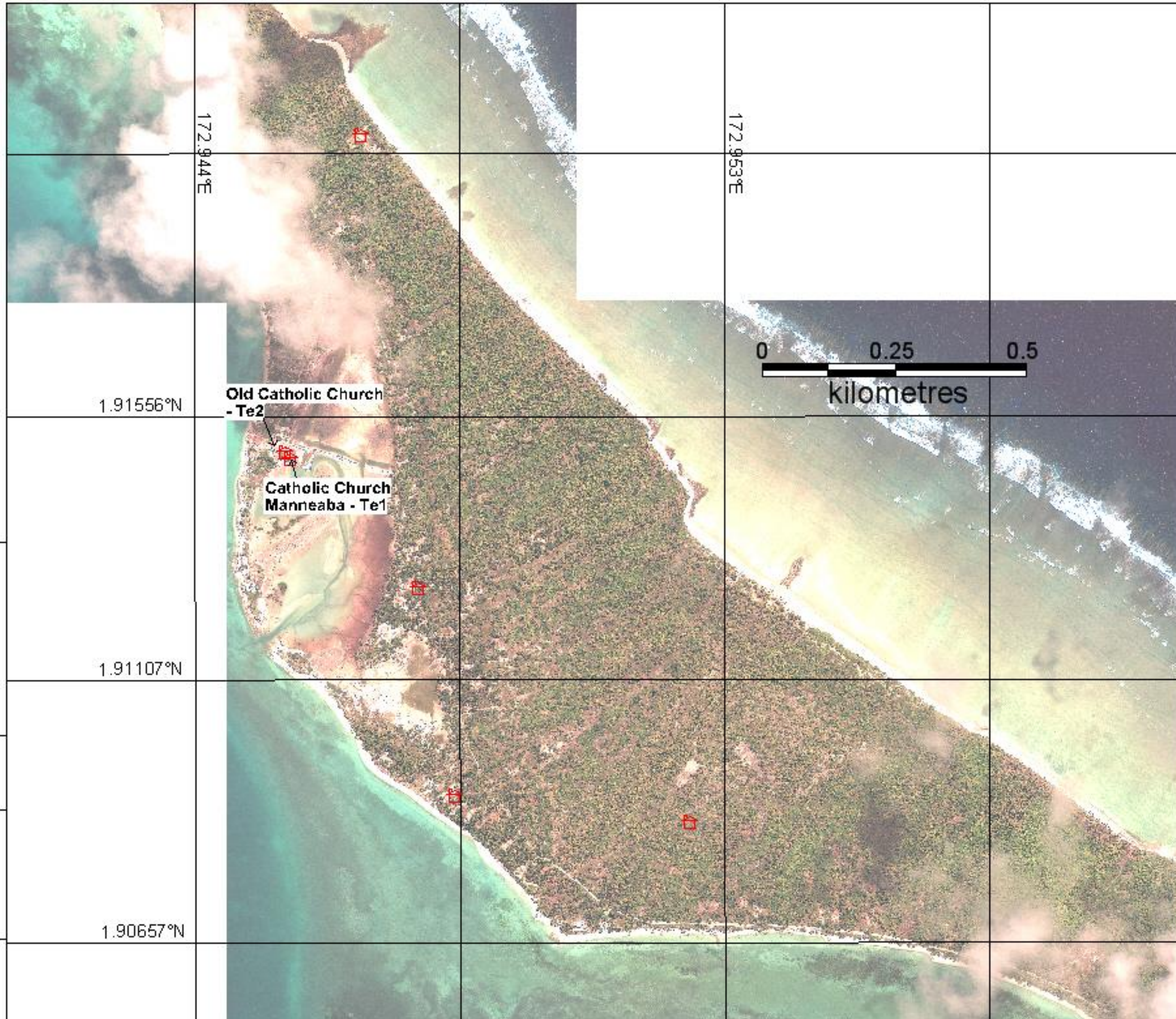


Figure A6.7 – TEBUNGINAKO, ABAIANG TARGET COMMUNAL BUILDING FOR RWH

ABAIANG ATOLL



LEGEND:

- surveyed buildings

NOTES

- Communal buildings with existing permanent roof materials selected for rainwater harvesting support
- Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

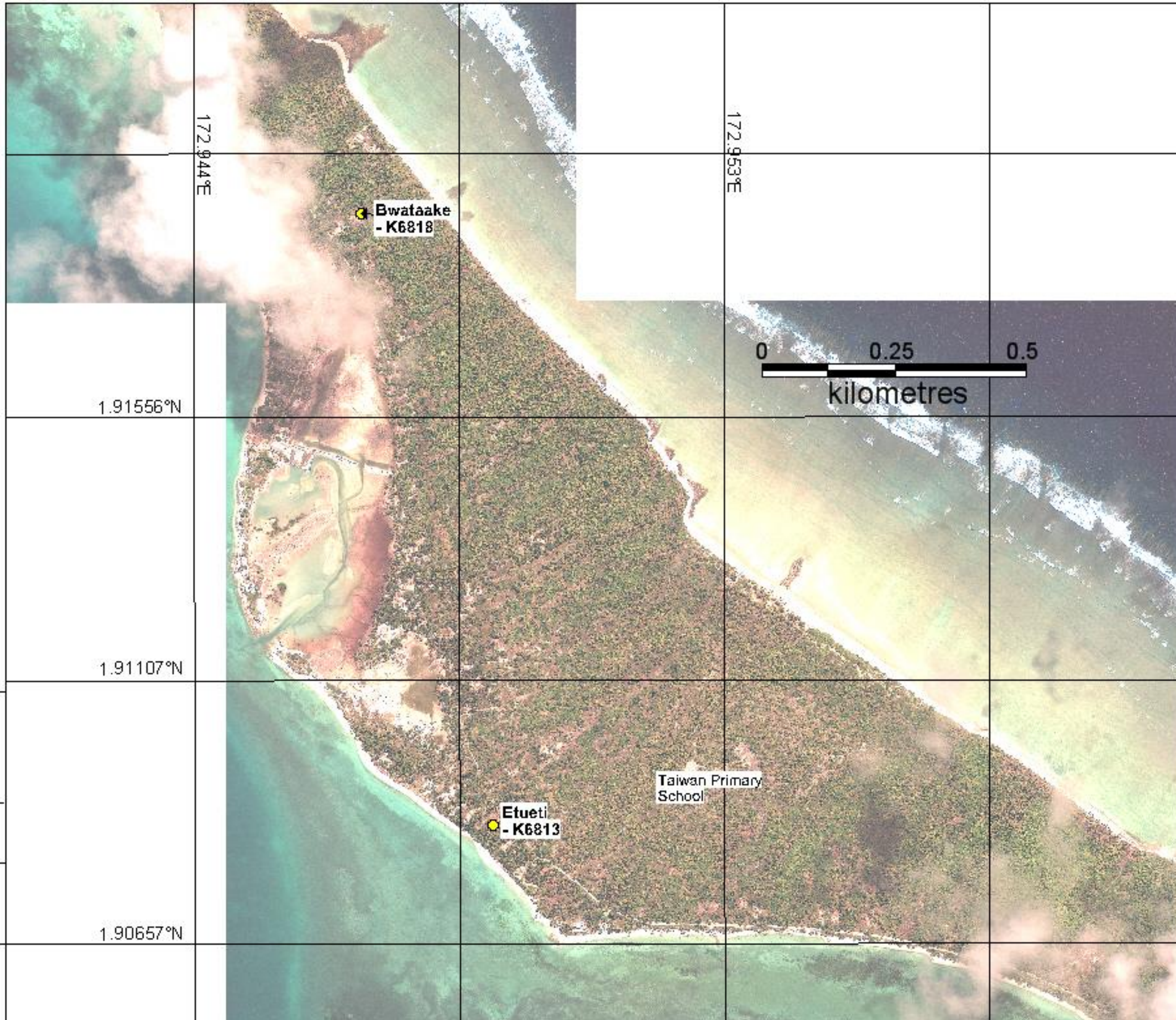
Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Tebunginako, Abaiang Atoll

Figure A6.8 – TEBUNGINAKO, ABAIANG CTD DIVER LOCATIONS

ABAIANG ATOLL



LEGEND:

- location of CTD divers

NOTES

* real-time groundwater monitoring devices installed in two wells during the village assessment and subsequent to consultation with well owners

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Tebunginako, Abaiang Atoll

Figure A6.9 – TEBUNGINAKO, ABAIANG – WATER RESOURCES SURVEY MAP

ABAIANG ATOLL

LEGEND:

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

NOTES

* the location of the village well 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
Tebunginako, Abaiang Atoll

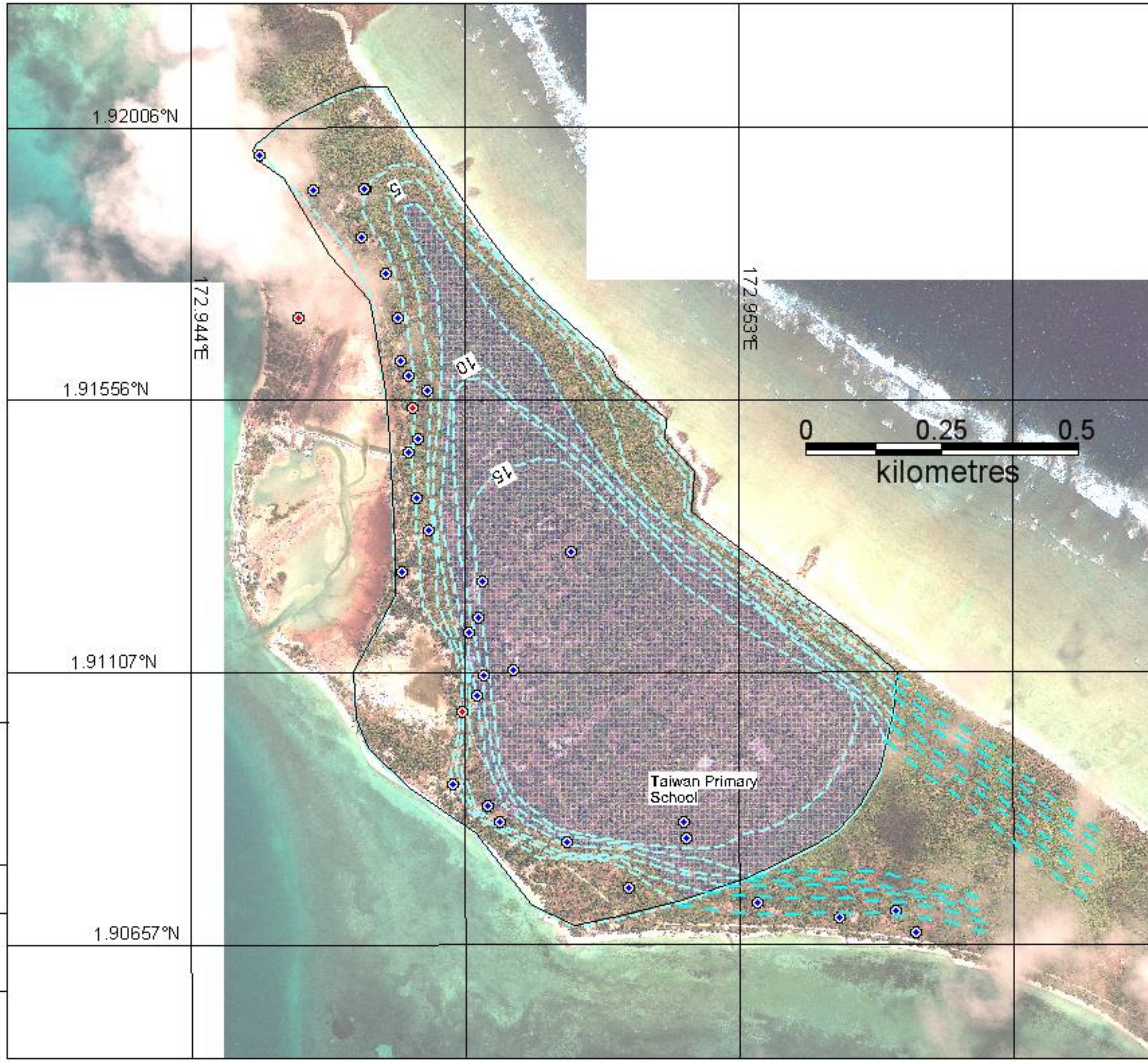


Figure A6.10 – TEBUNGINAKO, ABAIANG WATER BACTERIOLOGICAL SAMPLING

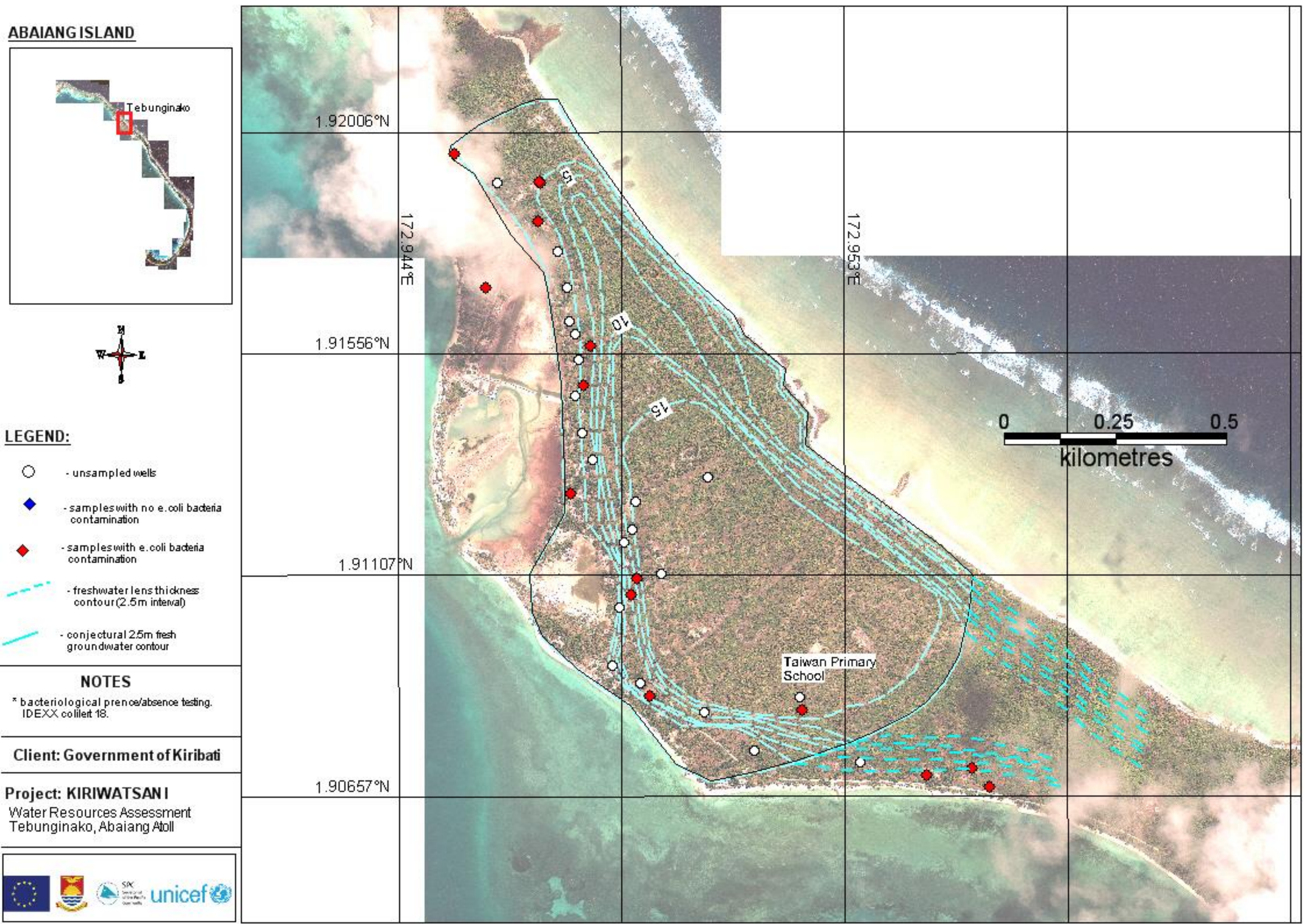
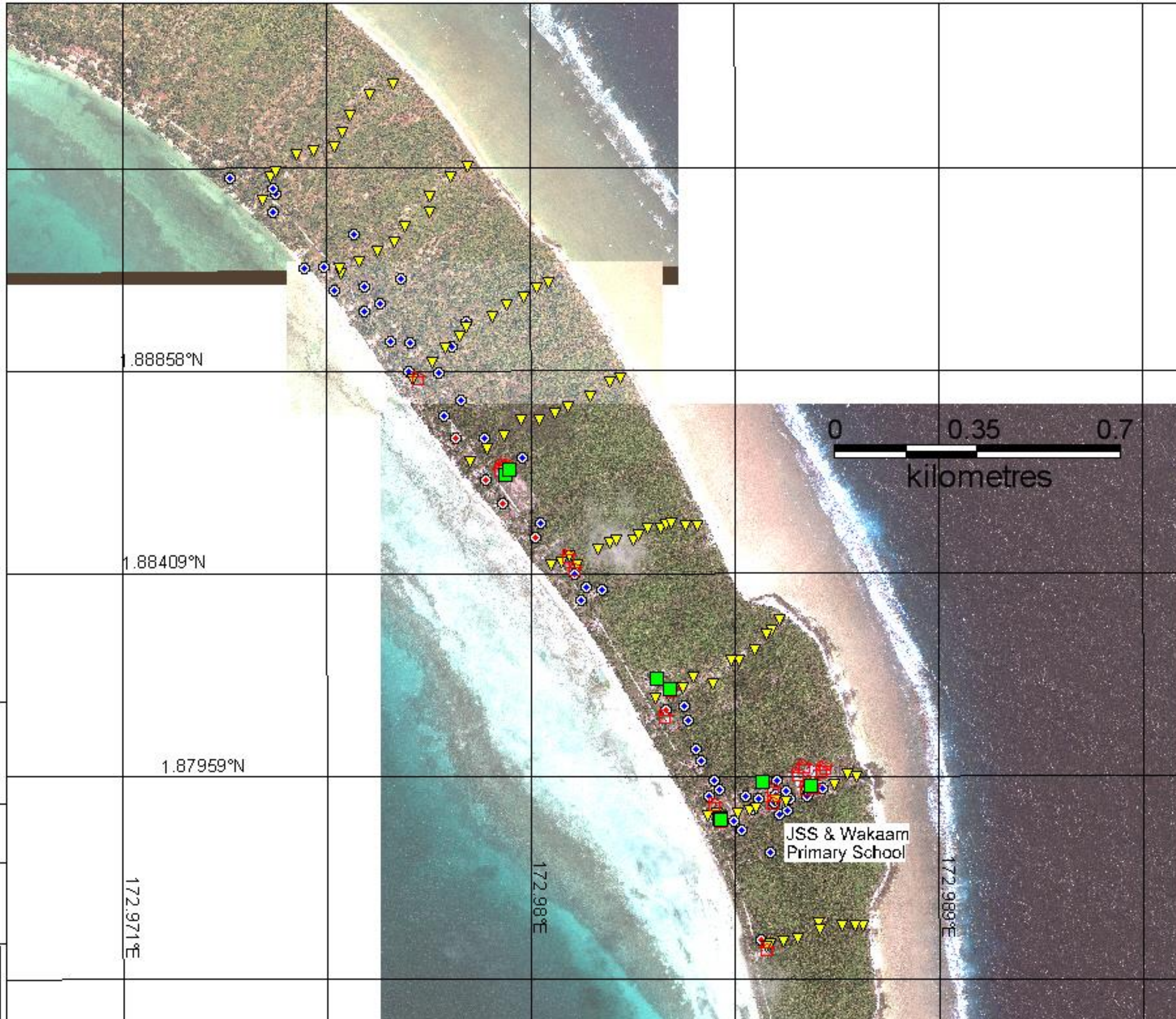


Figure A6.11 – AONOBUAKA, ABAIANG WATER RESOURCES SURVEY MAP

ABAIANG ATOLL



LEGEND:

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

NOTES

*Abaiang JSS & Wakaam Primary School were also surveyed

*survey is restricted to the target village extents

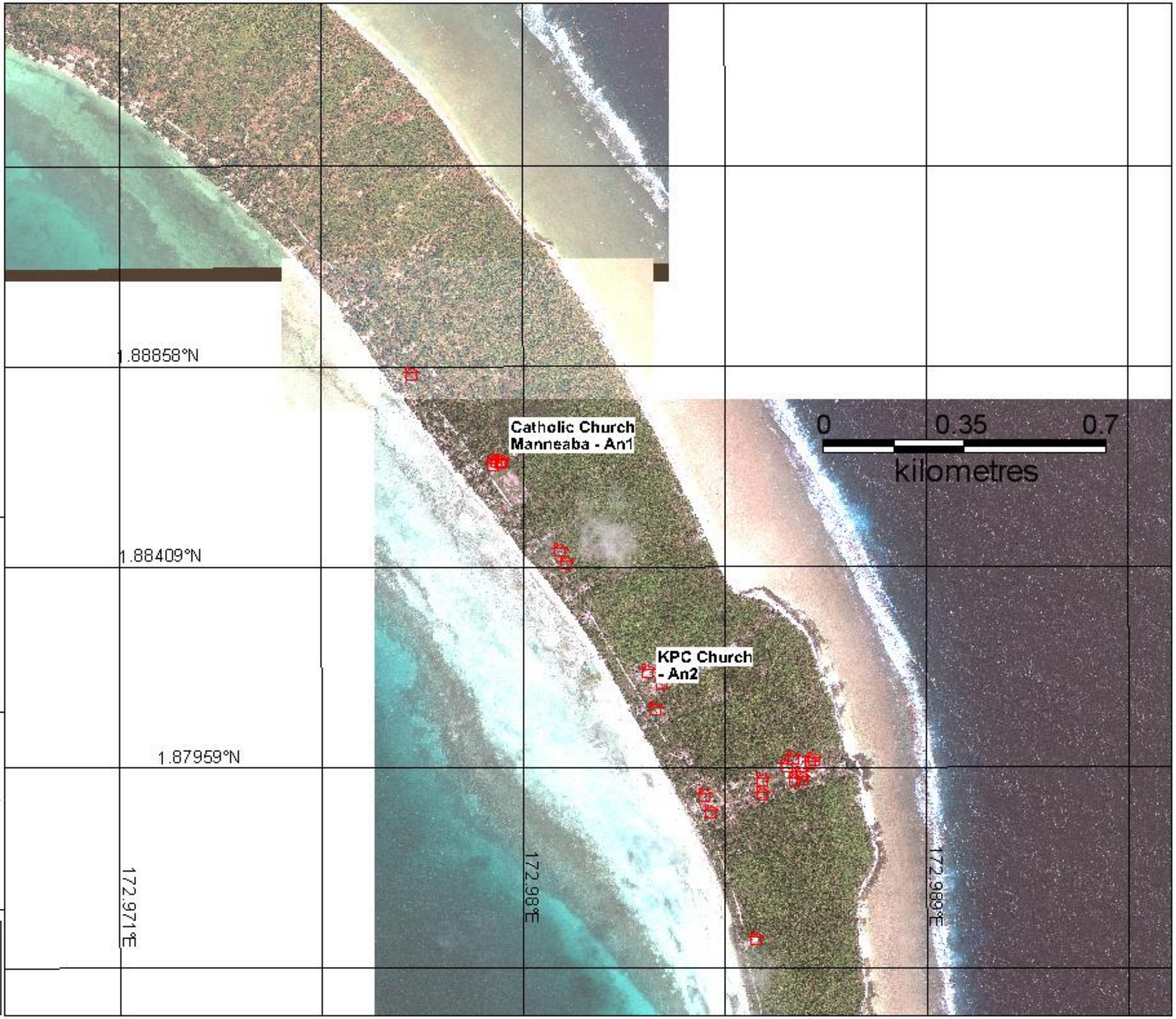
Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Aonobuaka, Abaiang Atoll

Figure A6.12 – AONOBUAKA, ABAIANG TARGET COMMUNAL BUILDINGS FOR RWH

ABAIANG ATOLL



LEGEND:

- surveyed buildings

NOTES

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

- Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Aonobuaka, Abaiang Atoll

Figure A6.13 – AONOBUAKA, ABAIANG CTD DIVER LOCATIONS

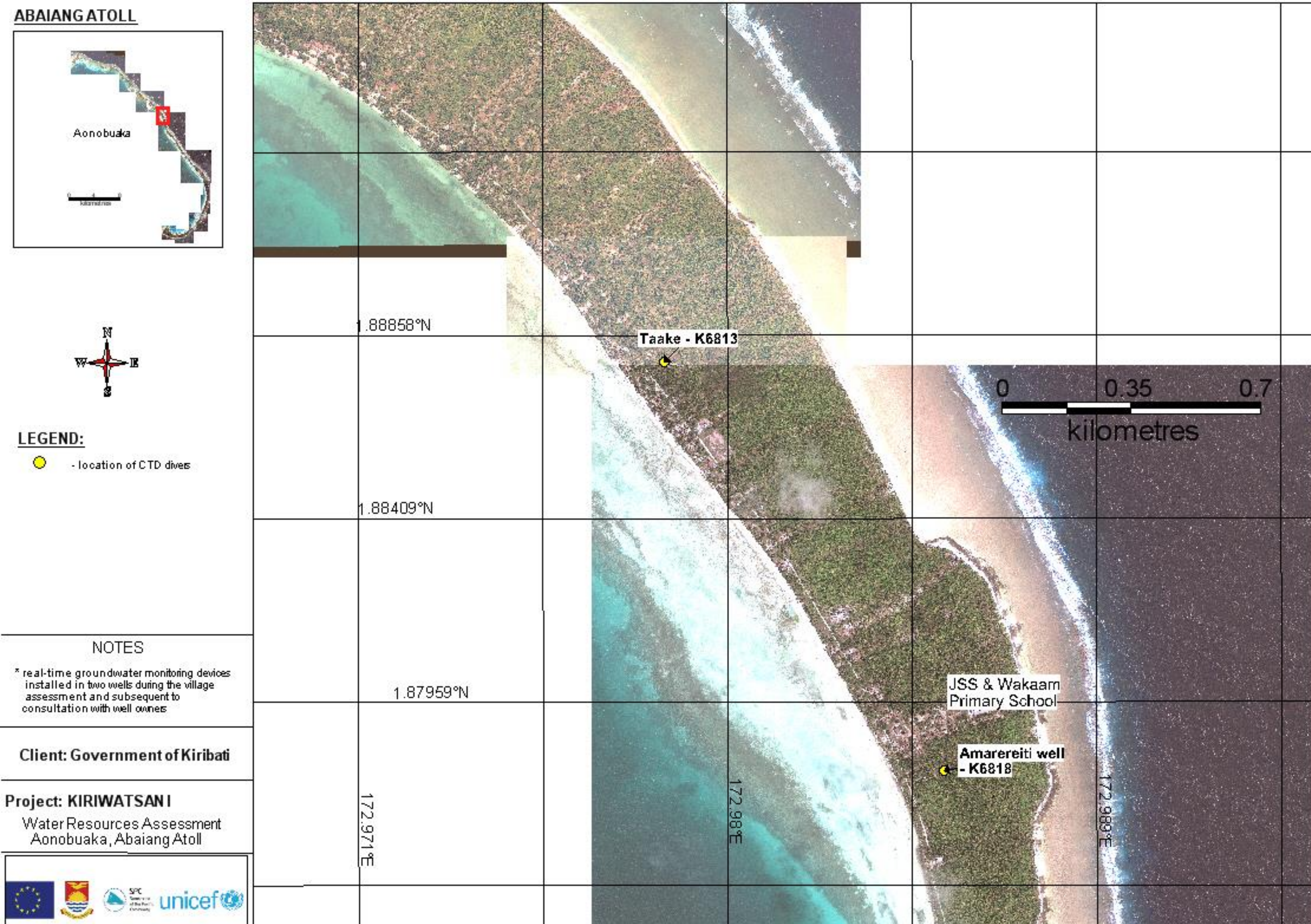
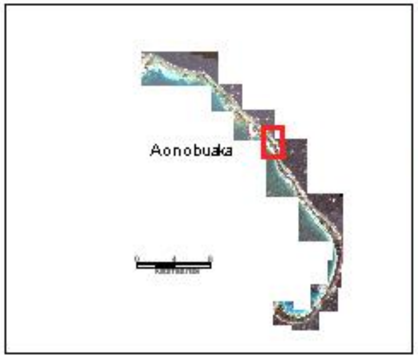


Figure A6.14 – AONOBUAKA, ABAIANG FRESH GROUNDWATER LENS PONTENTIAL

ABAIANG 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

NOTES

* the location of the village well 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
Aonobuaka, Abaiang Atoll

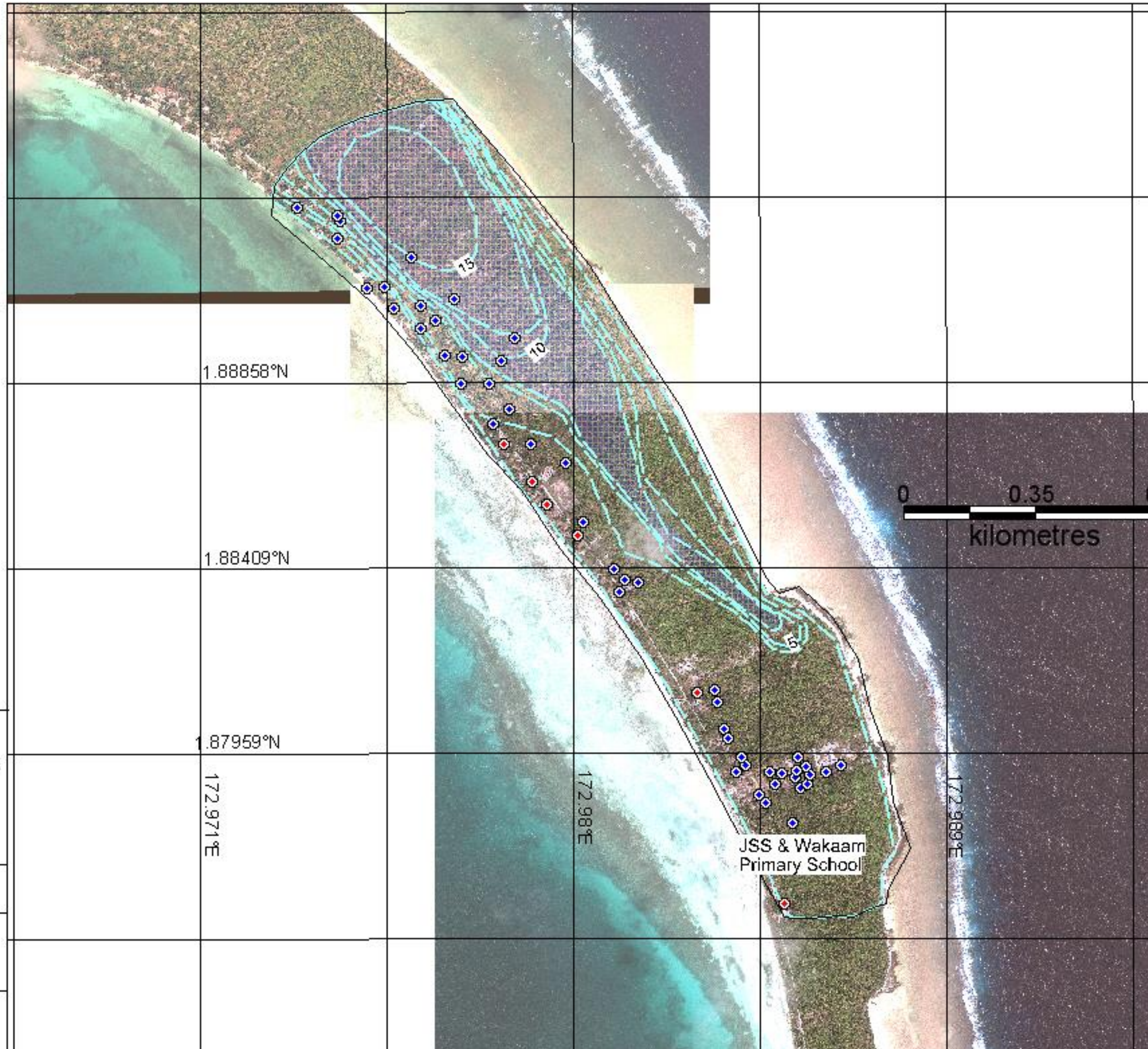
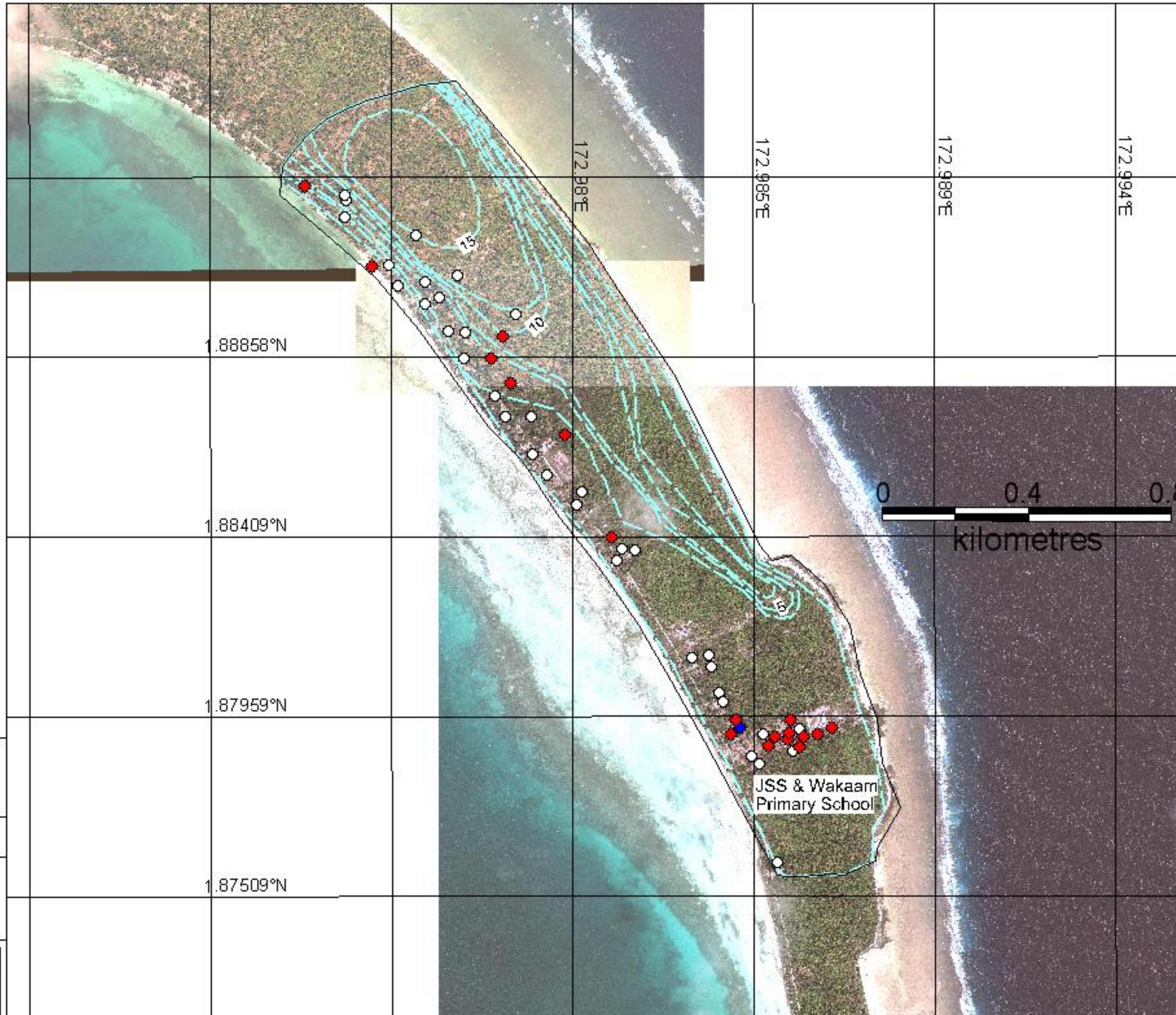


Figure A6.15 – AONOBUAKA, ABAIANG BACTERIOLOGICAL SAMPLING

ABAIANG ATOLL



LEGEND:

- unsampled wells
- samples with no e.coli bacteria contamination
- samples with e.coli bacteria contamination
- freshwater lens thickness contour (2.5m interval)

NOTES

* bacteriological prence/absence testing. IDEXX colilert 18.

Client: Government of Kiribati

Project: KIRIWATSAN I
Water Resources Assessment
Aonobuaka, Abaiang Atoll

Figure A6.16 – EWENA, ABAIANG – WATER RESOURCES SURVEY MAP

ABAIANG ATOLL

LEGEND:

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

NOTES

* survey is restricted to the target village extent

Client: Government of Kiribati

Project: KIRIWATSAN I
Water Resources Assessment
Ewena, Abaiang Atoll

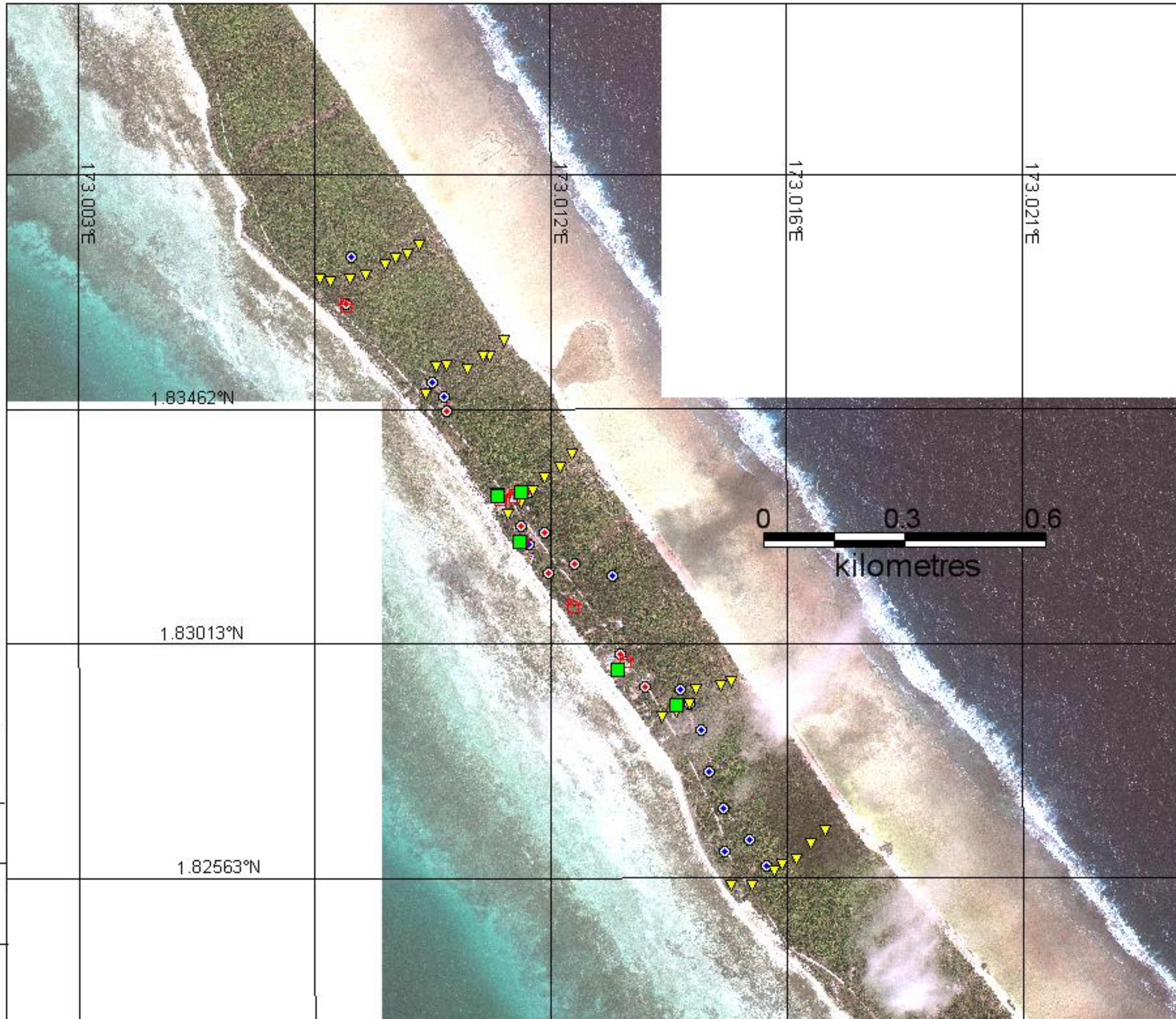


Figure A6.17 – EWENA, ABAIANG TARGET COMMUNAL BUILDINGS FOR RWH

ABAIANG ATOLL

LEGEND:

- surveyed buildings

NOTES

- Communal buildings with existing permanent roof materials selected for rainwater harvesting support
- Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Ewena, Abaiang Atoll

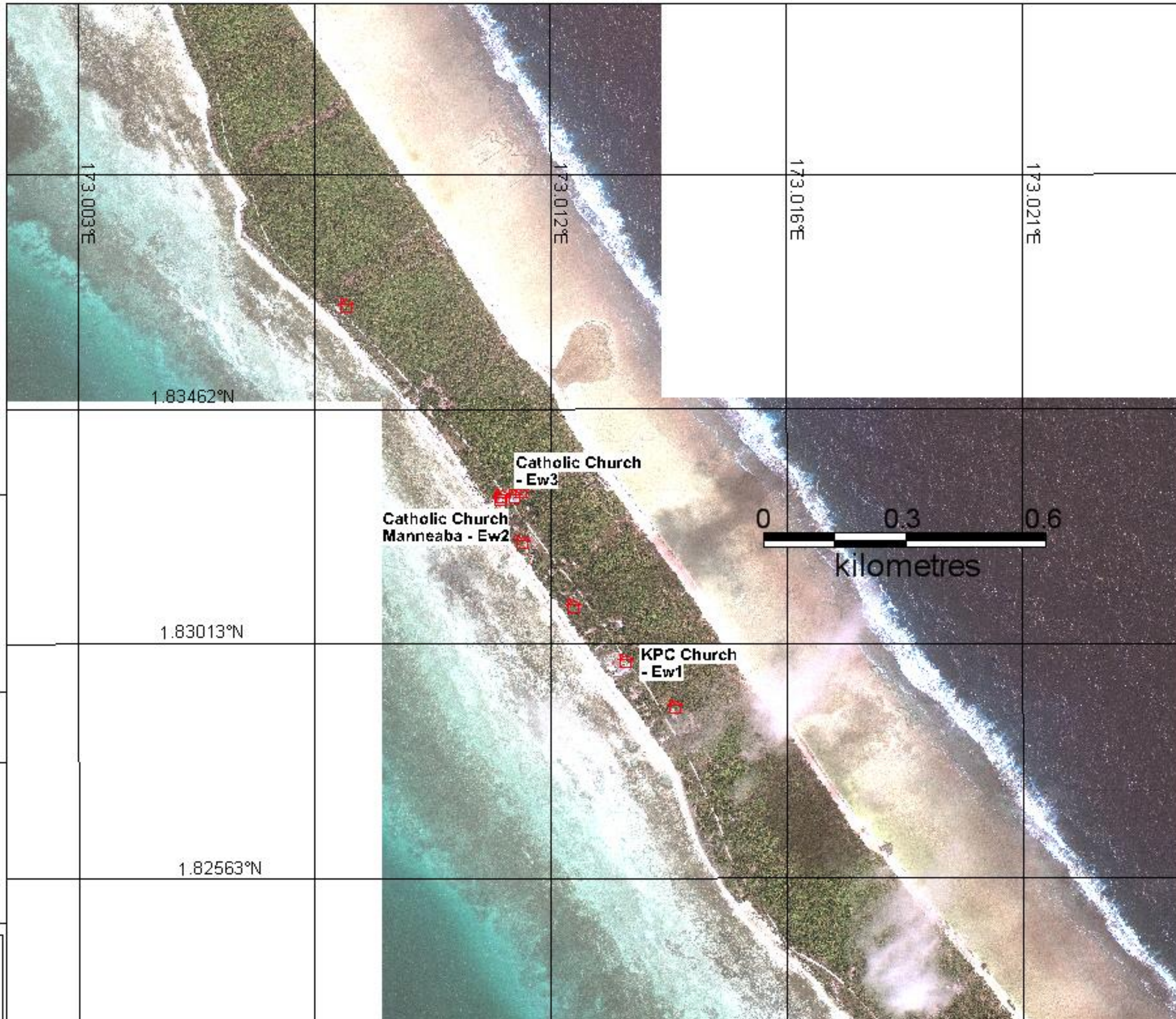


Figure A6.18 – EWENA, ABAIANG CTD DIVER LOCATIONS

ABAIANG ATOLL

LEGEND:

- location of CTD divers

NOTES

* real-time groundwater monitoring devices installed in two wells during the village assessment and subsequent to consultation with well owners

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Ewena, Abaiang Atoll

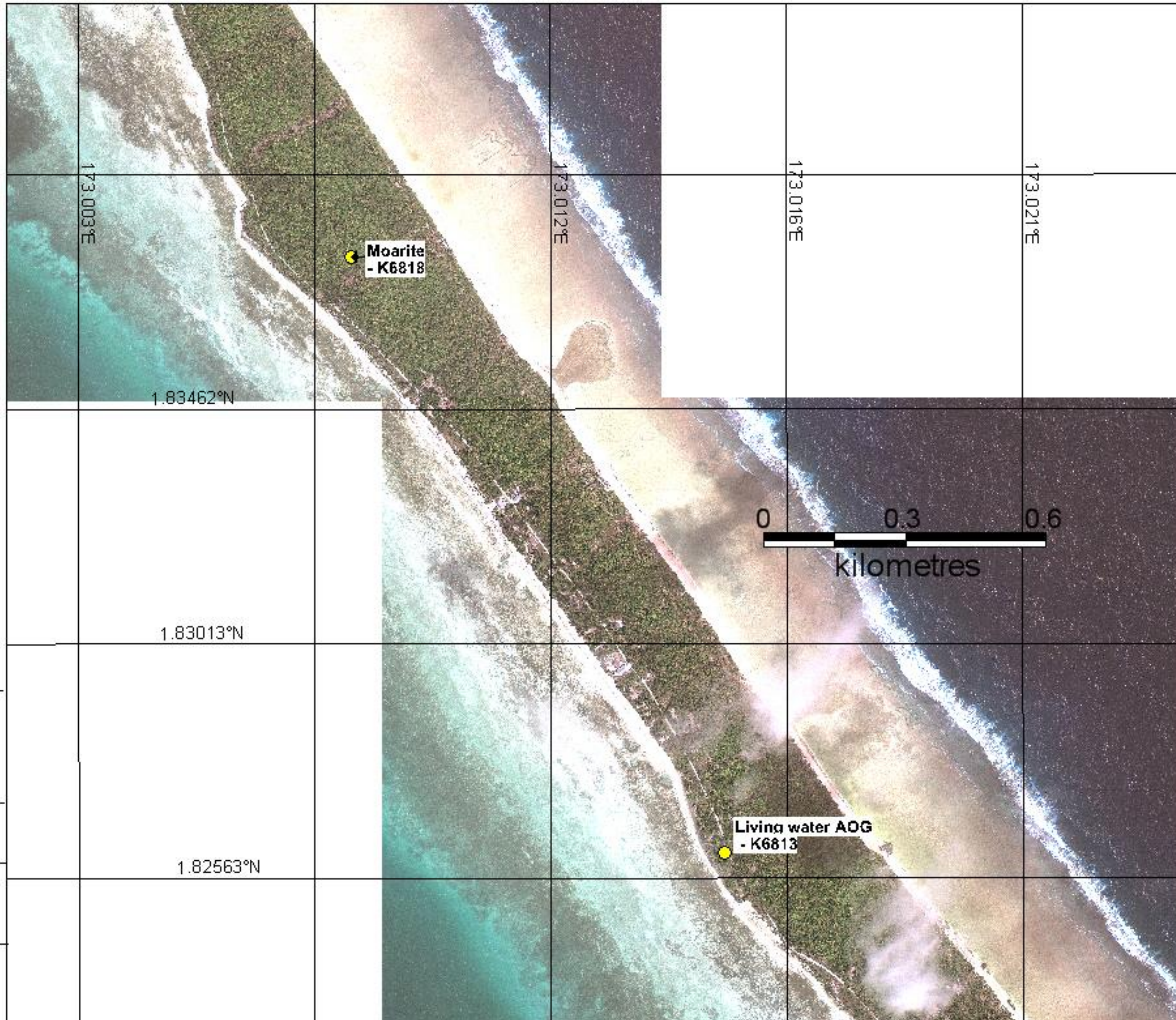


Figure A6.19 – EWENA, ABAIANG FRESH GROUNDWATER LENS POTENTIAL

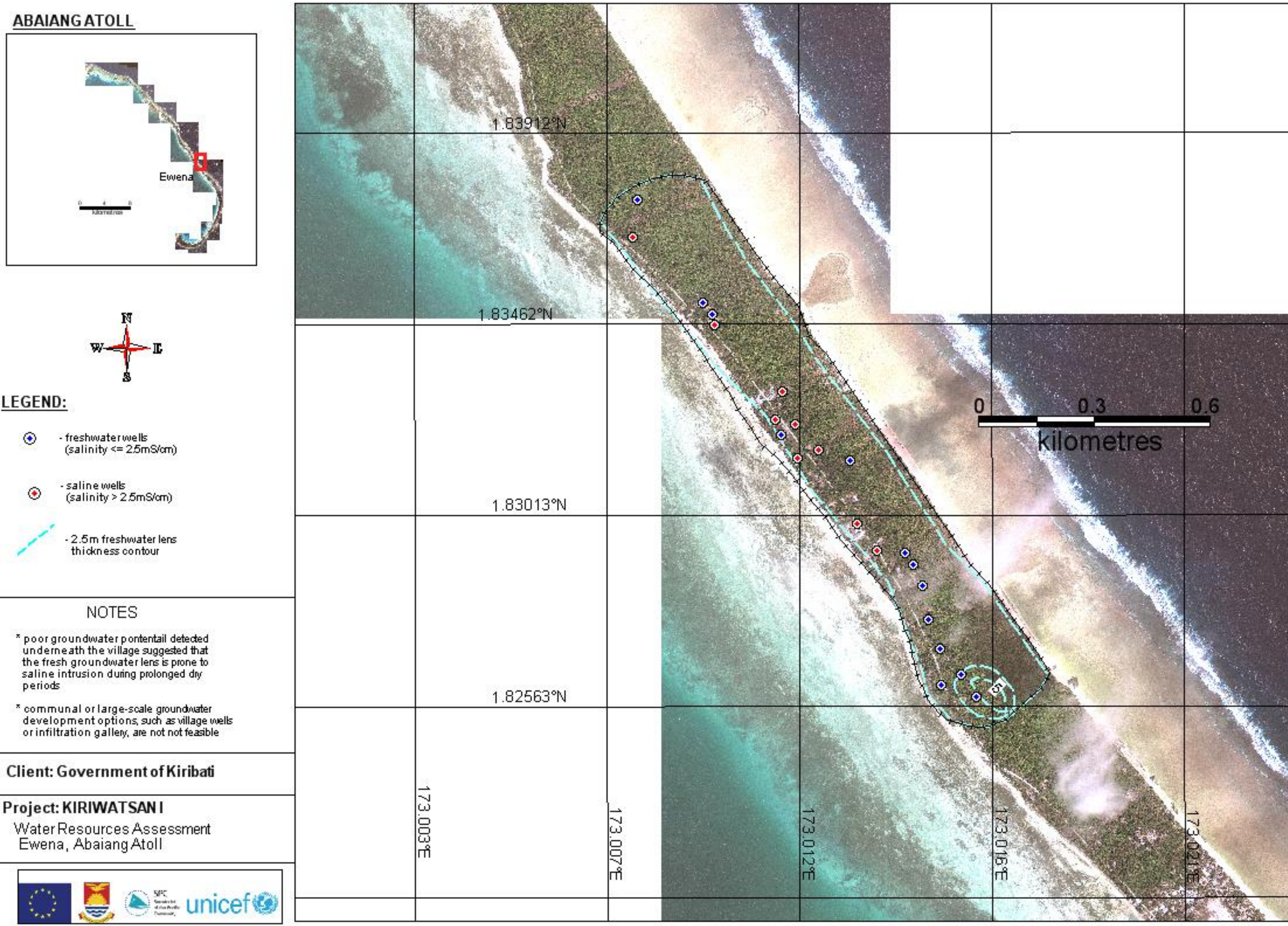


Figure A6.20 – EWENA, ABAIANG – BACTERIOLOGICAL SAMPLING

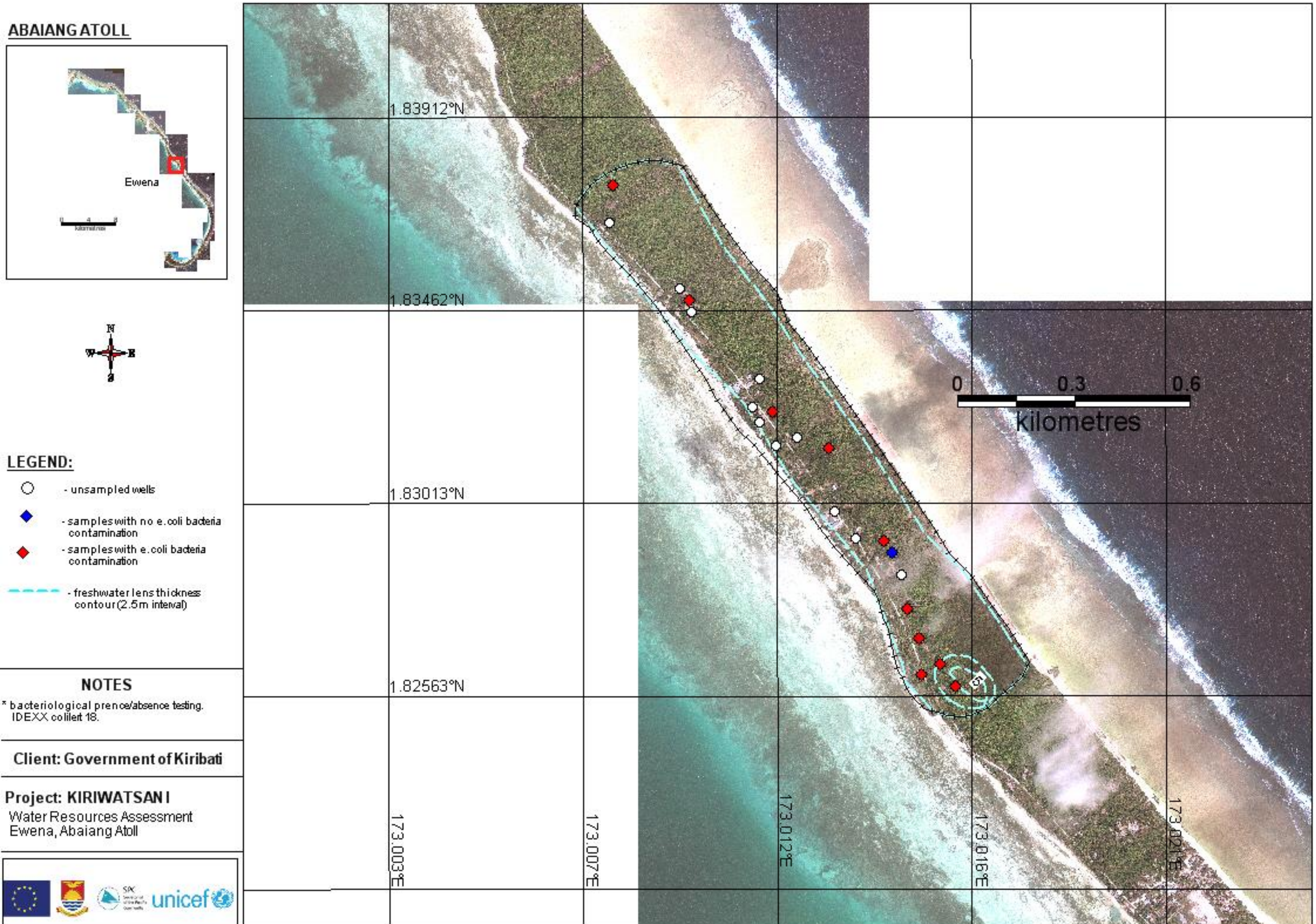


Figure A6.21 – TUARABU, ABAIANG WATER RESOURCES SURVEY MAP

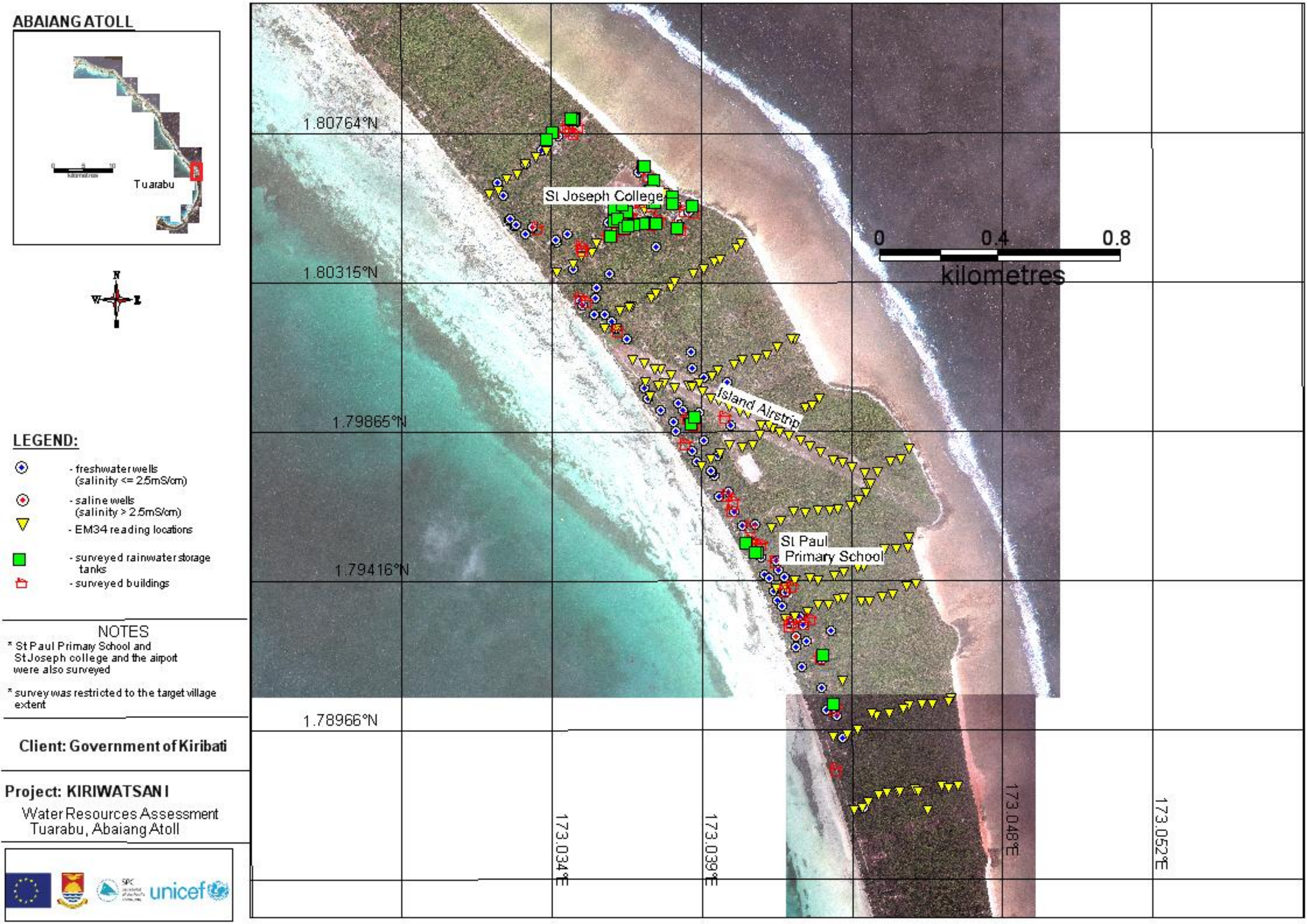


Figure A6.22 – TUARABU, ABAIANG TARGET COMMUNAL BUILDINGS FOR RWH

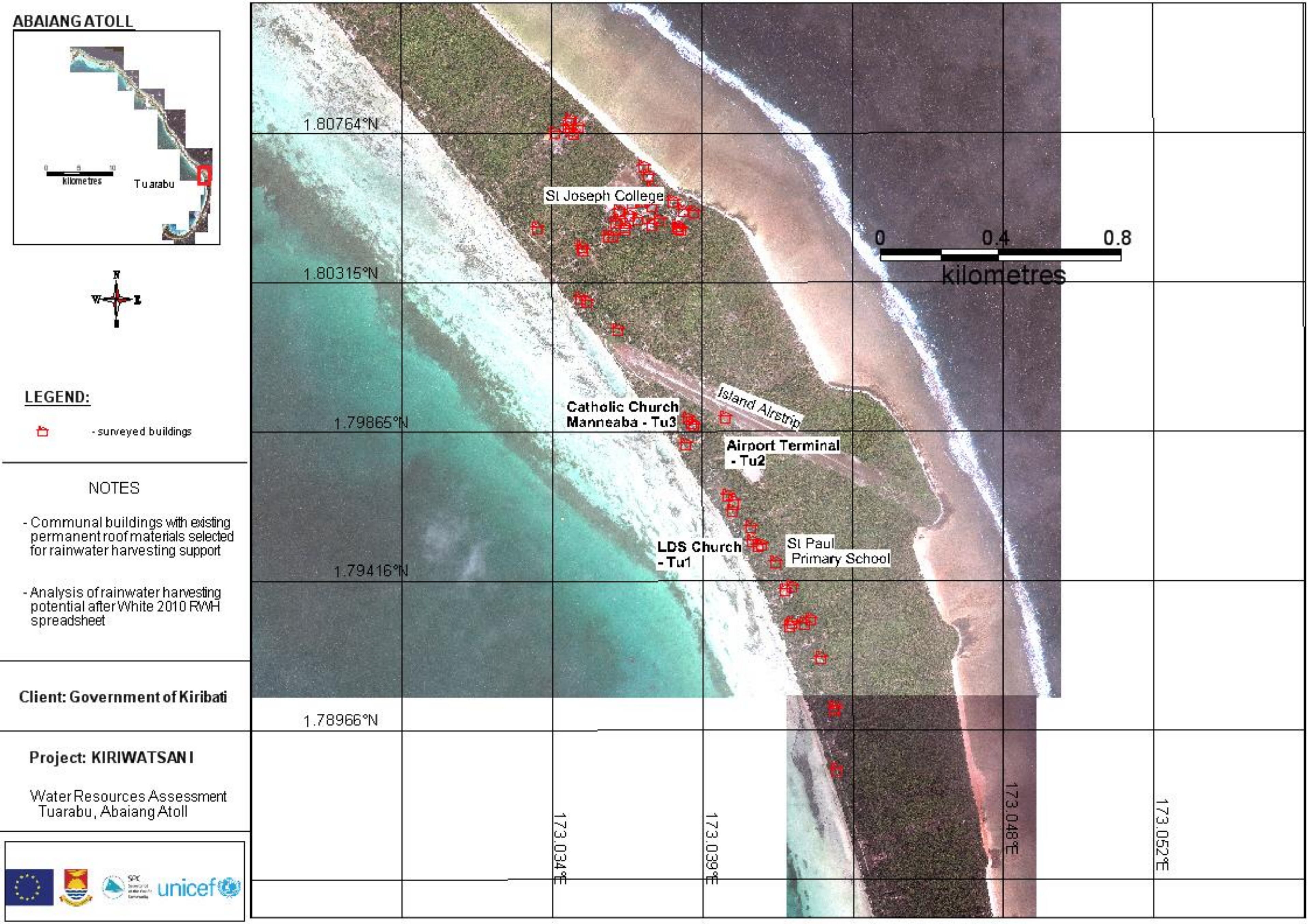


Figure A6.23 – TUARABU, ABAIANG CTD DIVER LOCATIONS

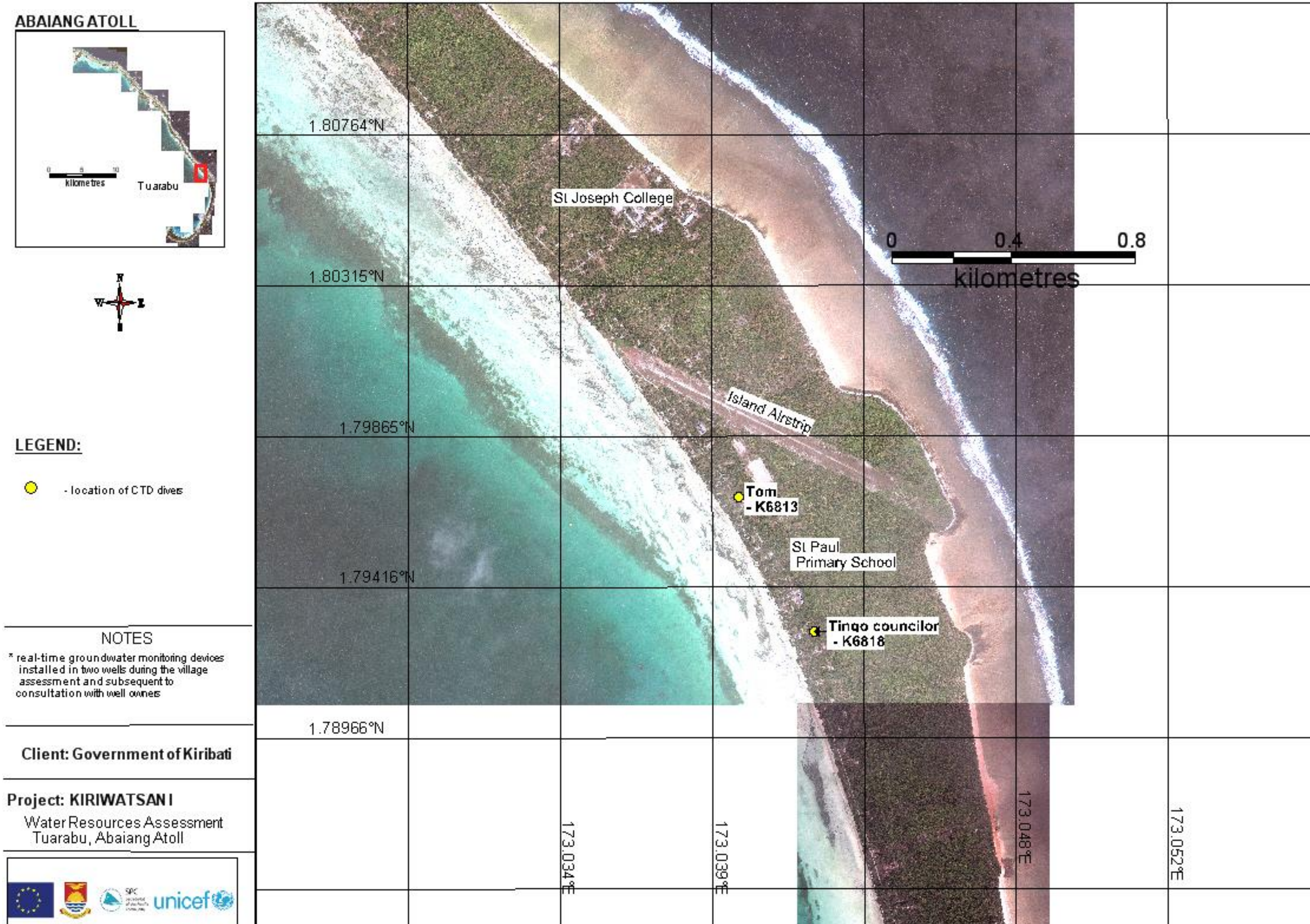


Figure A6.24 – TUARABU, ABAIANG FRESH GROUNDWATER LENS POTENTIAL

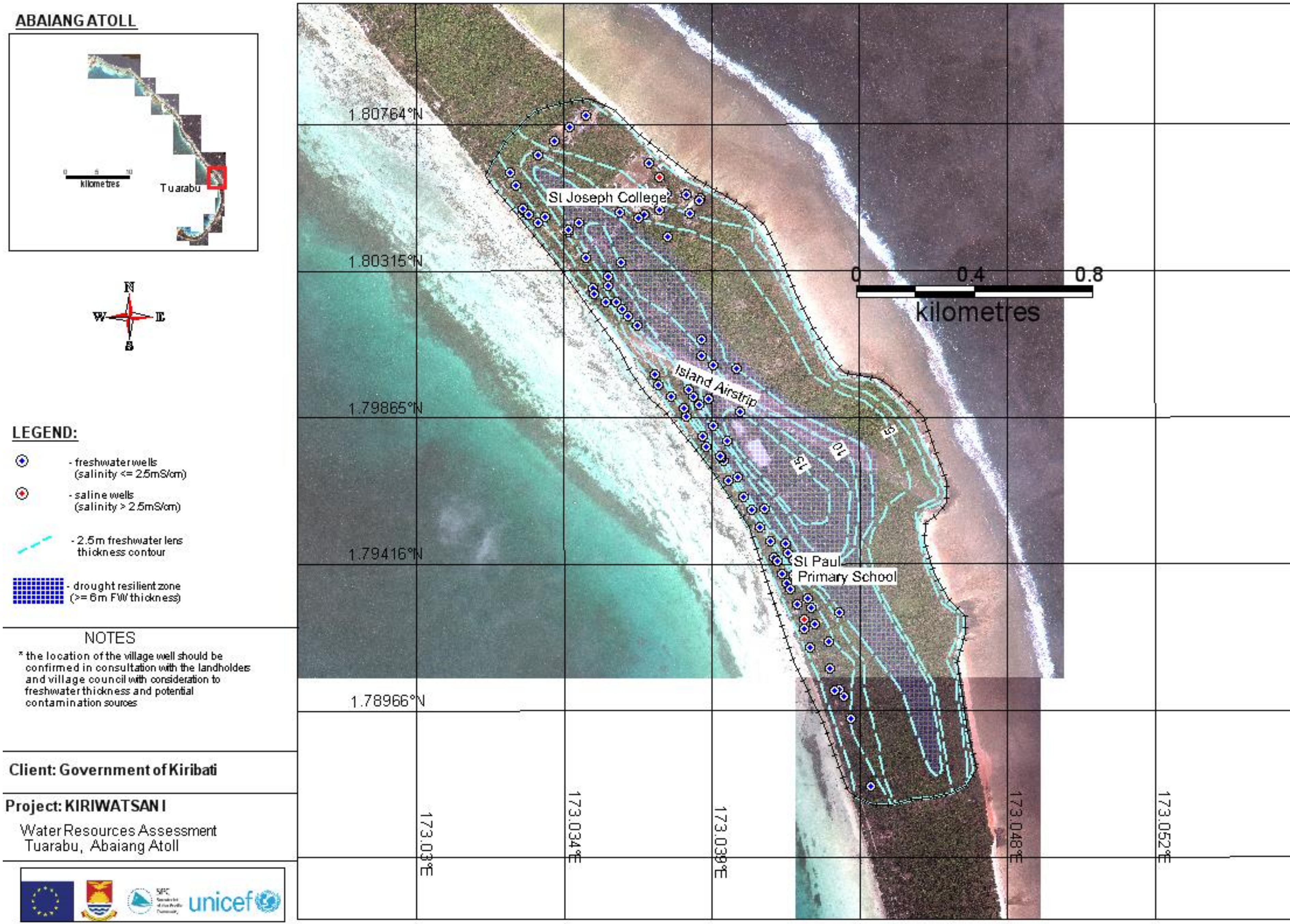
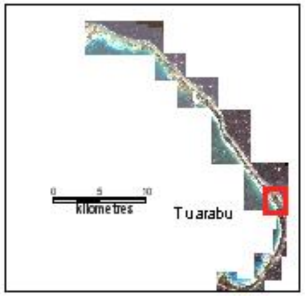
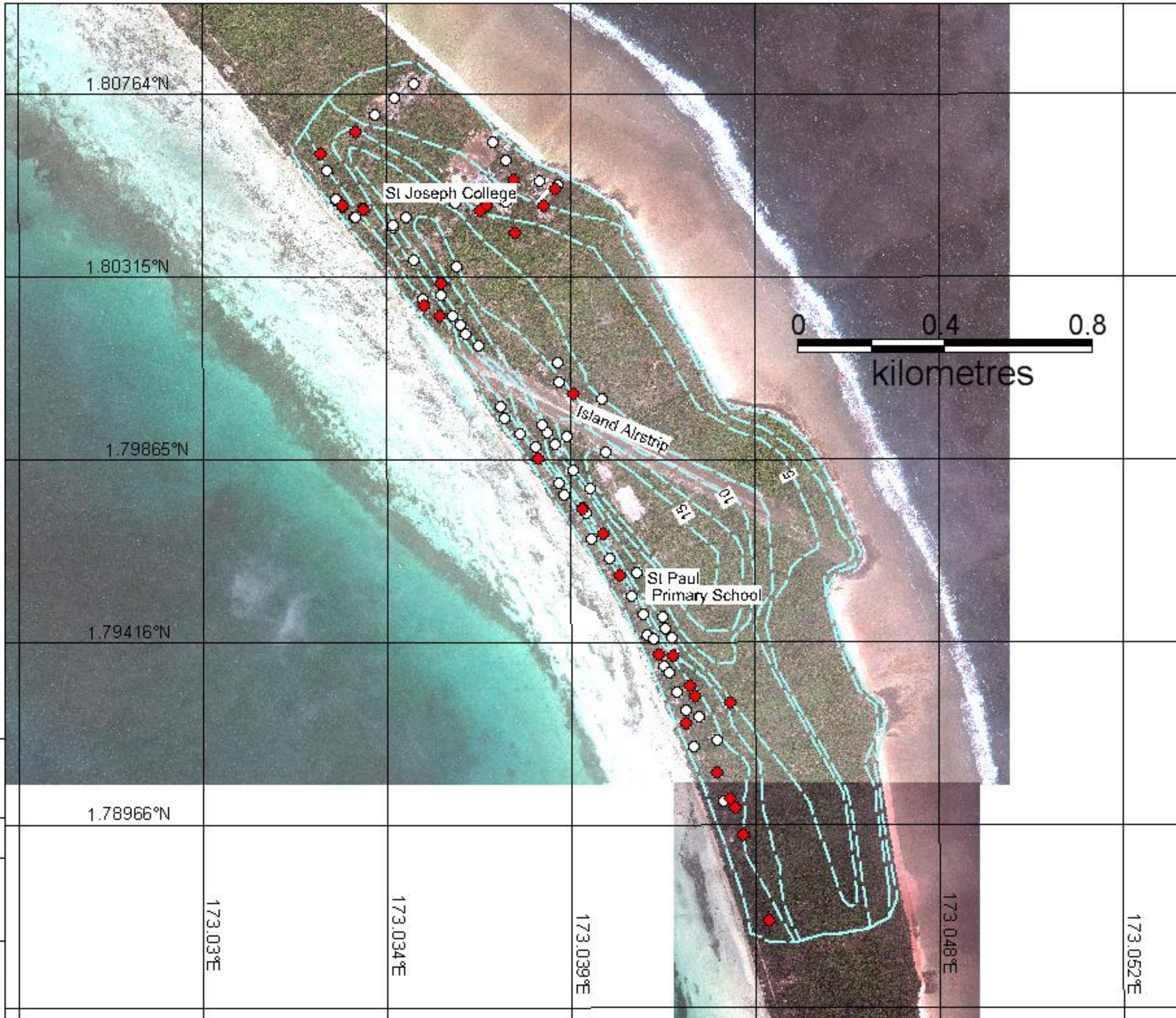


Figure A6.25 – TUARABU, ABAIANG BACTERIOLOGICAL SAMPLING

ABAIANG ATOLL





LEGEND:

- unsampled wells
- samples with no e.coli bacteria contamination
- samples with e.coli bacteria contamination
- freshwater lens thickness contour (2.5m interval)

NOTES

* bacteriological prence/absence testing. IDEXX colilert 18.

Client: Government of Kiribati

Project: KIRIWATSAN I
Water Resources Assessment
Tuarabu, Abaiang Atoll

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Figure A6.26 – TANIAU, ABAIANG – WATER RESOURCES SURVEY MAP

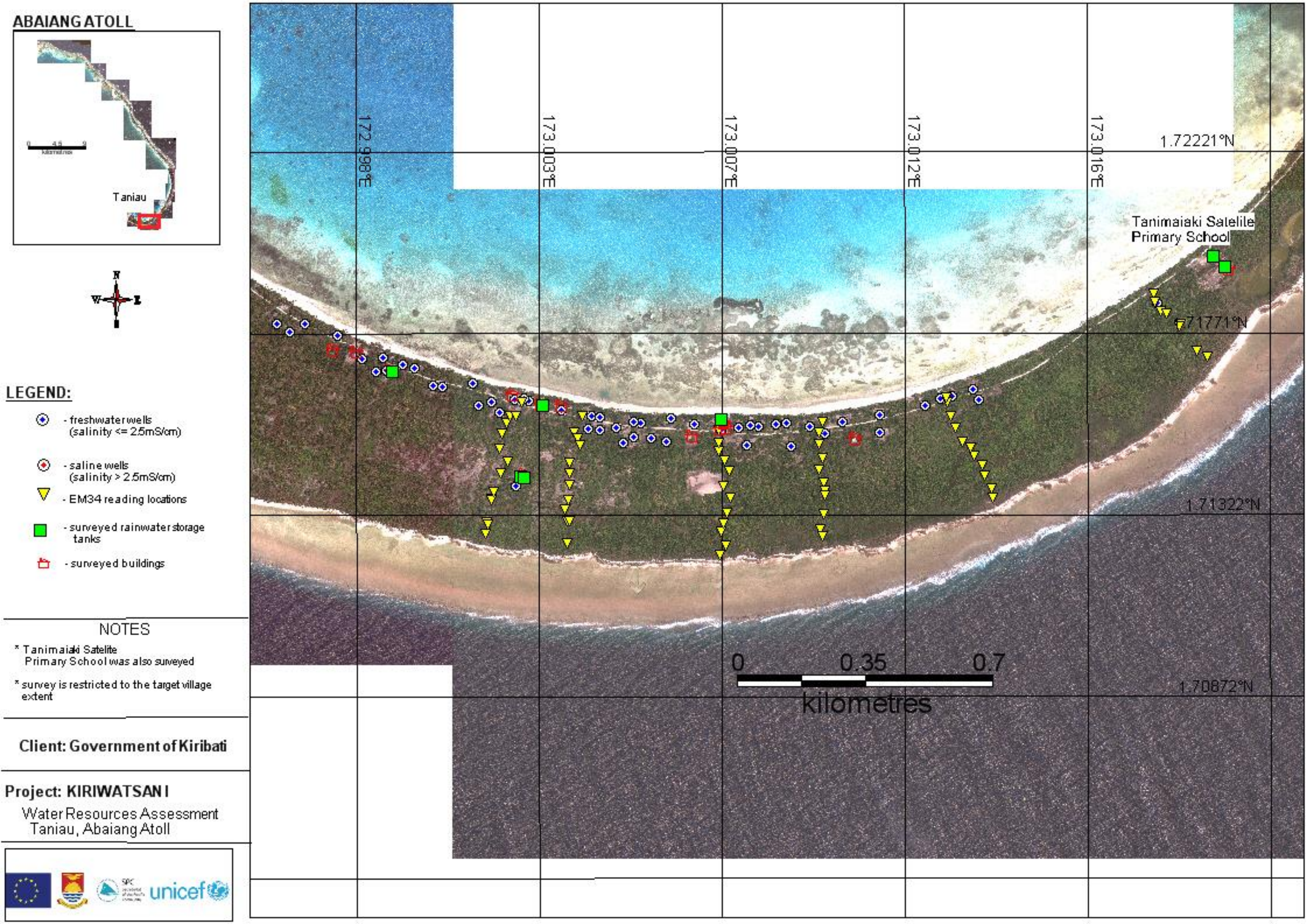
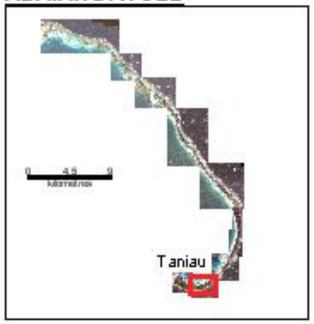


Figure A6.27 – TANIAU, ABAIANG – TARGET COMMUNAL BUILDINGS FOR RWH

ABAIANG ATOLL



N
W E
S

LEGEND:

- surveyed buildings

NOTES

- Communal buildings with existing permanent roof materials selected for rainwater harvesting support
- Analysis of rainwater harvesting potential after White 2010 RWH spreadsheet

Client: Government of Kiribati

Project: KIRIWATSAN I

Water Resources Assessment
Taniau, Abaiang Atoll

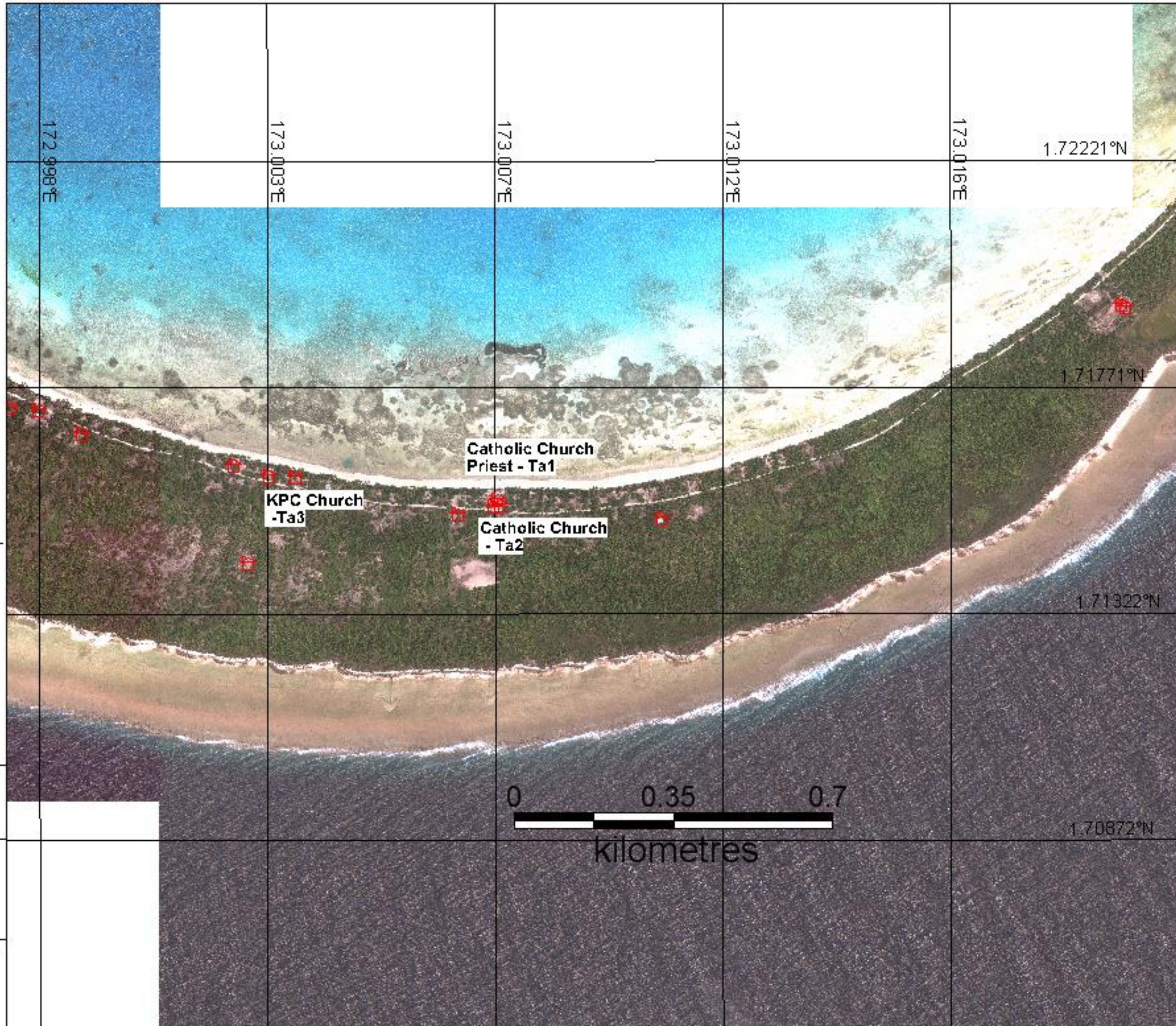
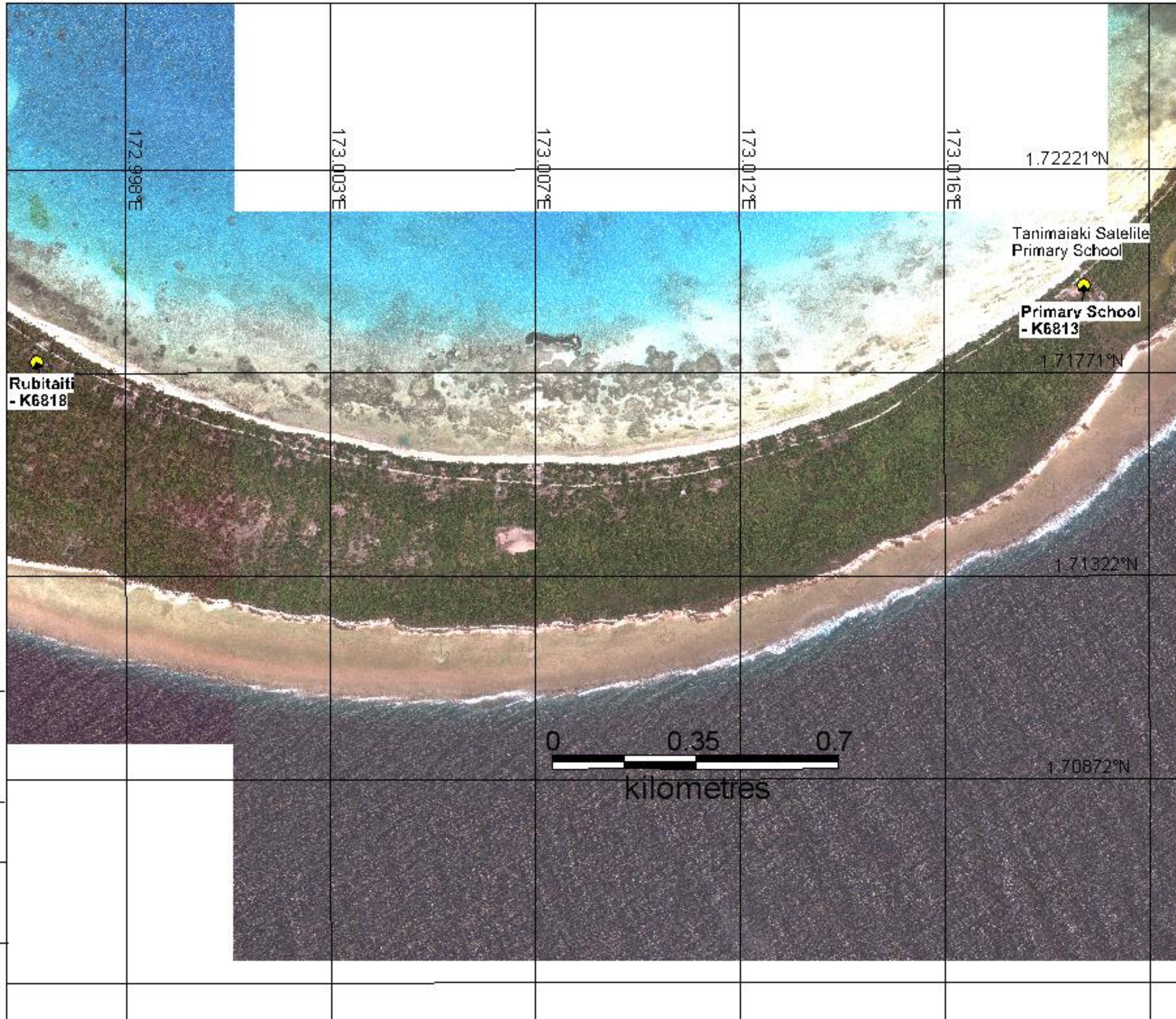


Figure A6.28 – EWENA, ABAIANG CTD DIVER LOCATIONS

ABAIANG ATOLL



LEGEND:

- location of CTD divers

NOTES

* real-time groundwater monitoring devices installed in two wells during the village assessment and subsequent to consultation with well owners

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Water Resources Assessment
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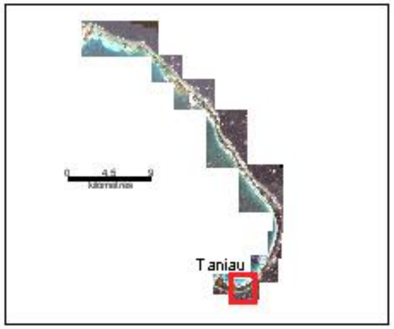
Figure A6.29 – TANIAU, ABAIANG – FRESH GROUNDWATER LENS POTENTIAL

ABAIANG ATOLL



LEGEND:

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

NOTES

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

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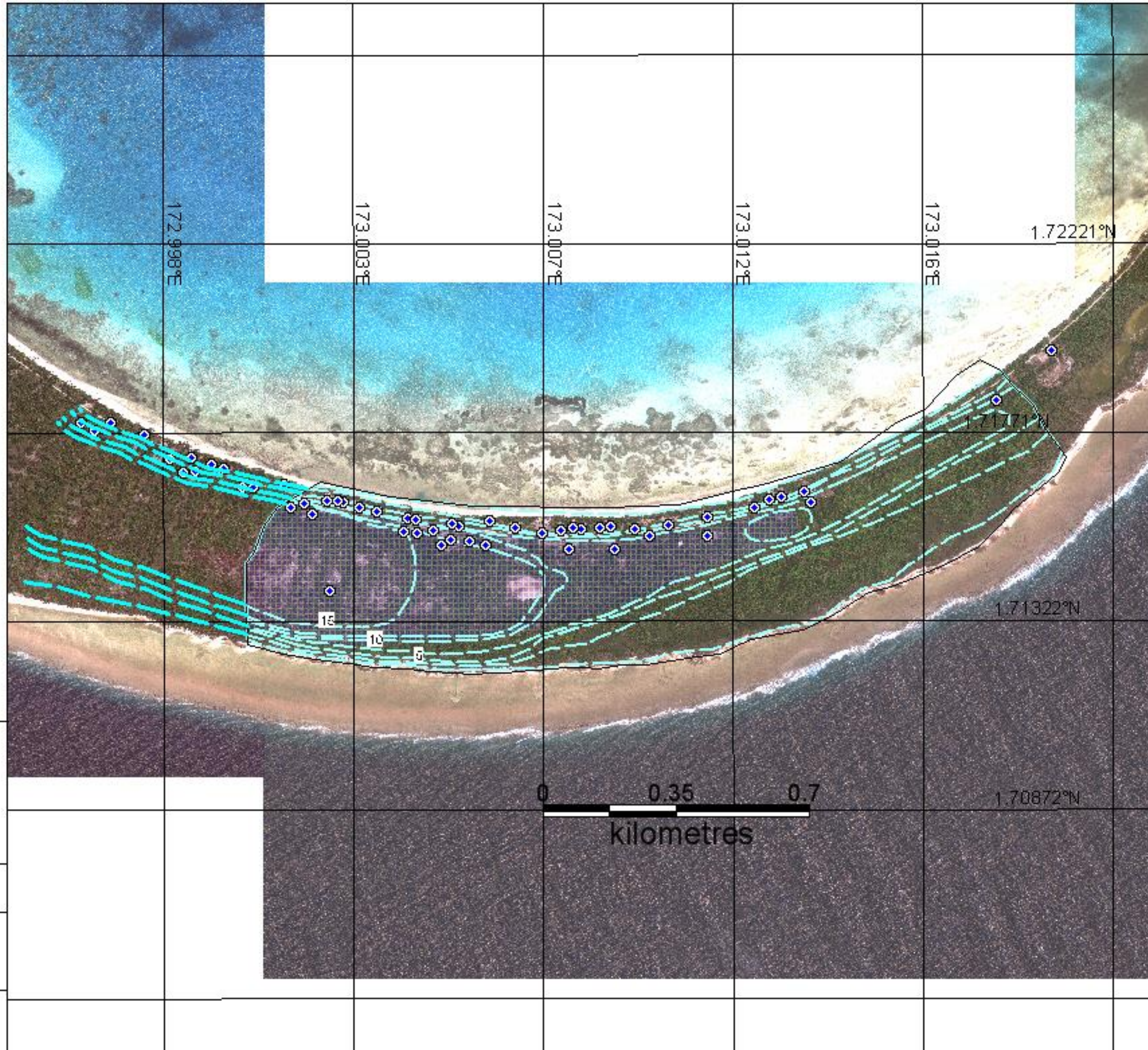
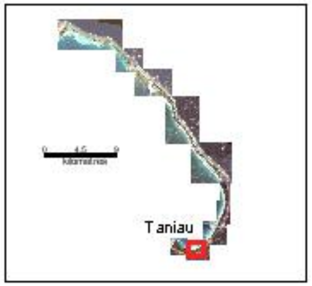


Figure A6.30 – TANIAU, ABAIANG BACTERIOLOGICAL SAMPLING

ABAIANG ATOLL



LEGEND:

- unsampled wells
- samples with no e.coli bacteria contamination
- samples with e.coli bacteria contamination
- freshwater lens thickness contour (2.5m interval)
- conjectural 2.5m freshwater lens thickness contour

NOTES

* bacteriological prence/absence testing. IDEXX colilert 18.

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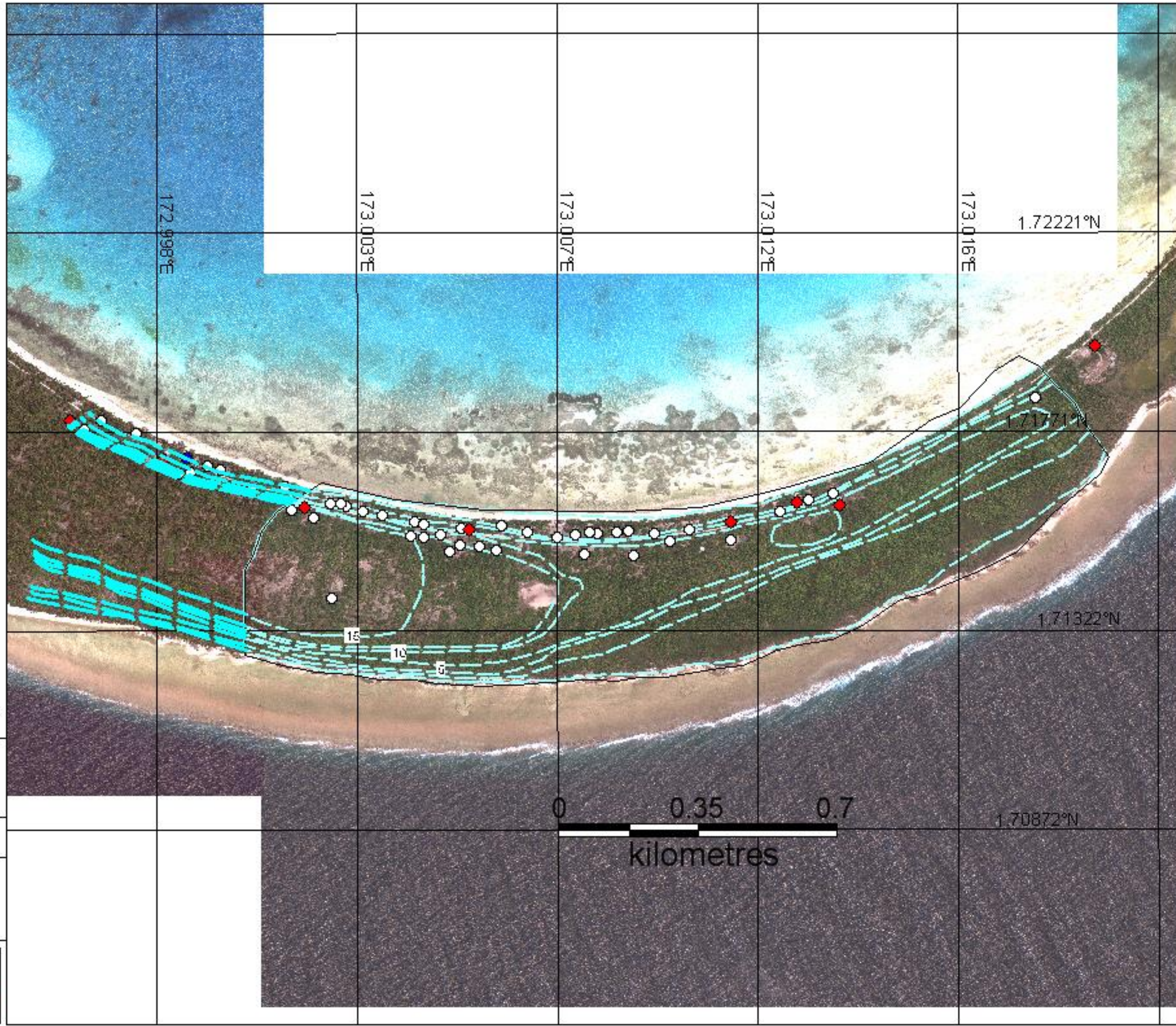


Annex 7

E.coli Compact Dry Plate and Filtration Membrane Sampling Procedures

Standard Membrane Filtration Method

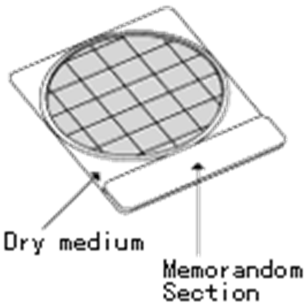
(Adapted from the US Environmental Protection Agency (EPA) and American Public Health Association (APHA) methods (EPA, 2000; APHA, 1995)

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

2) Pre-sampling procedure (sample bottles sterilisation)

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

3) Lab Sampling Preparation

Set-up procedures

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

1 ml sample preparation

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

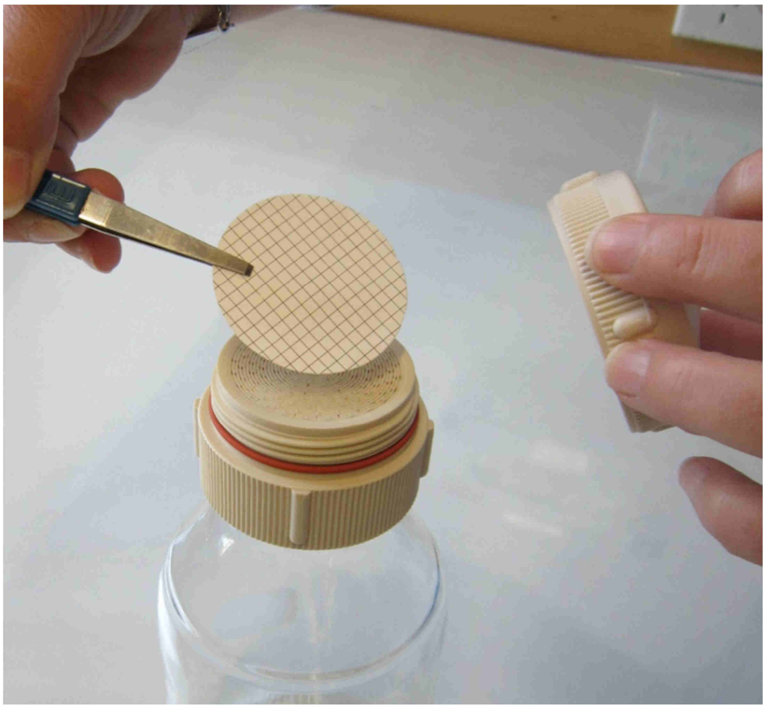
e. Repeat the above, until all samples have been prepared for 1 ml analysis.
f. Store all the rehydrated 1 ml plates in a cooler box and record the incubation start time.

50 ml sample preparation

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

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

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



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

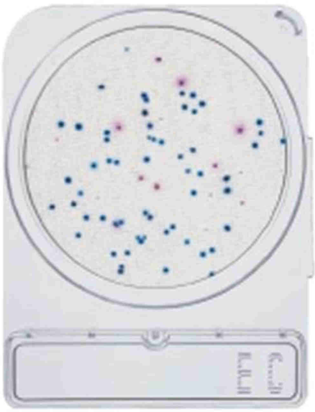
k. Use the sanitised tweezers to transfer the filter paper from the housing to the re-hydrated plate.
l. Repeat steps **d to e** until all samples have been prepared for 50 ml analysis.
m. For the CONTROL, use sterile water, instead of sample water, and subsequent to thoroughly rinsing the syringe and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

4) Post sampling procedure

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

Counting Procedure:

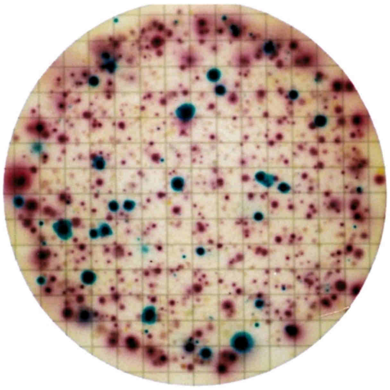
Compact Dry plates: Count the number of red and blue colonies

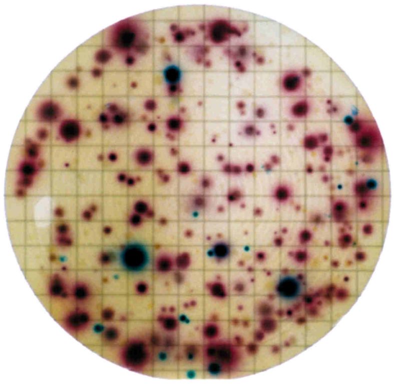


The number of red and blue colonies = Total Coliforms

The number of blue colonies = E.coli

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





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

Cleaning of Equipment:

Clean the syringes and filter housing using 5% bleach and then **three (3)** times with boiled water to remove any residual bleach. Then put a large pot of water on the stove to boil. Let this come to the boil and boil it for 10 minutes to kill any pathogens in it. Then place the syringes and filter housings in it and boil it for a further 10 minutes. Turn of 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.

NOTES

Annex 8

EM34 Geophysics Principles & Abaiang 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 investigations 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 Abaiang 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 (Annex 12). One week prior to the survey, field equipment and techniques were tested and reviewed (Annex 12). Salinity readings and water level depths from multi-depth tubes at six (6) selected monitoring bores (BN1, BN2, BN21, BN26, BN27 and BN11) 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 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 three (3) calibration datasets were considered to allow comparison between results. These include:

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

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

The three calibration datasets are presented as logarithmic curves and equations (Figure A8-1), which we used to calculate freshwater thickness.

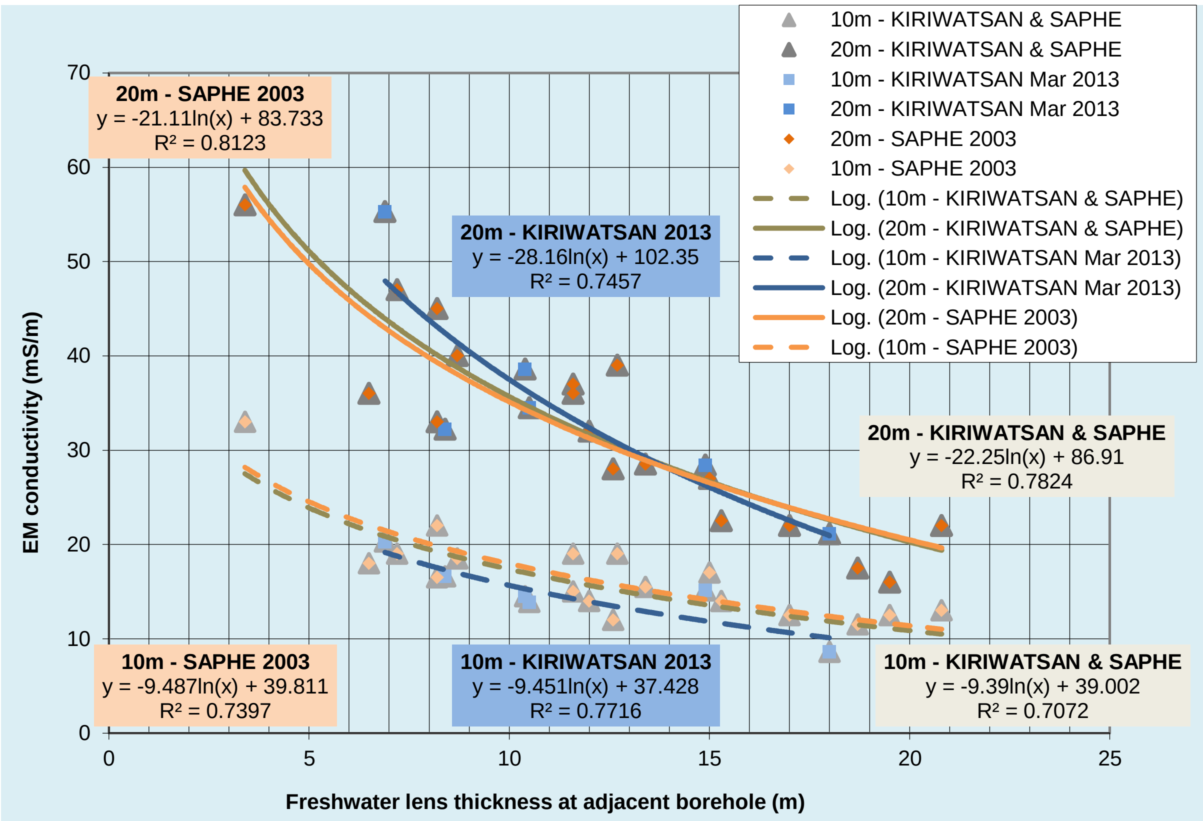


Figure A8-1. Calibration data from (1) SAPHE 2003; (2) KIRIWATSAN; and combined (3) KIRIWATSAN & SAPHE 2003. Note that (3) was used to estimate the freshwater lens thickness for 10 m and 20 m separations.

SAPHE 2003 data shows a good fit for the November 2003 20-m spacing measurements, expressed by the high coefficient of determination of 0.81 (R^2), whilst the 10-m responses showed slightly more variability and a slightly lower R^2 of 0.74. 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 -28.16 and a lower R^2 value of 0.75, in relation to the SAPHE 2003 – 20 m. Hence, the 2003 20 m trend appears to be a reasonable fit due to its slightly higher R^2 value. The KIRIWATSAN 10 m, mostly plotted below the 10 m – SAPHE 2003, showing a slightly lower slope of -9.45 with a slightly higher R^2 value of 0.77. This overall low EM response is attributed to the saturated subsurface condition, which better represents the climatic and ground conditions prevalent during the Abaiang 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 include:

- 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; and
- 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 relationships, shown on Figure A8-1, was used on all 10 m and 20 m field measurements to estimate the freshwater lens thickness, whilst the adopted lens thickness at each survey point was guided by the specific conditions and "rules of thumb". Summary of all the survey lines in the different target villages and the maximum freshwater lens thickness is presented in Table A8-1 (below).

Freshwater lens thicknesses were produced using a 2.5 m contour interval of the ground conductivity indicating groundwater salinity 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 represent ideal options for sustainable groundwater use and management.

4) Summary of findings

Clearly, EM34 provides a useful and rapid assessment on estimates of freshwater lens thickness based on salinity during the time of the survey. It does not make any inference on the portability of the groundwater or its risk from contamination. Water quality testing is required to determine the likelihood of contamination of the groundwater from faecal sources in any specific area. Groundwater quality sampling undertaken and the results indicating the risk of groundwater contamination from faecal sources is provided in Annex 5.

Table A8-1. All survey results with additional groundwater comments based on Falkland (2004).

Waypoint	Village	(m)	10 m	20 m	FW_10 m	FW_20 m	Adopted thickness	N degrees	E degrees	Additional comment re Groundwater
ABG1X1	Ribono	10	82.3	138.9	0.0	0.1	0.0	1°57.532'	172°51.610'	Very thin - Very likely to no fresh groundwater in a drought
ABG1X2	Ribono	40	72.5	104.9	0.0	0.4	0.0	1°57.534'	172°51.599'	Very thin - Very likely to no fresh groundwater in a drought
ABG1X3	Ribono	70	53.6	85.4	0.2	1.1	0.2	1°57.550'	172°51.584'	Very thin - Very likely to no fresh groundwater in a drought
ABG1X4	Ribono	100	59.8	88.9	0.1	0.9	0.1	1°57.562'	172°51.574'	Very thin - Very likely to no fresh groundwater in a drought
ABG1X5	Ribono	130	61.5	84.1	0.1	1.1	0.1	1°57.575'	172°51.562'	Very thin - Very likely to no fresh groundwater in a drought
ABG1X6	Ribono	160	60.4	91.4	0.1	0.8	0.1	1°57.583'	172°51.548'	Very thin - Very likely to no fresh groundwater in a drought
ABG1X7	Ribono	190	76.6	116.9	0.0	0.3	0.0	1°57.586'	172°51.534'	Very thin - Very likely to no fresh groundwater in a drought
ABG2X1	Ribono	10	89.6	179.1	0.0	0.0	0.0	1°57.640'	172°51.682'	Very thin - Very likely to no fresh groundwater in a drought
ABG2X2	Ribono	40	31.5	53.4	2.2	4.5	2.2	1°57.638'	172°51.672'	Very thin - Very likely to no fresh groundwater in a drought
ABG3X1	Ribono	10	16.4	52.8	11.1	4.6	4.6	1°57.736'	172°51.781'	Thin - Likely to be little or no fresh groundwater in a drought
ABG3X2	Ribono	40	18.6	35.2	8.8	10.2	10.2	1°57.746'	172°51.768'	Thick - fresh groundwater likely to be found at all times
ABG3X3	Ribono	70	14.2	36.0	14.0	9.9	9.9	1°57.755'	172°51.759'	Moderately thick - fresh groundwater likely to be found all year round
ABG3X4	Ribono	100	19.5	36.1	8.0	9.8	9.8	1°57.766'	172°51.751'	Moderately thick - fresh groundwater likely to be found all year round
ABG3X5	Ribono	130	19.2	37.7	8.2	9.1	9.1	1°57.777'	172°51.731'	Moderately thick - fresh groundwater likely to be found all year round
ABG3X6	Ribono	160	23.2	38.6	5.4	8.8	8.8	1°57.775'	172°51.730'	Moderately thick - fresh groundwater likely to be found all year round
ABG4X1	Ribono	10	15.0	32.3	12.9	11.6	11.6	1°57.782'	172°51.845'	Thick - fresh groundwater likely to be found at all times
ABG4X2	Ribono	40	14.4	26.4	13.7	15.2	15.2	1°57.796'	172°51.834'	Thick - fresh groundwater likely to be found at all times
ABG4X3	Ribono	70	14.4	26.6	13.7	15.0	15.0	1°57.829'	172°51.826'	Thick - fresh groundwater likely to be found at all times

ABG4X4	Ribono	100	17.1	29.0	10.3	13.5	13.5	1°57.851'	172°51.813'	Thick - fresh groundwater likely to be found at all times
ABG4X5	Ribono	130	11.5	25.9	18.7	15.5	15.5	1°57.873'	172°51.799'	Thick - fresh groundwater likely to be found at all times
ABG4X6	Ribono	160	9.8	26.1	22.4	15.4	15.4	1°57.881'	172°51.790'	Thick - fresh groundwater likely to be found at all times
ABG4X7	Ribono	190	19.1	30.6	8.3	12.6	12.6	1°57.895'	172°51.755'	Thick - fresh groundwater likely to be found at all times
ABG4X8	Ribono	210	16.3	31.3	11.2	12.2	12.2	1°57.913'	172°51.739'	Thick - fresh groundwater likely to be found at all times
ABG5X1	Ribono	10	24.4	57.8	4.7	3.7	4.7	1°57.841'	173°51.990'	Thin - Likely to be little or no fresh groundwater in a drought
ABG5X2	Ribono	40	14.1	31.2	14.2	12.2	12.2	1°57.849'	173°51.982	Thick - fresh groundwater likely to be found at all times
ABG6X1	Ribono	10	12.7	32.6	16.5	11.5	11.5	1°57.909'	172°51.751'	Thick - fresh groundwater likely to be found at all times
ABG6X2	Ribono	40	22.0	33.2	6.1	11.2	11.2	1°57.899'	172°51.739'	Thick - fresh groundwater likely to be found at all times
ABG6X3	Ribono	70	19.0	30.9	8.4	12.4	12.4	1°57.888'	172°51.720'	Thick - fresh groundwater likely to be found at all times
ABG6X4	Ribono	100	12.8	32.2	16.3	11.7	11.7	1°57.532'	172°51.610'	Thick - fresh groundwater likely to be found at all times
ABG6X5	Ribono	130	17.5	32.6	9.9	11.5	11.5	1°57.866'	172°51.712'	Thick - fresh groundwater likely to be found at all times
ABG6X6	Ribono	160	15.0	33.4	12.9	11.1	11.1	1°57.847'	172°51.712'	Thick - fresh groundwater likely to be found at all times
ABG6X7	Ribono	190	18.5	38.1	8.9	9.0	9.0	1°57.825'	172°51.714'	Moderately thick - fresh groundwater likely to be found all year round
ABG6X8	Ribono	210	22.8	42.1	5.6	7.5	5.6	1°57.813'	172°51.708'	Thin - Likely to be little or no fresh groundwater in a drought
ABG7X1	Tebunginako	10	100.3	158.7	0.0	0.0	0.0	1°55.156'	172°56.738'	Very thin - Very likely to no fresh groundwater in a drought
ABG7X2	Tebunginako	40	92.6	147.5	0.0	0.1	0.0	1°55.161'	172°56.745'	Very thin - Very likely to no fresh groundwater in a drought
ABG7X3	Tebunginako	70	42.3	103.1	0.7	0.5	0.7	1°55.161'	172°56.761'	Very thin - Very likely to no fresh groundwater in a drought
ABG7X4	Tebunginako	100	35.3	85.2	1.5	1.1	1.5	1°55.168'	172°56.764'	Very thin - Very likely to no fresh groundwater in a drought
ABG7X5	Tebunginako	130	37.2	86.9	1.2	1.0	1.2	1°55.185'	172°56.789'	Very thin - Very likely to no fresh groundwater in a drought

ABG7X6	Tebunginako	160	51.3	95.1	0.3	0.7	0.3	1°55.195'	172°56.803'	Very thin - Very likely to no fresh groundwater in a drought
ABG7X7	Tebunginako	190	29.0	78.1	2.9	1.5	2.9	1°55.205'	172°56.819'	Thin - Likely to be little or no fresh groundwater in a drought
ABG7X8	Tebunginako	220	33.3	82.7	1.8	1.2	1.8	1°55.219'	172°56.830'	Very thin - Very likely to no fresh groundwater in a drought
ABG8X1	Tebunginako	10	52.1	138.1	0.2	0.1	0.2	1°55.088'	172°56.825'	Very thin - Very likely to no fresh groundwater in a drought
ABG8X2	Tebunginako	40	31.6	81.8	2.2	1.3	2.2	1°55.091'	172°56.843'	Very thin - Very likely to no fresh groundwater in a drought
ABG8X3	Tebunginako	70	27.1	53.1	3.6	4.6	3.6	1°55.095'	172°56.856'	Thin - Likely to be little or no fresh groundwater in a drought
ABG8X4	Tebunginako	100	21.0	60.3	6.8	3.3	6.8	1°55.107'	172°56.871'	Moderately thick - fresh groundwater likely to be found all year round
ABG8X5	Tebunginako	130	16.5	55.6	11.0	4.1	4.1	1°55.117'	172°56.879'	Thin - Likely to be little or no fresh groundwater in a drought
ABG8X6	Tebunginako	160	19.2	60.9	8.2	3.2	3.2	1°55.128'	172°56.895'	Thin - Likely to be little or no fresh groundwater in a drought
ABG9X1	Tebunginako	10	54.1	118.4	0.2	0.2	0.2	1°54.937'	172°56.878'	Very thin - Very likely to no fresh groundwater in a drought
ABG9X2	Tebunginako	40	27.7	67.2	3.3	2.4	3.3	1°54.940'	172°56.895'	Thin - Likely to be little or no fresh groundwater in a drought
ABG9X3	Tebunginako	70	23.7	56.6	5.1	3.9	5.1	1°54.933'	172°56.894'	Thin - Likely to be little or no fresh groundwater in a drought
ABG9X4	Tebunginako	100	18.4	44.9	9.0	6.6	6.6	1°54.927'	172°56.914'	Moderately thick - fresh groundwater likely to be found all year round
ABG9X5	Tebunginako	130	12.1	34.1	17.5	10.7	10.7	1°54.937'	172°56.924'	Thick - fresh groundwater likely to be found at all times
ABG9X6	Tebunginako	160	13.1	35.1	15.8	10.3	10.3	1°54.948'	172°56.951'	Thick - fresh groundwater likely to be found at all times
ABG9X7	Tebunginako	190	11.5	35.5	18.7	10.1	10.1	1°54.955'	172°56.968'	Thick - fresh groundwater likely to be found at all times
ABG9X8	Tebunginako	220	13.6	40.7	15.0	8.0	8.0	1°54.969'	172°56.975'	Moderately thick - fresh groundwater likely to be found all year round
ABG9X9	Tebunginako	250	12.5	40.4	16.8	8.1	8.1	1°54.978'	172°56.988'	Moderately thick - fresh groundwater likely to be found all year round
ABG9X10	Tebunginako	280	12.8	43.2	16.3	7.1	7.1	1°54.994'	172°56.996'	Moderately thick - fresh groundwater likely to be found all year round
ABG9X11	Tebunginako	310	21.1	53.3	6.7	4.5	6.7	1°54.998'	172°57.022'	Moderately thick - fresh groundwater likely to be found all year round

ABG10X1	Tebunginako	10	50.6	82.6	0.3	1.2	0.3	1°54.777'	172°56.877'	Very thin - Very likely to no fresh groundwater in a drought
ABG10X2	Tebunginako	40	44.7	70.1	0.5	2.1	0.5	1°54.774'	172°56.883'	Very thin - Very likely to no fresh groundwater in a drought
ABG10X3	Tebunginako	70	25.8	45.4	4.1	6.5	4.1	1°54.773'	172°56.901'	Thin - Likely to be little or no fresh groundwater in a drought
ABG10X4	Tebunginako	100	16.9	31.6	10.5	12.0	12.0	1°54.780'	172°56.919'	Thick - fresh groundwater likely to be found at all times
ABG10X5	Tebunginako	130	13.3	25.8	15.4	15.6	15.6	1°54.786'	172°56.942'	Thick - fresh groundwater likely to be found at all times
ABG10X6	Tebunginako	160	9.8	22.3	22.4	18.2	18.2	1°54.798'	172°56.963'	Thick - fresh groundwater likely to be found at all times
ABG10X7	Tebunginako	190	10.7	32.0	20.4	11.8	11.8	1°54.805'	172°56.969'	Thick - fresh groundwater likely to be found at all times
ABG10X8	Tebunginako	210	10.1	19.8	21.7	20.4	20.4	1°54.813'	172°56.989'	Thick - fresh groundwater likely to be found at all times
ABG10X9	Tebunginako	240	10.1	22.9	21.7	17.8	17.8	1°54.825'	172°57.009'	Thick - fresh groundwater likely to be found at all times
ABG10X10	Tebunginako	270	10.2	23.7	21.5	17.1	17.1	1°54.835'	172°57.020'	Thick - fresh groundwater likely to be found at all times
ABG10X11	Tebunginako	300	8.3	22.3	26.3	18.2	18.2	1°54.843'	172°57.034'	Thick - fresh groundwater likely to be found at all times
ABG10X12	Tebunginako	330	9.5	25.6	23.1	15.7	15.7	1°54.854'	172°57.044'	Thick - fresh groundwater likely to be found at all times
ABG10X13	Tebunginako	360	11.6	32.7	18.5	11.4	11.4	1°54.862'	172°57.057'	Thick - fresh groundwater likely to be found at all times
ABG10X14	Tebunginako	390	15.6	44.6	12.1	6.7	6.7	1°54.869'	172°57.077'	Moderately thick - fresh groundwater likely to be found all year round
ABG10X15	Tebunginako	420	16.4	51.4	11.1	4.9	4.9	1°54.881'	172°57.090'	Thin - Likely to be little or no fresh groundwater in a drought
ABG10X16	Tebunginako	450	17.0	54.9	10.4	4.2	4.2	1°54.891'	172°57.111'	Thin - Likely to be little or no fresh groundwater in a drought
ABG11X1	Tebunginako	10	18.0	57.6	9.4	3.7	3.7	1°54.791'	172°57.181'	Thin - Likely to be little or no fresh groundwater in a drought
ABG11X2	Tebunginako	40	13.9	40.2	14.5	8.2	8.2	1°54.784'	172°57.166'	Moderately thick - fresh groundwater likely to be found all year round
ABG11X3	Tebunginako	70	12.6	36.3	16.6	9.7	9.7	1°54.773'	172°57.155'	Moderately thick - fresh groundwater likely to be found all year round
ABG11X4	Tebunginako	100	11.6	32.5	18.5	11.5	11.5	1°54.760'	172°57.147'	Thick - fresh groundwater likely to be found at all times

ABG11X5	Tebunginako	130	9.9	27.3	22.2	14.6	14.6	1°54.747'	172°57.131'	Thick - fresh groundwater likely to be found at all times
ABG11X6	Tebunginako	160	7.8	21.1	27.7	19.3	19.3	1°54.739'	172°57.124'	Thick - fresh groundwater likely to be found at all times
ABG11X7	Tebunginako	190	9.4	21.2	23.4	19.2	19.2	1°54.728'	172°57.103'	Thick - fresh groundwater likely to be found at all times
ABG11X8	Tebunginako	220	11.3	21.3	19.1	19.1	19.1	1°54.720'	172°57.087'	Thick - fresh groundwater likely to be found at all times
ABG11X9	Tebunginako	250	8.8	15.8	24.9	24.4	24.4			Thick - fresh groundwater likely to be found at all times
ABG11X10	Tebunginako	280	9.0	18.6	24.4	21.5	21.5	1°54.702'	172°57.057'	Thick - fresh groundwater likely to be found at all times
ABG11X11	Tebunginako	310	7.2	17.6	29.6	22.5	22.5	1°54.699'	172°57.039'	Thick - fresh groundwater likely to be found at all times
ABG11X12	Tebunginako	340	7.6	15.0	28.3	25.3	25.3	1°54.685'	172°57.027'	Thick - fresh groundwater likely to be found at all times
ABG11X13	Tebunginako	370	10.9	20.9	19.9	19.4	19.4	1°54.682'	172°57.010'	Thick - fresh groundwater likely to be found at all times
ABG11X14	Tebunginako	400	9.6	18.7	22.9	21.4	21.4	1°54.680'	172°56.997'	Thick - fresh groundwater likely to be found at all times
ABG11X15	Tebunginako	430	12.2	20.4	17.4	19.9	19.9	1°54.672'	172°56.976'	Thick - fresh groundwater likely to be found at all times
ABG11X16	Tebunginako	460	11.7	22.8	18.3	17.8	17.8	1°54.670'	172°56.967'	Thick - fresh groundwater likely to be found at all times
ABG11X17	Tebunginako	490	11.1	32.0	19.5	11.8	11.8	1°54.659'	172°56.924'	Thick - fresh groundwater likely to be found at all times
ABG11X18	Tebunginako	520	32.2	62.7	2.1	3.0	2.1	1°54.661'	172°56.927'	Very thin - Very likely to no fresh groundwater in a drought
ABG12X1	Tebunginako	10	48.5	81.7	0.4	1.3	0.4	1°54.514'	172°56.936'	Very thin - Very likely to no fresh groundwater in a drought
ABG12X2	Tebunginako	40	17.5	36.2	9.9	9.8	9.8	1°54.523'	172°56.958'	Moderately thick - fresh groundwater likely to be found all year round
ABG12X3	Tebunginako	70	15.5	23.6	12.2	17.2	17.2	1°54.532'	172°56.974'	Thick - fresh groundwater likely to be found at all times
ABG12X4	Tebunginako	100	12.9	21.8	16.1	18.7	18.7	1°54.539'	172°56.992'	Thick - fresh groundwater likely to be found at all times
ABG12X5	Tebunginako	130	9.2	19.7	23.9	20.5	20.5	1°54.552'	172°57.004'	Thick - fresh groundwater likely to be found at all times
ABG12X6	Tebunginako	160	7.1	15.2	29.9	25.1	25.1	1°54.557'	172°57.004'	Thick - fresh groundwater likely to be found at all times

ABG12X7	Tebunginako	190	8.9	15.5	24.7	24.8	24.8	1°54.565'	172°57.014'	Thick - fresh groundwater likely to be found at all times
ABG12X8	Tebunginako	210	7.1	15.8	29.9	24.4	24.4	1°54.569'	172°57.033'	Thick - fresh groundwater likely to be found at all times
ABG12X9	Tebunginako	240	9.3	15.8	23.6	24.4	24.4	1°54.571'	172°57.047'	Thick - fresh groundwater likely to be found at all times
ABG12X10	Tebunginako	270			63.7	49.7	49.7			Thick - fresh groundwater likely to be found at all times
ABG12X11	Tebunginako	300	7.7	15.6	28.0	24.7	24.7	1°54.574'	172°57.057'	Thick - fresh groundwater likely to be found at all times
ABG12X12	Tebunginako	330	6.9	12.6	30.5	28.2	28.2	1°54.589'	172°57.073'	Thick - fresh groundwater likely to be found at all times
ABG12X13	Tebunginako	360	5.0	10.4	37.4	31.1	31.1	1°54.598'	172°57.086'	Thick - fresh groundwater likely to be found at all times
ABG12X14	Tebunginako	390	6.0	13.4	33.6	27.2	27.2	1°54.614'	172°57.096'	Thick - fresh groundwater likely to be found at all times
ABG12X15	Tebunginako	420	6.1	14.3	33.2	26.1	26.1	1°54.628'	172°57.112'	Thick - fresh groundwater likely to be found at all times
ABG12X16	Tebunginako	450	5.9	14.2	34.0	26.3	26.3	1°54.639'	172°57.119'	Thick - fresh groundwater likely to be found at all times
ABG12X17	Tebunginako	480			63.7	49.7	49.7			Thick - fresh groundwater likely to be found at all times
ABG12X18	Tebunginako	510	6.2	15.5	32.9	24.8	24.8	1°54.651'	172°57.129'	Thick - fresh groundwater likely to be found at all times
ABG12X19	Tebunginako	540	6.8	16.2	30.9	24.0	24.0	1°54.662'	172°57.134'	Thick - fresh groundwater likely to be found at all times
ABG12X20	Tebunginako	570	7.1	18.1	29.9	22.0	22.0	1°54.668'	172°57.143'	Thick - fresh groundwater likely to be found at all times
ABG12X21	Tebunginako	600			63.7	49.7	49.7			Thick - fresh groundwater likely to be found at all times
ABG12X22	Tebunginako	630	8.1	19.5	26.9	20.7	20.7	1°54.685'	172°57.163'	Thick - fresh groundwater likely to be found at all times
ABG12X23	Tebunginako	660	8.1	19.3	26.9	20.9	20.9			Thick - fresh groundwater likely to be found at all times
ABG12X24	Tebunginako	690	10.8	25.3	20.2	15.9	15.9	1°54.698'	172°57.192'	Thick - fresh groundwater likely to be found at all times
ABG12X25	Tebunginako	720	11.1	25.5	19.5	15.8	15.8	1°54.719'	172°57.208'	Thick - fresh groundwater likely to be found at all times

ABG12X26	Tebunginako	750	11.2	30.7	19.3	12.5	12.5	1°54.723'	172°57.219'	Thick - fresh groundwater likely to be found at all times
ABG12X27	Tebunginako	780	11.6	33.6	18.5	11.0	11.0	1°54.738'	172°57.222'	Thick - fresh groundwater likely to be found at all times
ABG12X28	Tebunginako	810	13.9	43.7	14.5	7.0	7.0	1°54.745'	172°57.228'	Moderately thick - fresh groundwater likely to be found all year round
ABG13X1	Tebunginako	10	10.7	32.9	20.4	11.3	11.3	1°54.671'	172°57.332'	Thick - fresh groundwater likely to be found at all times
ABG13X2	Tebunginako	40	7.5	26.5	28.6	15.1	15.1	1°54.659'	172°57.311'	Thick - fresh groundwater likely to be found at all times
ABG13X3	Tebunginako	70	6.5	25.5	31.9	15.8	15.8	1°54.651'	172°57.314'	Thick - fresh groundwater likely to be found at all times
ABG13X4	Tebunginako	100	8.5	22.7	25.7	17.9	17.9	1°54.629'	172°57.295'	Thick - fresh groundwater likely to be found at all times
ABG13X5	Tebunginako	130	8.4	18.2	26.0	21.9	21.9	1°54.627'	172°57.294'	Thick - fresh groundwater likely to be found at all times
ABG13X6	Tebunginako	160	9.5	21.6	23.1	18.8	18.8	1°54.600'	172°57.278'	Thick - fresh groundwater likely to be found at all times
ABG13X7	Tebunginako	190	9.8	20.4	22.4	19.9	19.9	1°54.586'	172°57.272'	Thick - fresh groundwater likely to be found at all times
ABG13X8	Tebunginako	210	8.7	18.2	25.2	21.9	21.9	1°54.580'	172°57.268'	Thick - fresh groundwater likely to be found at all times
ABG13X9	Tebunginako	240	8.6	18.1	25.5	22.0	22.0	1°54.569'	172°57.243'	Thick - fresh groundwater likely to be found at all times
ABG13X10	Tebunginako	270	8.5	17.3	25.7	22.8	22.8	1°54.560'	172°57.224'	Thick - fresh groundwater likely to be found at all times
ABG13X11	Tebunginako	300	8.5	16.1	25.7	24.1	24.1	1°54.553'	172°57.209'	Thick - fresh groundwater likely to be found at all times
ABG13X12	Tebunginako	330	7.8	12.7	27.7	28.1	28.1	1°54.545'	172°57.198'	Thick - fresh groundwater likely to be found at all times
ABG13X13	Tebunginako	360	7.2	15.8	29.6	24.4	24.4	1°54.538'	172°57.183'	Thick - fresh groundwater likely to be found at all times
ABG13X14	Tebunginako	390	7.9	15.5	27.4	24.8	24.8	1°54.533'	172°57.171'	Thick - fresh groundwater likely to be found at all times
ABG13X15	Tebunginako	420	9.7	18.6	22.7	21.5	21.5	1°54.628'	172°57.112'	Thick - fresh groundwater likely to be found at all times
ABG13X16	Tebunginako	450	9.9	18.8	22.2	21.4	21.4	1°54.526'	172°57.157'	Thick - fresh groundwater likely to be found at all times

ABG13X17	Tebunginako	480	9.1	19.8	24.2	20.4	20.4	1°54.518'	172°57.137'	Thick - fresh groundwater likely to be found at all times
ABG13X18	Tebunginako	510	8.4	19.5	26.0	20.7	20.7	1°54.507'	172°57.133'	Thick - fresh groundwater likely to be found at all times
ABG13X19	Tebunginako	540	9.2	21.7	23.9	18.7	18.7	1°54.507'	172°57.106'	Thick - fresh groundwater likely to be found at all times
ABG13X20	Tebunginako	570	14.3	28.4	13.9	13.9	13.9	1°54.496'	172°57.100'	Thick - fresh groundwater likely to be found at all times
ABG13X21	Tebunginako	600	25.6	40.6	4.2	8.0	8.0	1°54.490'	172°57.090'	Moderately thick - fresh groundwater likely to be found all year round
ABG13X22	Tebunginako	630	32.7	54.6	2.0	4.3	2.0	1°54.476'	172°57.067'	Very thin - Very likely to no fresh groundwater in a drought
ABG13X23	Tebunginako	660	43.1	71.0	0.6	2.0	0.6	1°54.472'	172°57.057'	Very thin - Very likely to no fresh groundwater in a drought
ABG13X24	Tebunginako	690	64.1	106.0	0.1	0.4	0.1	1°54.460'	172°57.036'	Very thin - Very likely to no fresh groundwater in a drought
ABG13X25	Tebunginako	720	89.4	106.4	0.0	0.4	0.0	1°54.456'	172°57.039'	Very thin - Very likely to no fresh groundwater in a drought
ABG14X1	Aonobuaka	10	33.4	63.4	1.8	2.9	1.8	1°53.542'	172°58.466'	Very thin - Very likely to no fresh groundwater in a drought
ABG14X2	Aonobuaka	40	9.9	35.2	22.2	10.2	10.2	1°53.573'	172°58.477'	Thick - fresh groundwater likely to be found at all times
ABG14X3	Aonobuaka	70	7.5	20.0	28.6	20.2	20.2	1°53.580'	172°58.483'	Thick - fresh groundwater likely to be found at all times
ABG14X4	Aonobuaka	100	8.4	18.9	26.0	21.3	21.3	1°53.603'	172°58.512'	Thick - fresh groundwater likely to be found at all times
ABG14X5	Aonobuaka	130	6.6	18.0	31.5	22.1	22.1	1°53.609'	172°58.533'	Thick - fresh groundwater likely to be found at all times
ABG14X6	Aonobuaka	160	6.1	18.1	33.2	22.0	22.0	1°53.614'	172°58.561'	Thick - fresh groundwater likely to be found at all times
ABG14X7	Aonobuaka	190	8.3	22.8	26.3	17.8	17.8	1°53.632'	172°58.572'	Thick - fresh groundwater likely to be found at all times
ABG14X8	Aonobuaka	220	7.4	22.4	28.9	18.2	18.2	1°53.655'	172°58.583'	Thick - fresh groundwater likely to be found at all times
ABG14X9	Aonobuaka	250	8.7	27.5	25.2	14.4	14.4	1°53.683'	172°58.609'	Thick - fresh groundwater likely to be found at all times
ABG14X10	Aonobuaka	280	8.4	30.8	26.0	12.5	12.5	1°53.696'	172°58.639'	Thick - fresh groundwater likely to be found at all times

ABG15X1	Aonobuaka	10	9.4	18.6	23.4	21.5	21.5	1°53.587'	172°58.737'	Thick - fresh groundwater likely to be found at all times
ABG15X2	Aonobuaka	40	8.3	27.7	26.3	14.3	14.3	1°53.573'	172°58.716'	Thick - fresh groundwater likely to be found at all times
ABG15X3	Aonobuaka	70	11.8	29.8	18.1	13.0	13.0	1°53.548'	172°58.687'	Thick - fresh groundwater likely to be found at all times
ABG15X4	Aonobuaka	100	10.6	28.5	20.6	13.8	13.8	1°53.526'	172°58.688'	Thick - fresh groundwater likely to be found at all times
ABG15X5	Aonobuaka	130	10.4	21.8	21.0	18.7	18.7	1°53.508'	172°58.654'	Thick - fresh groundwater likely to be found at all times
ABG15X6	Aonobuaka	160	9.8	25.1	22.4	16.1	16.1	1°53.487'	172°58.640'	Thick - fresh groundwater likely to be found at all times
ABG15X7	Aonobuaka	190	10.4	30.4	21.0	12.7	12.7	1°53.475'	172°58.619'	Thick - fresh groundwater likely to be found at all times
ABG15X8	Aonobuaka	220	11.1	29.2	19.5	13.4	13.4	1°53.461'	172°58.594'	Thick - fresh groundwater likely to be found at all times
ABG15X9	Aonobuaka	250	12.8	34.5	16.3	10.5	10.5	1°53.445'	172°58.570'	Thick - fresh groundwater likely to be found at all times
ABG15X10	Aonobuaka	280	23.3	59.7	5.3	3.4	5.3	1°53.451'	172°58.568'	Thin - Likely to be little or no fresh groundwater in a drought
ABG16X1	Aonobuaka	10	25.4	62.5	4.3	3.0	4.3	1°53.304'	172°58.664'	Thin - Likely to be little or no fresh groundwater in a drought
ABG16X2	Aonobuaka	40	15.5	54.1	12.2	4.4	4.4	1°53.326'	172°58.691'	Thin - Likely to be little or no fresh groundwater in a drought
ABG16X3	Aonobuaka	70	14.4	46.5	13.7	6.1	6.1	1°53.345'	172°58.708'	Moderately thick - fresh groundwater likely to be found all year round
ABG16X4	Aonobuaka	100	9.4	35.0	23.4	10.3	10.3	1°53.362'	172°58.727'	Thick - fresh groundwater likely to be found at all times
ABG16X5	Aonobuaka	130	10.9	33.1	19.9	11.2	11.2	1°53.374'	172°58.736'	Thick - fresh groundwater likely to be found at all times
ABG16X6	Aonobuaka	160	9.8	33.9	22.4	10.8	10.8	1°53.388'	172°58.770'	Thick - fresh groundwater likely to be found at all times
ABG16X7	Aonobuaka	190	16.8	38.5	10.6	8.8	8.8	1°53.403'	172°58.790'	Moderately thick - fresh groundwater likely to be found all year round
ABG16X8	Aonobuaka	220	9.7	39.6	22.7	8.4	8.4	1°53.414'	172°58.812'	Moderately thick - fresh groundwater likely to be found all year round
ABG16X9	Aonobuaka	250	18.9	55.4	8.5	4.1	4.1	1°53.426'	172°58.829'	Thin - Likely to be little or no fresh groundwater in a drought

ABG16X10	Aonobuaka	280	13.6	71.2	15.0	2.0	2.0	1°53.432'	172°58.844'	Very thin - Very likely to no fresh groundwater in a drought
ABG17X1	Aonobuaka	10	24.3	70.2	4.8	2.1	4.8	1°53.306'	172°58.939'	Thin - Likely to be little or no fresh groundwater in a drought
ABG17X2	Aonobuaka	40	21.0	71.3	6.8	2.0	6.8	1°53.300'	172°58.926'	Moderately thick - fresh groundwater likely to be found all year round
ABG17X3	Aonobuaka	70	20.2	57.6	7.4	3.7	7.4	1°53.281'	172°58.899'	Moderately thick - fresh groundwater likely to be found all year round
ABG17X4	Aonobuaka	100	16.0	50.1	11.6	5.2	5.2	1°53.268'	172°58.870'	Thin - Likely to be little or no fresh groundwater in a drought
ABG17X5	Aonobuaka	130	19.1	59.3	8.3	3.5	3.5	1°53.259'	172°58.853'	Thin - Likely to be little or no fresh groundwater in a drought
ABG17X6	Aonobuaka	160	20.8	69.9	6.9	2.1	6.9	1°53.250'	172°58.832'	Moderately thick - fresh groundwater likely to be found all year round
ABG17X7	Aonobuaka	190	25.8	77.7	4.1	1.5	4.1	1°53.249'	172°58.808'	Thin - Likely to be little or no fresh groundwater in a drought
ABG17X8	Aonobuaka	210	29.6	91.5	2.7	0.8	2.7	1°53.229'	172°58.785'	Thin - Likely to be little or no fresh groundwater in a drought
ABG17X9	Aonobuaka	240	38.9	100.5	1.0	0.5	1.0	1°53.212'	172°58.764'	Very thin - Very likely to no fresh groundwater in a drought
ABG17X10	Aonobuaka	270	61.8	137.5	0.1	0.1	0.1	1°53.195'	172°58.741'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X1	Aonobuaka	10	69.1	155.7	0.0	0.0	0.0	1°53.056'	172°58.847'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X2	Aonobuaka	40	48.5	119.2	0.4	0.2	0.4	1°53.061'	172°58.861'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X3	Aonobuaka	70	44.6	107.3	0.6	0.4	0.6	1°53.069'	172°58.872'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X4	Aonobuaka	100	39.5	97.4	0.9	0.6	0.9	1°53.056'	172°58.882'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X5	Aonobuaka	130	27.6	82.3	3.4	1.2	3.4	1°53.078'	172°58.910'	Thin - Likely to be little or no fresh groundwater in a drought
ABG18X6	Aonobuaka	160	25.4	69.7	4.3	2.2	4.3	1°53.086'	172°58.925'	Thin - Likely to be little or no fresh groundwater in a drought
ABG18X7	Aonobuaka	190	23.8	68.3	5.0	2.3	5.0	1°53.089'	172°58.934'	Thin - Likely to be little or no fresh groundwater in a drought
ABG18X8	Aonobuaka	220	21.9	61.9	6.2	3.1	6.2	1°53.090'	172°58.957'	Moderately thick - fresh groundwater likely to be found all year round

ABG18X9	Aonobuaka	250	27.2	62.3	3.5	3.0	3.5	1°53.096'	172°58.964'	Thin - Likely to be little or no fresh groundwater in a drought
ABG18X10	Aonobuaka	280	31.5	73.5	2.2	1.8	2.2	1°53.105'	172°58.976'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X11	Aonobuaka	310	31.5	76.5	2.2	1.6	2.2	1°53.105'	172°58.992'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X12	Aonobuaka	340	32.3	84.2	2.0	1.1	2.0	1°53.110'	172°59.000'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X13	Aonobuaka	370	35.2	80.3	1.5	1.3	1.5	1°53.112'	172°59.007'	Very thin - Very likely to no fresh groundwater in a drought
ABG18X14	Aonobuaka	400	27.3	72.3	3.5	1.9	3.5	1°53.109'	172°59.026'	Thin - Likely to be little or no fresh groundwater in a drought
ABG18X15	Aonobuaka	430	26.9	78.1	3.6	1.5	3.6	1°53.108'	172°59.041'	Thin - Likely to be little or no fresh groundwater in a drought
ABG19X1	Aonobuaka	10	93.7	125.9	0.0	0.2	0.0	1°52.983'	172°59.150'	Very thin - Very likely to no fresh groundwater in a drought
ABG19X2	Aonobuaka	40	28.1	76.5	3.2	1.6	3.2	1°52.969'	172°59.139'	Thin - Likely to be little or no fresh groundwater in a drought
ABG19X3	Aonobuaka	70	21.2	65.4	6.7	2.6	6.7	1°52.964'	172°59.132'	Moderately thick - fresh groundwater likely to be found all year round
ABG19X4	Aonobuaka	100	22.1	65.0	6.0	2.7	6.0	1°52.944'	172°59.117'	Moderately thick - fresh groundwater likely to be found all year round
ABG19X5	Aonobuaka	130	36.7	87.0	1.3	1.0	1.3	1°52.930'	172°59.096'	Very thin - Very likely to no fresh groundwater in a drought
ABG19X6	Aonobuaka	160	37.5	83.3	1.2	1.2	1.2	1°52.929'	172°59.086'	Very thin - Very likely to no fresh groundwater in a drought
ABG19X7	Aonobuaka	190	46.7	88.5	0.4	0.9	0.4	1°52.898'	172°59.062'	Very thin - Very likely to no fresh groundwater in a drought
ABG19X8	Aonobuaka	210	53.4	108.2	0.2	0.4	0.2	1°52.514'		Very thin - Very likely to no fresh groundwater in a drought
ABG19X9	Aonobuaka	240	52.1	102.3	0.2	0.5	0.2	1°52.907'	172°59.036'	Very thin - Very likely to no fresh groundwater in a drought
ABG19X10	Aonobuaka	270	48.4	105.4	0.4	0.4	0.4	1°52.893'	172°59.022'	Very thin - Very likely to no fresh groundwater in a drought
ABG19X11	Aonobuaka	300	56.2	132.5	0.2	0.1	0.2	1°52.884'	172°59.003'	Very thin - Very likely to no fresh groundwater in a drought
ABG19X12	Aonobuaka	330	64.4	136.4	0.1	0.1	0.1	1°52.879'	172°58.985'	Very thin - Very likely to no fresh groundwater in a drought

ABG20X1	Aonobuaka	10	48.4	119.3	0.4	0.2	0.4	1°52.723'	172°59.054'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X2	Aonobuaka	40	41.2	99.0	0.8	0.6	0.8	1°52.726'	172°59.067'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X3	Aonobuaka	70	37.7	95.4	1.1	0.7	1.1	1°52.727'	172°59.094'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X4	Aonobuaka	100	37.2	86.7	1.2	1.0	1.2	1°52.729'	172°59.110'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X5	Aonobuaka	130	37.8	85.4	1.1	1.1	1.1	1°52.733'	172°59.118'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X6	Aonobuaka	160	37.9	84.5	1.1	1.1	1.1	1°52.744'	172°59.144'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X7	Aonobuaka	190	37.5	87.5	1.2	1.0	1.2	1°52.741'	172°59.159'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X8	Aonobuaka	210	38.1	86.1	1.1	1.0	1.1	1°52.755'	172°59.184'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X9	Aonobuaka	240	45.1	84.6	0.5	1.1	0.5	1°52.756'	172°59.193'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X10	Aonobuaka	270	73.4	88.7	0.0	0.9	0.0	1°52.764'	172°59.223'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X11	Aonobuaka	300	39.1	125.1	1.0	0.2	1.0	1°52.779'	172°59.239'	Very thin - Very likely to no fresh groundwater in a drought
ABG20X12	Aonobuaka	330	67.8	127.0	0.0	0.2	0.0	1°52.775'	172°59.251'	Very thin - Very likely to no fresh groundwater in a drought
ABG21X1	Aonobuaka	10	78.5	141.1	0.0	0.1	0.0	1°52.576'	172°59.260'	Very thin - Very likely to no fresh groundwater in a drought
ABG21X2	Aonobuaka	40	67.7	130.4	0.0	0.1	0.0	1°52.576'	172°59.249'	Very thin - Very likely to no fresh groundwater in a drought
ABG21X3	Aonobuaka	70	59.2	125.4	0.1	0.2	0.1	1°52.577'	172°59.232'	Very thin - Very likely to no fresh groundwater in a drought
ABG21X4	Aonobuaka	100	69.1	122.5	0.0	0.2	0.0	1°52.581'	172°59.202'	Very thin - Very likely to no fresh groundwater in a drought
ABG21X5	Aonobuaka	130	53.1	123.9	0.2	0.2	0.2	1°52.572'	172°59.203'	Very thin - Very likely to no fresh groundwater in a drought
ABG21X6	Aonobuaka	160	56.3	108.4	0.2	0.4	0.2	1°52.559'	172°59.174'	Very thin - Very likely to no fresh groundwater in a drought
ABG21X7	Aonobuaka	190	46.4	114.2	0.5	0.3	0.5	1°52.556'	172°59.155'	Very thin - Very likely to no fresh groundwater in a drought

ABG21X8	Aonobuaka	210	63.4	138.8	0.1	0.1	0.1	1°52.552'	172°59.138'	Very thin - Very likely to no fresh groundwater in a drought
ABG21X9	Aonobuaka	240	62.4	150.2	0.1	0.1	0.1	1°52.549'	172°59.132'	Very thin - Very likely to no fresh groundwater in a drought
ABG22X1	Aonobuaka	10	93.4	143.1	0.0	0.1	0.0	1°50.224'	173°00.459'	Very thin - Very likely to no fresh groundwater in a drought
ABG22X2	Ewena	40	42.0	94.5	0.7	0.7	0.7	1°50.227'	173°00.447'	Very thin - Very likely to no fresh groundwater in a drought
ABG22X3	Ewena	70	36.4	91.3	1.3	0.8	1.3	1°50.228'	173°00.482'	Very thin - Very likely to no fresh groundwater in a drought
ABG22X4	Ewena	100	40.5	84.4	0.9	1.1	0.9	1°50.232'	173°00.499'	Very thin - Very likely to no fresh groundwater in a drought
ABG22X5	Ewena	130	30.3	85.5	2.5	1.1	2.5	1°50.244'	173°00.522'	Thin - Likely to be little or no fresh groundwater in a drought
ABG22X6	Ewena	160	34.8	81.8	1.6	1.3	1.6	1°50.251'	173°00.534'	Very thin - Very likely to no fresh groundwater in a drought
ABG22X7	Ewena	190	39.2	91.2	1.0	0.8	1.0	1°50.256'	173°00.547'	Very thin - Very likely to no fresh groundwater in a drought
ABG22X8	Ewena	220	48.8	107.2	0.4	0.4	0.4	1°50.267'	173°00.561'	Very thin - Very likely to no fresh groundwater in a drought
ABG23X1	Ewena	10	76.4	142.2	0.0	0.1	0.0	1°50.157'	173°00.658'	Very thin - Very likely to no fresh groundwater in a drought
ABG23X2	Ewena	40	35.5	91.2	1.5	0.8	1.5	1°50.139'	173°00.641'	Very thin - Very likely to no fresh groundwater in a drought
ABG23X3	Ewena	70	32.2	87.1	2.1	1.0	2.1	1°50.138'	173°00.633'	Very thin - Very likely to no fresh groundwater in a drought
ABG23X4	Ewena	100	37.2	99.2	1.2	0.6	1.2	1°50.124'	173°00.616'	Very thin - Very likely to no fresh groundwater in a drought
ABG23X5	Ewena	130	49.7	114.8	0.3	0.3	0.3	1°50.128'	173°00.591'	Very thin - Very likely to no fresh groundwater in a drought
ABG23X6	Ewena	160	35.6	92.2	1.4	0.8	1.4	1°50.095'	173°00.567'	Very thin - Very likely to no fresh groundwater in a drought
ABG23X7	Ewena	190	40.7	115.2	0.8	0.3	0.8	1°50.126'	173°00.580'	Very thin - Very likely to no fresh groundwater in a drought
ABG24X1	Ewena	10	89.2	163.3	0.0	0.0	0.0	1°49.957'	173°00.661'	Very thin - Very likely to no fresh groundwater in a drought
ABG24X2	Ewena	40	74.4	132.4	0.0	0.1	0.0	1°49.970'	173°00.677'	Very thin - Very likely to no fresh groundwater in a drought

ABG24X3	Ewena	70	58.4	112.3	0.1	0.3	0.1	1°49.984'	173°00.690'	Very thin - Very likely to no fresh groundwater in a drought
ABG24X4	Ewena	100	34.8	90.2	1.6	0.9	1.6	1°49.998'	173°00.704'	Very thin - Very likely to no fresh groundwater in a drought
ABG24X5	Ewena	130	39.2	98.6	1.0	0.6	1.0	1°50.010'	173°00.721'	Very thin - Very likely to no fresh groundwater in a drought
ABG24X6	Ewena	160	42.4	113.2	0.7	0.3	0.7	1°50.025'	173°00.735'	Very thin - Very likely to no fresh groundwater in a drought
ABG25X1	Ewena	10	40.4	106.4	0.9	0.4	0.9	1°49.764'	173°00.917'	Very thin - Very likely to no fresh groundwater in a drought
ABG25X2	Ewena	40	35.6	94.9	1.4	0.7	1.4	1°49.760'	173°00.905'	Very thin - Very likely to no fresh groundwater in a drought
ABG25X3	Ewena	70	41.9	105.3	0.7	0.4	0.7	1°49.755'	173°00.877'	Very thin - Very likely to no fresh groundwater in a drought
ABG25X4	Ewena	100	50.3	120.4	0.3	0.2	0.3	1°49.739'	173°00.869'	Very thin - Very likely to no fresh groundwater in a drought
ABG25X5	Ewena	130	63.5	120.4	0.1	0.2	0.1	1°49.729'	173°00.854'	Very thin - Very likely to no fresh groundwater in a drought
ABG25X6	Ewena	160	83.4	149.2	0.0	0.1	0.0	1°49.723'	173°00.837'	Very thin - Very likely to no fresh groundwater in a drought
ABG26X1	Ewena	10	49.0	114.8	0.3	0.3	0.3	1°49.530'	173°00.917'	Very thin - Very likely to no fresh groundwater in a drought
ABG26X2	Ewena	40	31.9	80.1	2.1	1.4	2.1	1°49.529'	173°00.940'	Very thin - Very likely to no fresh groundwater in a drought
ABG26X3	Ewena	70	23.6	65.9	5.2	2.6	5.2	1°49.546'	173°00.966'	Thin - Likely to be little or no fresh groundwater in a drought
ABG26X4	Ewena	100	19.0	63.8	8.4	2.8	2.8	1°49.553'	173°00.975'	Thin - Likely to be little or no fresh groundwater in a drought
ABG26X5	Ewena	130	25.7	70.8	4.1	2.1	4.1	1°49.560'	173°00.991'	Thin - Likely to be little or no fresh groundwater in a drought
ABG26X6	Ewena	160	30.6	78.1	2.4	1.5	2.4	1°49.578'	173°01.008'	Very thin - Very likely to no fresh groundwater in a drought
ABG26X7	Ewena	190	29.7	86.4	2.7	1.0	2.7	1°49.592'	173°01.024'	Thin - Likely to be little or no fresh groundwater in a drought
ABG27X1	Tuarabu	10	54.8	118.6	0.2	0.2	0.2	1°47.234'	173°02.603'	Very thin - Very likely to no fresh groundwater in a drought
ABG27X2	Tuarabu	40	51.9	95.6	0.3	0.7	0.3	1°47.239'	173°02.617'	Very thin - Very likely to no fresh groundwater in a drought

ABG27X3	Tuarabu	70	31.3	75.3	2.3	1.7	2.3	1°47.249'	173°02.628'	Very thin - Very likely to no fresh groundwater in a drought
ABG27X4	Tuarabu	100	21.6	61.3	6.4	3.2	6.4	1°47.261'	173°02.648'	Moderately thick - fresh groundwater likely to be found all year round
ABG27X5	Tuarabu	130	21.3	55.2	6.6	4.2	6.6	1°47.266'	173°02.661'	Moderately thick - fresh groundwater likely to be found all year round
ABG27X6	Tuarabu	160	15.8	54.6	11.8	4.3	4.3	1°47.267'	173°02.682'	Thin - Likely to be little or no fresh groundwater in a drought
ABG27X7	Tuarabu	190	21.7	55.3	6.3	4.1	6.3	1°47.268'	173°02.685'	Moderately thick - fresh groundwater likely to be found all year round
ABG27X8	Tuarabu	220	20.8	54.7	6.9	4.3	6.9	1°47.272'	173°02.713'	Moderately thick - fresh groundwater likely to be found all year round
ABG27X9	Tuarabu	250	18.8	54.9	8.6	4.2	4.2	1°47.268'	173°02.719'	Thin - Likely to be little or no fresh groundwater in a drought
ABG27X10	Tuarabu	280	16.1	46.7	11.5	6.1	6.1	1°47.234'	173°02.735'	Moderately thick - fresh groundwater likely to be found all year round
ABG27X11	Tuarabu	310	15.6	50.8	12.1	5.1	5.1	1°47.279'	173°02.761'	Thin - Likely to be little or no fresh groundwater in a drought
ABG27X12	Tuarabu	340	19.8	57.5	7.7	3.8	7.7	1°47.274'	173°02.774'	Moderately thick - fresh groundwater likely to be found all year round
ABG27X13	Tuarabu	370	27.2	70.1	3.5	2.1	3.5	1°47.279'	173°02.789'	Thin - Likely to be little or no fresh groundwater in a drought
ABG28X1	Tuarabu	10	50.8	102.1	0.3	0.5	0.3	1°47.437'	173°02.778'	Very thin - Very likely to no fresh groundwater in a drought
ABG28X2	Tuarabu	40	20.3	60.2	7.3	3.3	7.3	1°47.431'	173°02.773'	Moderately thick - fresh groundwater likely to be found all year round
ABG28X3	Tuarabu	70	19.1	55.2	8.3	4.2	4.2	1°47.427'	173°02.743'	Thin - Likely to be little or no fresh groundwater in a drought
ABG28X4	Tuarabu	100	20.5	59.4	7.2	3.4	7.2	1°47.427'	173°02.725'	Moderately thick - fresh groundwater likely to be found all year round
ABG28X5	Tuarabu	130	23.8	60.3	5.0	3.3	5.0	1°47.425'	173°02.702'	Thin - Likely to be little or no fresh groundwater in a drought
ABG28X6	Tuarabu	160	23.6	61.1	5.2	3.2	5.2	1°47.418'	173°02.692'	Thin - Likely to be little or no fresh groundwater in a drought
ABG28X7	Tuarabu	190	18.2	51.2	9.2	5.0	5.0	1°47.410'	173°02.667'	Thin - Likely to be little or no fresh groundwater in a drought
ABG28X8	Tuarabu	220	19.9	50.8	7.6	5.1	7.6	1°47.406'	173°02.644'	Moderately thick - fresh groundwater likely to be found all year round

ABG28X9	Tuarabu	250	18.2	50.5	9.2	5.1	5.1	1°47.409'	173°02.635'	Thin - Likely to be little or no fresh groundwater in a drought
ABG28X10	Tuarabu	280	15.3	50.3	12.5	5.2	5.2	1°47.380'	173°02.610'	Thin - Likely to be little or no fresh groundwater in a drought
ABG28X11	Tuarabu	310	24.9	60.6	4.5	3.3	4.5	1°47.371'	173°02.591'	Thin - Likely to be little or no fresh groundwater in a drought
ABG28X12	Tuarabu	340	54.8	98.8	0.2	0.6	0.2	1°47.469'	173°02.582'	Very thin - Very likely to no fresh groundwater in a drought
ABG28X13	Tuarabu	370	67.4	139.9	0.0	0.1	0.0	1°47.367'	173°02.566'	Very thin - Very likely to no fresh groundwater in a drought
ABG29X1	Tuarabu	10	52.9	115.6	0.2	0.3	0.2	1°47.580'	173°02.479'	Very thin - Very likely to no fresh groundwater in a drought
ABG29X2	Tuarabu	40	36.8	50.9	1.3	5.0	1.3	1°47.585'	173°02.497'	Very thin - Very likely to no fresh groundwater in a drought
ABG29X3	Tuarabu	70	25.3	56.3	4.3	4.0	4.3	1°47.594'	173°02.520'	Thin - Likely to be little or no fresh groundwater in a drought
ABG29X4	Tuarabu	100	19.4	44.5	8.1	6.7	6.7	1°47.605'	173°02.539'	Moderately thick - fresh groundwater likely to be found all year round
ABG29X5	Tuarabu	130	15.4	37.5	12.3	9.2	9.2	1°47.605'	173°02.558'	Moderately thick - fresh groundwater likely to be found all year round
ABG29X6	Tuarabu	160	15.4	36.7	12.3	9.6	9.6	1°47.616'	173°02.574'	Moderately thick - fresh groundwater likely to be found all year round
ABG29X7	Tuarabu	190	12.9	39.8	16.1	8.3	8.3	1°47.618'	173°02.584'	Moderately thick - fresh groundwater likely to be found all year round
ABG29X8	Tuarabu	220	15.6	37.1	12.1	9.4	9.4	1°47.613'	173°02.617'	Moderately thick - fresh groundwater likely to be found all year round
ABG29X9	Tuarabu	250	17.3	47.3	10.1	5.9	5.9	1°47.612'	173°02.631'	Thin - Likely to be little or no fresh groundwater in a drought
ABG29X10	Tuarabu	280	14.3	47.2	13.9	6.0	6.0	1°47.621'	173°02.654'	Thin - Likely to be little or no fresh groundwater in a drought
ABG29X11	Tuarabu	310	13.7	47.5	14.8	5.9	5.9	1°47.625'	173°02.672'	Thin - Likely to be little or no fresh groundwater in a drought
ABG29X12	Tuarabu	340	18.8	55.4	8.6	4.1	4.1	1°47.640'	173°02.699'	Thin - Likely to be little or no fresh groundwater in a drought
ABG29X13	Tuarabu	370	26.7	73.0	3.7	1.9	3.7	1°47.643'	173°02.715'	Thin - Likely to be little or no fresh groundwater in a drought
ABG30X1	Tuarabu	10	20.1	61.8	7.5	3.1	7.5	1°47.709'	173°02.701'	Moderately thick - fresh groundwater likely to be found all year round

ABG30X2	Tuarabu	40	50.7	49.2	0.3	5.4	0.3	1°47.707'	173°02.679'	Very thin - Very likely to no fresh groundwater in a drought
ABG30X3	Tuarabu	70	14.4	45.4	13.7	6.5	6.5	1°47.706'	173°02.658'	Moderately thick - fresh groundwater likely to be found all year round
ABG30X4	Tuarabu	100	16.2	49.1	11.3	5.5	5.5	1°47.685'	173°02.645'	Thin - Likely to be little or no fresh groundwater in a drought
ABG30X5	Tuarabu	130	18.8	48.1	8.6	5.7	5.7	1°47.675'	173°02.621'	Thin - Likely to be little or no fresh groundwater in a drought
ABG30X6	Tuarabu	160	16.8	44.2	10.6	6.8	6.8	1°47.673'	173°02.611'	Moderately thick - fresh groundwater likely to be found all year round
ABG30X7	Tuarabu	190	16.7	42.8	10.8	7.3	7.3	1°47.664'	173°02.584'	Moderately thick - fresh groundwater likely to be found all year round
ABG30X8	Tuarabu	220	14.2	37.4	14.0	9.3	9.3	1°47.658'	173°02.569'	Moderately thick - fresh groundwater likely to be found all year round
ABG30X9	Tuarabu	250	14.8	35.1	13.2	10.3	10.3	1°47.651'	173°02.538'	Thick - fresh groundwater likely to be found at all times
ABG30X10	Tuarabu	280	13.5	34.2	15.1	10.7	10.7	1°47.654'	173°02.525'	Thick - fresh groundwater likely to be found at all times
ABG30X11	Tuarabu	310	14.1	37.5	14.2	9.2	9.2	1°47.650'	173°02.497'	Moderately thick - fresh groundwater likely to be found all year round
ABG30X12	Tuarabu	340	21.2	55.1	6.7	4.2	6.7	1°47.638'	173°02.481'	Moderately thick - fresh groundwater likely to be found all year round
ABG30X13	Tuarabu	370	31.1	69.2	2.3	2.2	2.3	1°47.636'	173°02.463'	Very thin - Very likely to no fresh groundwater in a drought
ABG31X1	Tuarabu	10	49.0	114.8	0.3	0.3	0.3	1°49.530'	173°00.917'	Very thin - Very likely to no fresh groundwater in a drought
ABG31X2	Tuarabu	40	31.9	80.1	2.1	1.4	2.1	1°49.529'	173°00.940'	Very thin - Very likely to no fresh groundwater in a drought
ABG31X3	Tuarabu	70	23.6	65.9	5.2	2.6	5.2	1°49.546'	173°00.966'	Thin - Likely to be little or no fresh groundwater in a drought
ABG31X4	Tuarabu	100	19.0	63.8	8.4	2.8	2.8	1°49.553'	173°00.975'	Thin - Likely to be little or no fresh groundwater in a drought
ABG31X5	Tuarabu	130	25.7	70.8	4.1	2.1	4.1	1°49.560'	173°00.991'	Thin - Likely to be little or no fresh groundwater in a drought
ABG31X6	Tuarabu	160	30.6	78.1	2.4	1.5	2.4	1°49.578'	173°01.008'	Very thin - Very likely to no fresh groundwater in a drought
ABG31X7	Tuarabu	190	29.7	86.4	2.7	1.0	2.7	1°49.592'	173°01.024'	Thin - Likely to be little or no fresh groundwater in a drought

ABG32X1	Tuarabu	10	84.1	122.3	0.0	0.2	0.0	1°48.350'	173°02.262'	Very thin - Very likely to no fresh groundwater in a drought
ABG32X2	Tuarabu	40	29.3	68.1	2.8	2.3	2.8	1°48.343'	173°02.248'	Thin - Likely to be little or no fresh groundwater in a drought
ABG32X3	Tuarabu	70	32.1	73.1	2.1	1.9	2.1	1°48.326'	173°02.230'	Very thin - Very likely to no fresh groundwater in a drought
ABG32X4	Tuarabu	100	26.6	62.8	3.7	3.0	3.7	1°48.321'	173°02.228'	Thin - Likely to be little or no fresh groundwater in a drought
ABG32X5	Tuarabu	130	23.4	52.2	5.3	4.8	5.3	1°48.301'	173°02.191'	Thin - Likely to be little or no fresh groundwater in a drought
ABG32X6	Tuarabu	160	18.5	43.1	8.9	7.2	7.2	1°48.287'	173°02.173'	Moderately thick - fresh groundwater likely to be found all year round
ABG32X7	Tuarabu	190	16.2	33.5	11.3	11.0	11.0	1°48.272'	173°02.162'	Thick - fresh groundwater likely to be found at all times
ABG32X8	Tuarabu	220	18.1	45.2	9.3	6.5	6.5	1°48.260'	173°02.142'	Moderately thick - fresh groundwater likely to be found all year round
ABG32X9	Tuarabu	250	9.6	20.3	22.9	20.0	20.0	1°48.243'	173°02.132'	Thick - fresh groundwater likely to be found at all times
ABG32X10	Tuarabu	280	14.9	39.7	13.0	8.3	8.3	1°48.236'	173°02.114'	Moderately thick - fresh groundwater likely to be found all year round
ABG32X11	Tuarabu	310	20.7	53.4	7.0	4.5	7.0	1°48.222'	173°02.099'	Moderately thick - fresh groundwater likely to be found all year round
ABG32X12	Tuarabu	340	37.5	83.1	1.2	1.2	1.2	1°48.207'	173°02.069'	Very thin - Very likely to no fresh groundwater in a drought
ABG33X1	Tuarabu	10	37.3	84.2	1.2	1.1	1.2	1°48.107'	173°02.156'	Very thin - Very likely to no fresh groundwater in a drought
ABG33X2	Tuarabu	40	17.1	45.8	10.3	6.3	6.3	1°48.107'	173°02.176'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X3	Tuarabu	70	14.7	38.8	13.3	8.7	8.7	1°48.137'	173°02.184'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X4	Tuarabu	100	14.8	37.8	13.2	9.1	9.1	1°48.144'	173°02.199'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X5	Tuarabu	130	16.5	42.0	11.0	7.5	7.5	1°48.145'	173°02.204'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X6	Tuarabu	160	21.4	48.3	6.5	5.7	6.5	1°48.160'	173°02.240'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X7	Tuarabu	190	23.9	49.3	5.0	5.4	5.0	1°48.169'	173°02.248'	Thin - Likely to be little or no fresh groundwater in a drought

ABG33X8	Tuarabu	220	20.3	48.7	7.3	5.6	7.3	1°48.180'	173°02.276'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X9	Tuarabu	250	19.8	50.0	7.7	5.3	7.7	1°48.191'	173°02.282'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X10	Tuarabu	280	13.6	43.2	15.0	7.1	7.1	1°48.206'	173°02.315'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X11	Tuarabu	310	11.2	38.7	19.3	8.7	8.7	1°48.214'	173°02.333'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X12	Tuarabu	340	12.8	43.4	16.3	7.1	7.1	1°48.227'	173°02.353'	Moderately thick - fresh groundwater likely to be found all year round
ABG33X13	Tuarabu	370	17.2	50.3	10.2	5.2	5.2	1°48.230'	173°02.364'	Thin - Likely to be little or no fresh groundwater in a drought
ABG33X14	Tuarabu	400	22.3	61.2	5.9	3.2	5.9	1°48.252'	173°02.393'	Thin - Likely to be little or no fresh groundwater in a drought
ABG33X15	Tuarabu	430	28.4	81.3	3.1	1.3	3.1	1°48.260'	173°02.401'	Thin - Likely to be little or no fresh groundwater in a drought
ABG34X1	Tuarabu	10	24.1	76.2	4.9	1.6	4.9	1°48.087'	173°02.497'	Thin - Likely to be little or no fresh groundwater in a drought
ABG34X2	Tuarabu	40	14.2	48.5	14.0	5.6	5.6	1°48.086'	173°02.492'	Thin - Likely to be little or no fresh groundwater in a drought
ABG34X3	Tuarabu	70	13.2	46.0	15.6	6.3	6.3	1°48.071'	173°02.466'	Moderately thick - fresh groundwater likely to be found all year round
ABG34X4	Tuarabu	100	13.6	43.9	15.0	6.9	6.9	1°48.057'	173°02.446'	Moderately thick - fresh groundwater likely to be found all year round
ABG34X5	Tuarabu	130	15.0	44.7	12.9	6.7	6.7	1°48.050'	173°02.429'	Moderately thick - fresh groundwater likely to be found all year round
ABG34X6	Tuarabu	160	16.1	43.7	11.5	7.0	7.0	1°48.048'	173°02.403'	Moderately thick - fresh groundwater likely to be found all year round
ABG34X7	Tuarabu	190	19.1	42.2	8.3	7.5	7.5	1°48.040'	173°02.388'	Moderately thick - fresh groundwater likely to be found all year round
ABG34X8	Tuarabu	220	17.3	42.6	10.1	7.3	7.3	1°48.029'	173°02.358'	Moderately thick - fresh groundwater likely to be found all year round
ABG34X9	Tuarabu	250	13.6	34.3	15.0	10.6	10.6	1°48.019'	173°02.349'	Thick - fresh groundwater likely to be found at all times
ABG34X10	Tuarabu	280	12.1	35.2	17.5	10.2	10.2	1°48.006'	173°02.325'	Thick - fresh groundwater likely to be found at all times
ABG34X11	Tuarabu	310	10.5	31.7	20.8	12.0	12.0	1°48.002'	173°02.306'	Thick - fresh groundwater likely to be found at all times

ABG34X12	Tuarabu	340	11.4	34.6	18.9	10.5	10.5	1°47.999'	173°02.281'	Thick - fresh groundwater likely to be found at all times
ABG34X13	Tuarabu	370	15.6	24.8	12.1	16.3	16.3	1°48.007'	173°02.263'	Thick - fresh groundwater likely to be found at all times
ABG34X14	Tuarabu	400	21.4	55.6	6.5	4.1	6.5	1°48.002'	173°02.251'	Moderately thick - fresh groundwater likely to be found all year round
ABG34X15	Tuarabu	430	35.2	55.1	1.5	4.2	1.5	1°47.984'	173°02.238'	Very thin - Very likely to no fresh groundwater in a drought
ABG35X1	Tuarabu	10	52.8	95.2	0.2	0.7	0.2	1°47.857'	173°02.330'	Very thin - Very likely to no fresh groundwater in a drought
ABG35X2	Tuarabu	40	40.2	39.1	0.9	8.6	8.6	1°47.869'	173°02.347'	Moderately thick - fresh groundwater likely to be found all year round
ABG35X3	Tuarabu	70	12.1	29.8	17.5	13.0	13.0	1°47.881'	173°02.362'	Thick - fresh groundwater likely to be found at all times
ABG35X4	Tuarabu	100	8.2	26.1	26.6	15.4	15.4	1°47.895'	173°02.380'	Thick - fresh groundwater likely to be found at all times
ABG35X5	Tuarabu	130	8.7	25.8	25.2	15.6	15.6	1°47.890'	173°02.402'	Thick - fresh groundwater likely to be found at all times
ABG35X6	Tuarabu	160	10.9	29.7	19.9	13.1	13.1	1°47.894'	173°02.422'	Thick - fresh groundwater likely to be found at all times
ABG35X7	Tuarabu	190	12.8	33.5	16.3	11.0	11.0	1°47.913'	173°02.435'	Thick - fresh groundwater likely to be found at all times
ABG35X8	Tuarabu	220	13.0	36.5	15.9	9.6	9.6	1°47.924'	173°02.457'	Moderately thick - fresh groundwater likely to be found all year round
ABG35X9	Tuarabu	250	20.9	42.1	6.9	7.5	6.9	1°47.934'	173°02.477'	Moderately thick - fresh groundwater likely to be found all year round
ABG35X10	Tuarabu	280	16.3	44.1	11.2	6.8	6.8	1°47.942'	173°02.492'	Moderately thick - fresh groundwater likely to be found all year round
ABG35X11	Tuarabu	310	12.5	39.3	16.8	8.5	8.5	1°47.962'	173°02.515'	Moderately thick - fresh groundwater likely to be found all year round
ABG35X12	Tuarabu	340	13.2	43.4	15.6	7.1	7.1	1°47.967'	173°02.528'	Moderately thick - fresh groundwater likely to be found all year round
ABG35X13	Tuarabu	370	16.3	49.1	11.2	5.5	5.5	1°47.979'	173°02.542'	thin - Likely to be little or no fresh groundwater in a drought
ABG36X1	Tuarabu	10	111.7	144.9	0.0	0.1	0.0	1°47.888'	173°02.702'	Very thin - Very likely to no fresh groundwater in a drought
ABG36X2	Tuarabu	40	22.1	94.8	6.0	0.7	6.0	1°47.870'	173°02.688'	Moderately thick - fresh groundwater likely to be found all year round

ABG36X3	Tuarabu	70	20.6	55.5	7.1	4.1	7.1	1°47.865'	173°02.669'	Moderately thick - fresh groundwater likely to be found all year round
ABG36X4	Tuarabu	100	15.2	45.1	12.6	6.5	6.5	1°47.846'	173°02.646'	Moderately thick - fresh groundwater likely to be found all year round
ABG36X5	Tuarabu	130	13.7	40.2	14.8	8.2	8.2	1°47.826'	173°02.630'	Moderately thick - fresh groundwater likely to be found all year round
ABG36X6	Tuarabu	160	33.4	40.5	1.8	8.1	8.1	1°47.808'	173°02.625'	Moderately thick - fresh groundwater likely to be found all year round
ABG36X7	Tuarabu	190	11.2	36.1	19.3	9.8	9.8	1°47.795'	173°02.612'	Moderately thick - fresh groundwater likely to be found all year round
ABG36X8	Tuarabu	220	13.8	40.4	14.6	8.1	8.1	1°47.786'	173°02.598'	Moderately thick - fresh groundwater likely to be found all year round
ABG36X9	Tuarabu	250	13.1	34.5	15.8	10.5	10.5	1°47.778'	173°02.575'	Thick - fresh groundwater likely to be found at all times
ABG36X10	Tuarabu	280	11.0	32.8	19.7	11.4	11.4	1°47.777'	173°02.560'	Thick - fresh groundwater likely to be found at all times
ABG36X11	Tuarabu	310	11.6	24.4	18.5	16.6	16.6	1°47.777'	173°02.538'	Thick - fresh groundwater likely to be found at all times
ABG36X12	Tuarabu	340	9.6	28.3	22.9	13.9	13.9	1°47.773'	173°02.516'	Thick - fresh groundwater likely to be found at all times
ABG36X13	Tuarabu	370	9.1	27.4	24.2	14.5	14.5	1°47.774'	173°02.494'	Thick - fresh groundwater likely to be found at all times
ABG36X14	Tuarabu	400	8.8	26.2	24.9	15.3	15.3	1°47.757'	173°02.472'	Thick - fresh groundwater likely to be found at all times
ABG36X15	Tuarabu	430	15.1	32.3	12.7	11.6	11.6	1°47.744'	173°02.456'	Thick - fresh groundwater likely to be found at all times
ABG36X16	Tuarabu	460	16.4	35.4	11.1	10.1	10.1	1°47.727'	173°02.702444'	Thick - fresh groundwater likely to be found at all times
ABG36X17	Tuarabu	490	42.1	85.5	0.7	1.1	0.7	1°47.716'	173°02.421'	Very thin - Very likely to no fresh groundwater in a drought
ABG37X1	Tuarabu	10	15.1	44.3	12.7	6.8	6.8	1°47.826'	173°02.634'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X2	Tuarabu	40	12.2	41.9	17.4	7.6	7.6	1°47.843'	173°02.622'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X3	Tuarabu	70	12.4	40.8	17.0	7.9	7.9	1°47.855'	173°02.599'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X4	Tuarabu	100	12.5	37.9	16.8	9.0	9.0	1°47.862'	173°02.584'	Moderately thick - fresh groundwater likely to be found all year round

ABG37X5	Tuarabu	130	12.4	38.8	17.0	8.7	8.7	1°47.867'	173°02.567'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X6	Tuarabu	160	15.2	38.0	12.6	9.0	9.0	1°47.883'	173°02.543'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X7	Tuarabu	190	12.5	37.1	16.8	9.4	9.4	1°47.893'	173°02.524'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X8	Tuarabu	220	13.6	37.2	15.0	9.3	9.3	1°47.904'	173°02.507'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X9	Tuarabu	250	13.7	37.5	14.8	9.2	9.2	1°47.912'	173°02.487'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X10	Tuarabu	280	15.2	39.3	12.6	8.5	8.5	1°47.919'	173°02.470'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X11	Tuarabu	310	14.2	39.0	14.0	8.6	8.6	1°47.931'	173°02.451'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X12	Tuarabu	340	14.1	38.1	14.2	9.0	9.0	1°47.931'	173°02.437'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X13	Tuarabu	370	14.8	39.1	13.2	8.6	8.6	1°47.951'	173°02.414'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X14	Tuarabu	400	14.1	36.7	14.2	9.6	9.6	1°47.957'	173°02.398'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X15	Tuarabu	430	12.6	35.4	16.6	10.1	10.1	1°47.965'	173°02.379'	Thick - fresh groundwater likely to be found at all times
ABG37X16	Tuarabu	460	12.9	34.6	16.1	10.5	10.5	1°47.974'	173°02.361'	Thick - fresh groundwater likely to be found at all times
ABG37X17	Tuarabu	490	13.8	33.9	14.6	10.8	10.8	1°47.980'	173°02.347'	Thick - fresh groundwater likely to be found at all times
ABG37X18	Tuarabu	520	13.4	32.3	15.3	11.6	11.6	1°47.992'	173°02.331'	Thick - fresh groundwater likely to be found at all times
ABG37X19	Tuarabu	550	12.3	32.3	17.2	11.6	11.6	1°48.001'	173°02.312'	Thick - fresh groundwater likely to be found at all times
ABG37X20	Tuarabu	580	10.1	32.3	21.7	11.6	11.6	1°48.008'	173°02.228'	Thick - fresh groundwater likely to be found at all times
ABG37X21	Tuarabu	610	10.9	35.2	19.9	10.2	10.2	1°48.021'	173°02.276'	Thick - fresh groundwater likely to be found at all times
ABG37X22	Tuarabu	640	14.7	40.7	13.3	8.0	8.0	1°48.032'	173°02.256'	Moderately thick - fresh groundwater likely to be found all year round
ABG37X23	Tuarabu	670	18.4	50.7	9.0	5.1	5.1	1°48.032'	173°02.246'	Thin - Likely to be little or no fresh groundwater in a drought

ABG37X24	Tuarabu	700	24.4	57.7	4.7	3.7	4.7	1°48.042'	173°02.226'	Thin - Likely to be little or no fresh groundwater in a drought
ABG37X25	Tuarabu	730	25.5	61.5	4.2	3.1	4.2	1°48.050'	173°02.205'	Thin - Likely to be little or no fresh groundwater in a drought
ABG38X1	Taniau	10	33.7	84.3	1.8	1.1	1.8	1°43.122'	173°01.078'	Very thin - Very likely to no fresh groundwater in a drought
ABG38X2	Taniau	40	18.1	56.1	9.3	4.0	4.0	1°43.109'	173°01.080'	Thin - Likely to be little or no fresh groundwater in a drought
ABG38X3	Taniau	70	16.0	46.4	11.6	6.2	6.2	1°43.096'	173°01.089'	Moderately thick - fresh groundwater likely to be found all year round
ABG38X4	Taniau	100	57.4	79.5	0.1	1.4	0.1	1°43.092'	173°01.097'	Very thin - Very likely to no fresh groundwater in a drought
ABG38X5	Taniau	130	21.7	61.8	6.3	3.1	6.3	1°43.077'	173°01.118'	Moderately thick - fresh groundwater likely to be found all year round
ABG38X6	Taniau	160	27.0	70.0	3.6	2.1	3.6	1°43.072'	173°01.116'	Thin - Likely to be little or no fresh groundwater in a drought
ABG38X7	Taniau	190	16.0	49.8	11.6	5.3	5.3	1°43.O48'	173°01.138'	Thin - Likely to be little or no fresh groundwater in a drought
ABG38X8	Taniau	220	56.1	108.5	0.2	0.4	0.2	1°43.036'	173°01.141'	Very thin - Very likely to no fresh groundwater in a drought
ABG38X9	Taniau	250	63.2	124.6	0.1	0.2	0.1	1°43.028'	173°01.157'	Very thin - Very likely to no fresh groundwater in a drought
ABG39X1	Taniau	10	147.7	178.9	0.0	0.0	0.0	1°42.818'	173°00.840'	Very thin - Very likely to no fresh groundwater in a drought
ABG39X2	Taniau	40	68.8	107.1	0.0	0.4	0.0	1°42.832'	173°00.838'	Very thin - Very likely to no fresh groundwater in a drought
ABG39X3	Taniau	70	51.8	98.8	0.3	0.6	0.3	1°42.851'	173°00.829'	Very thin - Very likely to no fresh groundwater in a drought
ABG39X4	Taniau	100	35.7	171.2	1.4	0.0	1.4	1°42.867'	173°00.824'	Very thin - Very likely to no fresh groundwater in a drought
ABG39X5	Taniau	130	39.2	88.2	1.0	0.9	1.0	1°42.881'	173°00.812'	very thin - Very likely to no fresh groundwater in a drought
ABG39X6	Taniau	160	42.2	69.2	0.7	2.2	0.7	1°42.893'	173°00.808'	Very thin - Very likely to no fresh groundwater in a drought
ABG39X7	Taniau	190	16.5	48.2	11.0	5.7	5.7	1°42.902'	173°00.795'	Thin - Likely to be little or no fresh groundwater in a drought
ABG39X8	Taniau	220	16.6	39.2	10.9	8.5	8.5	1°42.923'	173°00.786'	Moderately thick - fresh groundwater likely to be found all year round

ABG39X9	Taniau	250	9.9	37.5	22.2	9.2	9.2	1°42.940'	173°00.778'	Moderately thick - fresh groundwater likely to be found all year round
ABG39X10	Taniau	280	18.8	55.0	8.6	4.2	4.2	1°42.960'	173°00.774'	Thin - Likely to be little or no fresh groundwater in a drought
ABG39X11	Taniau	310	52.6	89.2	0.2	0.9	0.2	1°42.967'	173°00.771'	Very thin - Very likely to no fresh groundwater in a drought
ABG40X1	Taniau	10	44.9	89.7	0.5	0.9	0.5	1°42.931'	173°00.589'	Very thin - Very likely to no fresh groundwater in a drought
ABG40X2	Taniau	40	19.3	51.1	8.2	5.0	5.0	1°42.916'	173°00.584'	Thin - Likely to be little or no fresh groundwater in a drought
ABG40X3	Taniau	70	15.8	44.7	11.8	6.7	6.7	1°42.899'	173°00.583'	Moderately thick - fresh groundwater likely to be found all year round
ABG40X4	Taniau	100	15.6	43.1	12.1	7.2	7.2	1°42.877'	173°00.589'	Moderately thick - fresh groundwater likely to be found all year round
ABG40X5	Taniau	130	15.7	41.5	12.0	7.7	7.7	1°42.861'	173°00.584'	Moderately thick - fresh groundwater likely to be found all year round
ABG40X6	Taniau	160	13.9	43.8	14.5	6.9	6.9	1°42.841'	173°00.591'	Moderately thick - fresh groundwater likely to be found all year round
ABG40X7	Taniau	190	21.1	49.0	6.7	5.5	6.7	1°42.829'	173°00.592'	Moderately thick - fresh groundwater likely to be found all year round
ABG40X8	Taniau	220	29.7	59.7	2.7	3.4	2.7	1°42.822'	173°00.593'	Thin - Likely to be little or no fresh groundwater in a drought
ABG40X9	Taniau	250	71.3	84.9	0.0	1.1	0.0	1°42.795'	173°00.590'	Very thin - Very likely to no fresh groundwater in a drought
ABG40X10	Taniau	280	110.6	73.2	0.0	1.9	0.0	1°42.772'	173°00.586'	Very thin - Very likely to no fresh groundwater in a drought
ABG40X11	Taniau	310	184.7	176.4	0.0	0.0	0.0	1°42.762'	173°00.589'	Very thin - Very likely to no fresh groundwater in a drought
ABG41X1	Taniau	10	167.2	153.3	0.0	0.1	0.0	1°42.734'	173°00.437'	Very thin - Very likely to no fresh groundwater in a drought
ABG41X2	Taniau	40	36.5	70.3	1.3	2.1	1.3	1°42.747'	173°00.445'	Very thin - Very likely to no fresh groundwater in a drought
ABG41X3	Taniau	70	23.1	51.8	5.4	4.8	5.4	1°42.769'	173°00.439'	Thin - Likely to be little or no fresh groundwater in a drought
ABG41X4	Taniau	100	18.1	40.4	9.3	8.1	8.1	1°42.781'	173°00.443'	Moderately thick - fresh groundwater likely to be found all year round
ABG41X5	Taniau	130	15.0	40.6	12.9	8.0	8.0	1°42.797'	173°00.448'	Moderately thick - fresh groundwater likely to be found all year round

ABG41X6	Taniau	160	12.6	36.7	16.6	9.6	9.6	1°42.818'	173°00.453'	Moderately thick - fresh groundwater likely to be found all year round
ABG41X7	Taniau	190	9.4	32.0	23.4	11.8	11.8	1°42.837'	173°00.443'	Thick - fresh groundwater likely to be found at all times
ABG41X8	Taniau	220	12.3	34.5	17.2	10.5	10.5	1°42.858'	173°00.451'	Thick - fresh groundwater likely to be found at all times
ABG41X9	Taniau	250	12.7	36.3	16.5	9.7	9.7	1°42.874'	173°00.445'	Moderately thick - fresh groundwater likely to be found all year round
ABG41X10	Taniau	280	15.5	38.9	12.2	8.7	8.7	1°42.888'	173°00.436'	Moderately thick - fresh groundwater likely to be found all year round
ABG41X11	Taniau	310	15.9	40.6	11.7	8.0	8.0	1°42.901'	173°00.436'	Moderately thick - fresh groundwater likely to be found all year round
ABG41X12	Taniau	340	49.3	88.7	0.3	0.9	0.3	1°42.919'	173°00.435'	very thin - Very likely to no fresh groundwater in a drought
ABG42X1	Taniau	10	14.9	40.7	13.0	8.0	8.0	1°42.940'	173°00.235'	Moderately thick - fresh groundwater likely to be found all year round
ABG42X2	Taniau	40	10.5	25.4	20.8	15.9	15.9	1°42.916'	173°00.222'	Thick - fresh groundwater likely to be found at all times
ABG42X3	Taniau	70	7.5	22.3	28.6	18.2	18.2	1°42.908'	173°00.227'	Thick - fresh groundwater likely to be found at all times
ABG42X4	Taniau	100	7.3	21.7	29.3	18.7	18.7	1°42.897'	173°00.231'	Thick - fresh groundwater likely to be found at all times
ABG42X5	Taniau	130	7.1	20.8	29.9	19.5	19.5	1°42.871'	173°00.215'	Thick - fresh groundwater likely to be found at all times
ABG42X6	Taniau	160	7.5	21.5	28.6	18.9	18.9	1°42.855'	173°00.215'	Thick - fresh groundwater likely to be found at all times
ABG42X7	Taniau	190	6.4	20.8	32.2	19.5	19.5	1°42.838'	173°00.216'	Thick - fresh groundwater likely to be found at all times
ABG42X8	Taniau	220	6.7	22.5	31.2	18.1	18.1	1°42.816'	173°00.214'	Thick - fresh groundwater likely to be found at all times
ABG42X9	Taniau	250	11.5	26.7	18.7	15.0	15.0	1°42.802'	173°00.209'	Thick - fresh groundwater likely to be found at all times
ABG42X10	Taniau	280	10.1	28.1	21.7	14.1	14.1	1°42.785'	173°00.211'	Thick - fresh groundwater likely to be found at all times
ABG42X11	Taniau	310	11.7	35.8	18.3	9.9	9.9	1°42.785'	173°00.215'	Moderately thick - fresh groundwater likely to be found all year round
ABG42X12	Taniau	340	18.4	53.4	9.0	4.5	4.5	1°42.752'	173°00.212'	Thin - Likely to be little or no fresh groundwater in a drought

ABG43X1	Taniau	10	21.4	53.4	6.5	4.5	6.5	1°42.765'	173°00.092'	Moderately thick - fresh groundwater likely to be found all year round
ABG43X2	Taniau	40	13.5	36.6	15.1	9.6	9.6	1°42.783'	173°00.093'	Moderately thick - fresh groundwater likely to be found all year round
ABG43X3	Taniau	70	5.6	27.7	35.1	14.3	14.3	1°42.780'	173°00.094'	Thick - fresh groundwater likely to be found at all times
ABG43X4	Taniau	100	9.6	24.5	22.9	16.5	16.5	1°42.815'	173°00.100'	Thick - fresh groundwater likely to be found at all times
ABG43X5	Taniau	130	9.0	23.6	24.4	17.2	17.2	1°42.817'	173°00.099'	Thick - fresh groundwater likely to be found at all times
ABG43X6	Taniau	160	6.2	20.3	32.9	20.0	20.0	1°42.828'	173°00.104'	Thick - fresh groundwater likely to be found at all times
ABG43X7	Taniau	190	5.7	17.5	34.7	22.6	22.6	1°42.856'	173°00.113'	Thick - fresh groundwater likely to be found at all times
ABG43X8	Taniau	220	6.7	18.8	31.2	21.4	21.4	1°42.873'	173°00.124'	Thick - fresh groundwater likely to be found at all times
ABG43X9	Taniau	250	6.4	19.5	32.2	20.7	20.7	1°42.892'	173°00.112'	Thick - fresh groundwater likely to be found at all times
ABG43X10	Taniau	280	6.8	18.9	30.9	21.3	21.3	1°42.914'	173°00.116'	Thick - fresh groundwater likely to be found at all times
ABG43X11	Taniau	310	6.7	20.0	31.2	20.2	20.2	1°42.930'	173°00.122'	Thick - fresh groundwater likely to be found at all times
ABG43X12	Taniau	340	9.2	24.1	23.9	16.8	16.8	1°42.941'	173°00.127'	Thick - fresh groundwater likely to be found at all times
ABG43X13	Taniau	370	10.1	27.5	21.7	14.4	14.4	1°42.941'	173°00.137'	Thick - fresh groundwater likely to be found at all times
ABG43X14	Taniau	400	23.1	58.3	5.4	3.6	5.4	1°42.962'	173°00.144'	Thin - Likely to be little or no fresh groundwater in a drought

Annex 9

Village CTD Diver Data, Abaiang

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 Abaiang.

Table A9-1. Summary of water level data collected at Tingo's well in Tuarabu Village.

Abaiang predicted tides			Tingo, Tuarabu - Abaiang				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
16/03/2013 0:29	0.92	-1.46					
16/03/2013 6:41	2.37	1.37					
16/03/2013 12:52	1.00	-1.19	16/03/2013 15:00	0.45	-0.13	2:07	11%
16/03/2013 18:52	2.19	1.16	16/03/2013 20:45	0.579	0.13	1:52	11%
17/03/2013 0:54	1.04	-1.21	17/03/2013 3:30	0.45	-0.13	2:35	10%
17/03/2013 7:10	2.25	1.11	17/03/2013 9:15	0.57	0.13	2:04	12%
17/03/2013 13:22	1.15	-0.90	17/03/2013 15:30	0.44	-0.10	2:07	11%
17/03/2013 19:19	2.04	0.88	17/03/2013 21:30	0.54	0.12	2:10	14%
18/03/2013 1:20	1.17	-0.95	18/03/2013 3:30	0.42	-0.13	2:09	13%
18/03/2013 7:42	2.12	0.82	18/03/2013 9:45	0.55	0.12	2:02	14%
18/03/2013 13:59	1.29	-0.60	18/03/2013 16:00	0.43	-0.09	2:00	14%
18/03/2013 19:50	1.89	0.59	18/03/2013 21:30	0.52	0.10	1:39	17%
19/03/2013 1:52	1.31	-0.67	19/03/2013 4:00	0.42	-0.11	2:07	16%
19/03/2013 8:26	1.98	0.54	19/03/2013 10:15	0.52	0.52	1:48	
Mean						2:04	13%

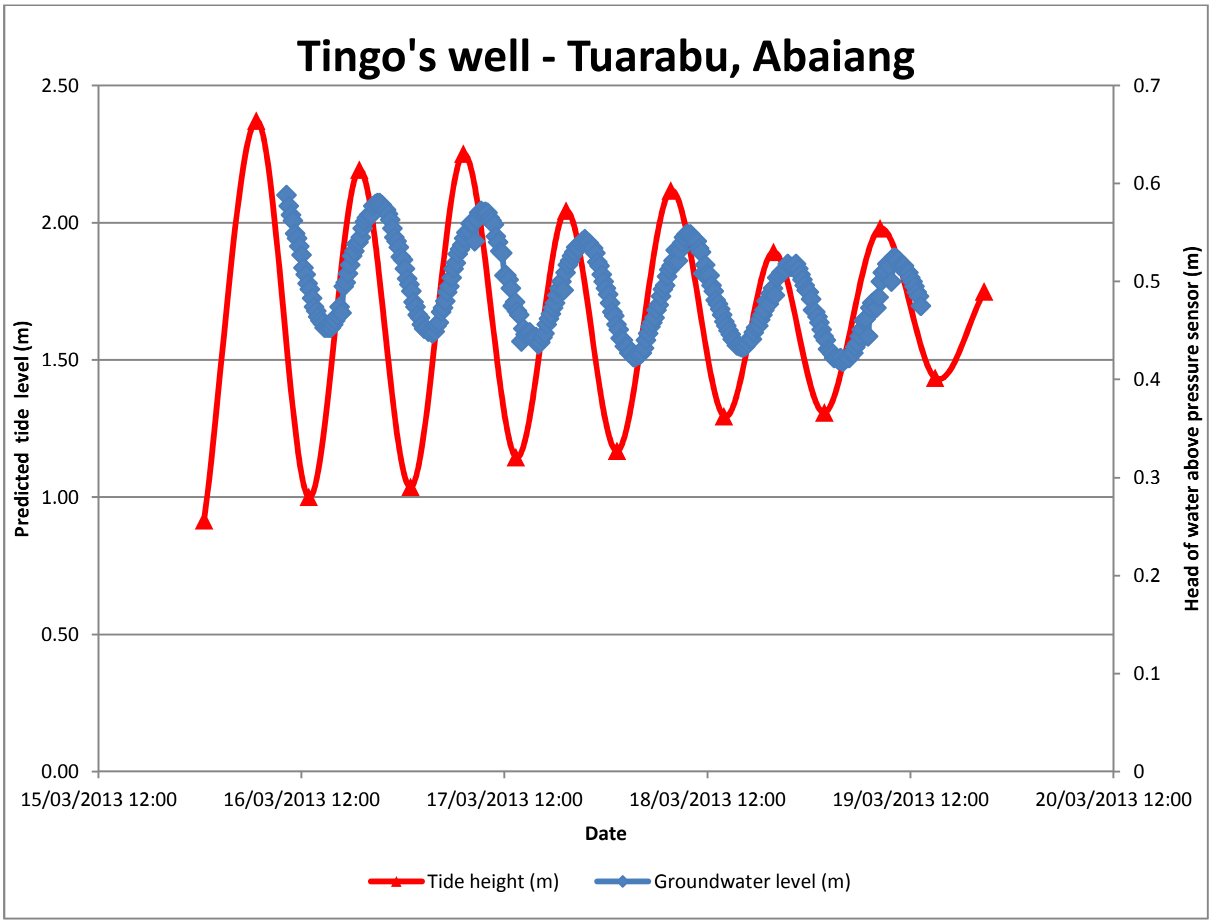


Figure A9-1. Graph of water-level fluctuation in relation to predicted tidal data.

Table A9-2. Groundwater level data measured during the monitoring period.

Date/time	Water head[cm]	Head (m)
16/03/2013 10:00	-0.7	-0.007
16/03/2013 10:15	58.8	0.588
16/03/2013 10:30	57.7	0.577
16/03/2013 10:45	56.8	0.568
16/03/2013 11:00	56.2	0.562
16/03/2013 11:15	54.9	0.549
16/03/2013 11:30	54.4	0.544
16/03/2013 11:45	53.6	0.536
16/03/2013 12:00	52.7	0.527
16/03/2013 12:15	51.4	0.514
16/03/2013 12:30	50.7	0.507
16/03/2013 12:45	49.8	0.498
16/03/2013 13:00	49.2	0.492
16/03/2013 13:15	48.3	0.483
16/03/2013 13:30	47.4	0.474
16/03/2013 13:45	47	0.47
16/03/2013 14:00	46.4	0.464
16/03/2013 14:15	46	0.46
16/03/2013 14:30	45.7	0.457
16/03/2013 14:45	45.3	0.453
16/03/2013 15:00	45.3	0.453
16/03/2013 15:15	45.3	0.453
16/03/2013 15:30	45.3	0.453
16/03/2013 15:45	45.6	0.456
16/03/2013 16:00	46	0.46
16/03/2013 16:15	46.5	0.465
16/03/2013 16:30	47.4	0.474
16/03/2013 16:45	46.8	0.468
16/03/2013 17:00	49.5	0.495
16/03/2013 17:15	49.9	0.499
16/03/2013 17:30	50.8	0.508
16/03/2013 17:45	51.7	0.517
16/03/2013 18:00	52.6	0.526
16/03/2013 18:15	53.1	0.531
16/03/2013 18:30	53.8	0.538
16/03/2013 18:45	54	0.54
16/03/2013 19:00	54.5	0.545
16/03/2013 19:15	55.4	0.554
16/03/2013 19:30	56.1	0.561
16/03/2013 19:45	56.5	0.565
16/03/2013 20:00	56.8	0.568
16/03/2013 20:15	56.8	0.568
16/03/2013 20:30	57.7	0.577
16/03/2013 20:45	57.9	0.579
16/03/2013 21:00	58	0.58
16/03/2013 21:15	58	0.58
16/03/2013 21:30	57.8	0.578
16/03/2013 21:45	57.5	0.575
16/03/2013 22:00	57.3	0.573
16/03/2013 22:15	56.9	0.569
16/03/2013 22:30	56.3	0.563
16/03/2013 22:45	55.4	0.554
16/03/2013 23:00	54.5	0.545
16/03/2013 23:15	54.1	0.541
16/03/2013 23:30	53.5	0.535
16/03/2013 23:45	52.5	0.525
17/03/2013 0:00	52.2	0.522
17/03/2013 0:15	51.3	0.513
17/03/2013 0:30	50.3	0.503
17/03/2013 0:45	49.7	0.497
17/03/2013 1:00	49	0.49
17/03/2013 1:15	47.9	0.479
17/03/2013 1:30	47.4	0.474
17/03/2013 1:45	46.6	0.466
17/03/2013 2:00	46.3	0.463
17/03/2013 2:15	45.6	0.456
17/03/2013 2:30	45.2	0.452
17/03/2013 2:45	45.2	0.452
17/03/2013 3:00	44.9	0.449
17/03/2013 3:15	44.9	0.449
17/03/2013 3:30	44.7	0.447
17/03/2013 3:45	44.9	0.449
17/03/2013 4:00	45.5	0.455
17/03/2013 4:15	45.8	0.458
17/03/2013 4:30	46.9	0.469
17/03/2013 4:45	47.3	0.473
17/03/2013 5:00	48	0.48
17/03/2013 5:15	48.9	0.489
17/03/2013 5:30	49.5	0.495
17/03/2013 5:45	50.4	0.504
17/03/2013 6:00	51.3	0.513
17/03/2013 6:15	51.9	0.519
17/03/2013 6:30	52.8	0.528
17/03/2013 6:45	53.3	0.533
17/03/2013 7:00	53.7	0.537
17/03/2013 7:15	54.4	0.544
17/03/2013 7:30	55	0.55
17/03/2013 7:45	55.2	0.552
17/03/2013 8:00	55.9	0.559
17/03/2013 8:15	55.9	0.559
17/03/2013 8:30	54.1	0.541
17/03/2013 8:45	56.3	0.563
17/03/2013 9:00	57	0.57
17/03/2013 9:15	57.2	0.572
17/03/2013 9:30	57	0.57
17/03/2013 9:45	57.1	0.571
17/03/2013 10:00	57	0.57
17/03/2013 10:15	56.5	0.565
17/03/2013 10:30	56.2	0.562
17/03/2013 10:45	55.8	0.558
17/03/2013 11:00	54.6	0.546
17/03/2013 11:15	54	0.54
17/03/2013 11:30	53.1	0.531
17/03/2013 11:45	52.9	0.529
17/03/2013 12:00	50.6	0.506
17/03/2013 12:15	50.6	0.506
17/03/2013 12:30	50.2	0.502
17/03/2013 12:45	49.3	0.493
17/03/2013 13:00	47.5	0.475
17/03/2013 13:15	47.9	0.479
17/03/2013 13:30	47	0.47
17/03/2013 13:45	46.6	0.466
17/03/2013 14:00	43.9	0.439
17/03/2013 14:15	45.2	0.452
17/03/2013 14:30	44.6	0.446
17/03/2013 14:45	44.8	0.448
17/03/2013 15:00	44.8	0.448
17/03/2013 15:15	44.3	0.443
17/03/2013 15:30	44.1	0.441
17/03/2013 15:45	44.3	0.443
17/03/2013 16:00	43.6	0.436
17/03/2013 16:15	43.8	0.438
17/03/2013 16:30	44.3	0.443
17/03/2013 16:45	44.7	0.447
17/03/2013 17:00	45.6	0.456

17/03/2013 17:15	46.2	0.462
17/03/2013 17:30	46.7	0.467
17/03/2013 17:45	47.3	0.473
17/03/2013 18:00	47.8	0.478
17/03/2013 18:15	48.6	0.486
17/03/2013 18:30	49.3	0.493
17/03/2013 18:45	50	0.5
17/03/2013 19:00	49.1	0.491
17/03/2013 19:15	50.9	0.509
17/03/2013 19:30	51.7	0.517
17/03/2013 19:45	52.1	0.521
17/03/2013 20:00	52.6	0.526
17/03/2013 20:15	53	0.53
17/03/2013 20:30	53.5	0.535
17/03/2013 20:45	53.4	0.534
17/03/2013 21:00	53.9	0.539
17/03/2013 21:15	54.1	0.541
17/03/2013 21:30	54.3	0.543
17/03/2013 21:45	54.1	0.541
17/03/2013 22:00	53.9	0.539
17/03/2013 22:15	53.6	0.536
17/03/2013 22:30	53.4	0.534
17/03/2013 22:45	52.9	0.529
17/03/2013 23:00	52	0.52
17/03/2013 23:15	51.6	0.516
17/03/2013 23:30	50.7	0.507
17/03/2013 23:45	50	0.5
18/03/2013 0:00	49.3	0.493
18/03/2013 0:15	48.7	0.487
18/03/2013 0:30	47.8	0.478
18/03/2013 0:45	46.9	0.469
18/03/2013 1:00	46.5	0.465
18/03/2013 1:15	45.6	0.456
18/03/2013 1:30	45.1	0.451
18/03/2013 1:45	44.2	0.442
18/03/2013 2:00	44	0.44
18/03/2013 2:15	43.4	0.434
18/03/2013 2:30	43.3	0.433
18/03/2013 2:45	42.7	0.427
18/03/2013 3:00	42.7	0.427
18/03/2013 3:15	42.3	0.423
18/03/2013 3:30	42.3	0.423
18/03/2013 3:45	42.5	0.425
18/03/2013 4:00	42.5	0.425
18/03/2013 4:15	42.7	0.427
18/03/2013 4:30	43.2	0.432
18/03/2013 4:45	44	0.44
18/03/2013 5:00	44.7	0.447
18/03/2013 5:15	45.4	0.454
18/03/2013 5:30	45.8	0.458
18/03/2013 5:45	46.3	0.463
18/03/2013 6:00	47.1	0.471
18/03/2013 6:15	47.6	0.476
18/03/2013 6:30	48.5	0.485
18/03/2013 6:45	49.2	0.492
18/03/2013 7:00	49.6	0.496
18/03/2013 7:15	50.5	0.505
18/03/2013 7:30	51.2	0.512
18/03/2013 7:45	51.6	0.516
18/03/2013 8:00	52.1	0.521
18/03/2013 8:15	53.2	0.532
18/03/2013 8:30	52.1	0.521
18/03/2013 8:45	53.2	0.532
18/03/2013 9:00	53.9	0.539

18/03/2013 9:15	54.5	0.545
18/03/2013 9:30	54.8	0.548
18/03/2013 9:45	54.8	0.548
18/03/2013 10:00	54.8	0.548
18/03/2013 10:15	54.5	0.545
18/03/2013 10:30	54.3	0.543
18/03/2013 10:45	54.1	0.541
18/03/2013 11:00	53.4	0.534
18/03/2013 11:15	53	0.53
18/03/2013 11:30	50.8	0.508
18/03/2013 11:45	51.7	0.517
18/03/2013 12:00	50.8	0.508
18/03/2013 12:15	50.6	0.506
18/03/2013 12:30	49.6	0.496
18/03/2013 12:45	49	0.49
18/03/2013 13:00	48.1	0.481
18/03/2013 13:15	47.7	0.477
18/03/2013 13:30	47.2	0.472
18/03/2013 13:45	46.6	0.466
18/03/2013 14:00	45.9	0.459
18/03/2013 14:15	45.5	0.455
18/03/2013 14:30	45	0.45
18/03/2013 14:45	44.6	0.446
18/03/2013 15:00	44.1	0.441
18/03/2013 15:15	43.9	0.439
18/03/2013 15:30	43.5	0.435
18/03/2013 15:45	43.4	0.434
18/03/2013 16:00	43.3	0.433
18/03/2013 16:15	43.3	0.433
18/03/2013 16:30	43.4	0.434
18/03/2013 16:45	43.7	0.437
18/03/2013 17:00	44.1	0.441
18/03/2013 17:15	44.1	0.441
18/03/2013 17:30	44.8	0.448
18/03/2013 17:45	45.3	0.453
18/03/2013 18:00	45.5	0.455
18/03/2013 18:15	46.1	0.461
18/03/2013 18:30	46.6	0.466
18/03/2013 18:45	47.1	0.471
18/03/2013 19:00	48	0.48
18/03/2013 19:15	47.7	0.477
18/03/2013 19:30	48.8	0.488
18/03/2013 19:45	49.3	0.493
18/03/2013 20:00	48.6	0.486
18/03/2013 20:15	50.4	0.504
18/03/2013 20:30	50.6	0.506
18/03/2013 20:45	50.9	0.509
18/03/2013 21:00	51.1	0.511
18/03/2013 21:15	51.3	0.513
18/03/2013 21:30	51.8	0.518
18/03/2013 21:45	51.5	0.515
18/03/2013 22:00	51.5	0.515
18/03/2013 22:15	51.5	0.515
18/03/2013 22:30	51.8	0.518
18/03/2013 22:45	51.3	0.513
18/03/2013 23:00	50.7	0.507
18/03/2013 23:15	50.2	0.502
18/03/2013 23:30	49.6	0.496
18/03/2013 23:45	49.1	0.491
19/03/2013 0:00	48.9	0.489
19/03/2013 0:15	48.2	0.482
19/03/2013 0:30	47.1	0.471
19/03/2013 0:45	46.9	0.469
19/03/2013 1:00	46.4	0.464

19/03/2013 1:15	45.8	0.458
19/03/2013 1:30	45.1	0.451
19/03/2013 1:45	44.4	0.444
19/03/2013 2:00	44	0.44
19/03/2013 2:15	43.1	0.431
19/03/2013 2:30	42.9	0.429
19/03/2013 2:45	42.6	0.426
19/03/2013 3:00	42.2	0.422
19/03/2013 3:15	42.2	0.422
19/03/2013 3:30	42	0.42
19/03/2013 3:45	42.2	0.422
19/03/2013 4:00	41.8	0.418
19/03/2013 4:15	42	0.42
19/03/2013 4:30	42.2	0.422
19/03/2013 4:45	42.2	0.422
19/03/2013 5:00	42.6	0.426
19/03/2013 5:15	42.7	0.427
19/03/2013 5:30	43.3	0.433
19/03/2013 5:45	43.7	0.437
19/03/2013 6:00	44.4	0.444
19/03/2013 6:15	45.1	0.451
19/03/2013 6:30	46	0.46
19/03/2013 6:45	46.2	0.462
19/03/2013 7:00	44.4	0.444
19/03/2013 7:15	47.3	0.473
19/03/2013 7:30	47.8	0.478
19/03/2013 7:45	48	0.48
19/03/2013 8:00	47.3	0.473
19/03/2013 8:15	48.4	0.484
19/03/2013 8:30	50	0.5
19/03/2013 8:45	50.9	0.509
19/03/2013 9:00	51.1	0.511
19/03/2013 9:15	51.8	0.518
19/03/2013 9:30	51.6	0.516
19/03/2013 9:45	50	0.5
19/03/2013 10:00	52.4	0.524
19/03/2013 10:15	52.4	0.524
19/03/2013 10:30	52.2	0.522
19/03/2013 10:45	51.6	0.516
19/03/2013 11:00	51.6	0.516
19/03/2013 11:15	51.6	0.516
19/03/2013 11:30	51.1	0.511
19/03/2013 11:45	50.9	0.509
19/03/2013 12:00	50.4	0.504
19/03/2013 12:15	50	0.5
19/03/2013 12:30	49.5	0.495
19/03/2013 12:45	48.9	0.489
19/03/2013 13:00	48.5	0.485
19/03/2013 13:15	47.5	0.475

Table A9-3. Summary of measured groundwater level and predicted tidal data for Tom's well, Tuarabu Village, Abaiang.

Abaiang predicted tides			**Tom, Tuarabu - Abaiang**				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
16/03/2013 0:29	0.92	-1.46					
16/03/2013 6:41	2.37	1.37					
16/03/2013 12:52	1.00	-1.19	16/03/2013 15:45	0.25	-0.11	2:52	-8%
16/03/2013 18:52	2.19	1.16	16/03/2013 21:45	0.363	0.12	2:52	-10%
17/03/2013 0:54	1.04	-1.21	17/03/2013 3:30	0.24	-0.10	2:35	-9%
17/03/2013 7:10	2.25	1.11	17/03/2013 9:45	0.35	0.12	2:34	-10%
17/03/2013 13:22	1.15	-0.90	17/03/2013 16:45	0.23	-0.09	3:22	-8%
17/03/2013 19:19	2.04	0.88	17/03/2013 22:15	0.32	0.11	2:55	-12%
18/03/2013 1:20	1.17	-0.95	18/03/2013 4:00	0.21	-0.10	2:39	-12%
18/03/2013 7:42	2.12	0.82	18/03/2013 10:00	0.31	0.11	2:17	-11%
18/03/2013 13:59	1.29	-0.60	18/03/2013 16:30	0.21	-0.08	2:30	-10%
18/03/2013 19:50	1.89	0.59	18/03/2013 22:00	0.29	0.09	2:09	-15%
19/03/2013 1:52	1.31	-0.67	19/03/2013 4:30	0.20	-0.09	2:37	-15%

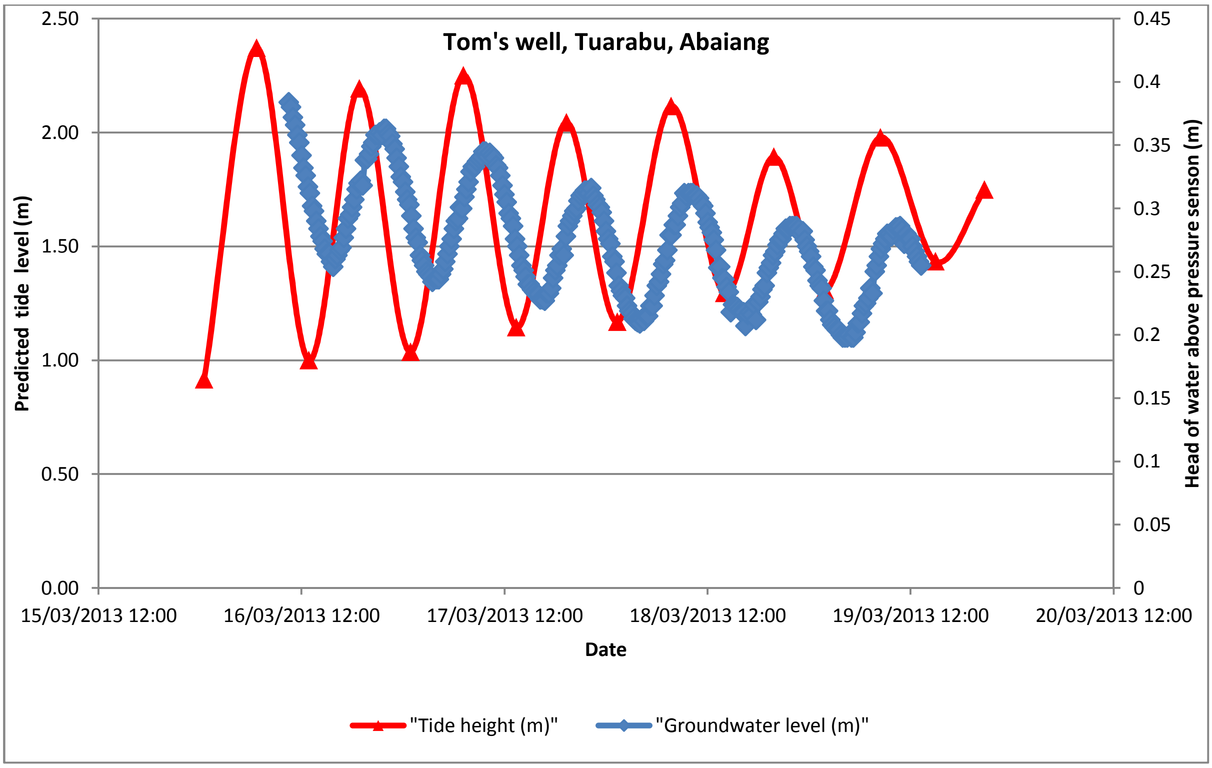


Figure A9-2. Groundwater level and predicted tidal data for Tom's well, Tuarabu Village, Abaiang.

Table A9-4. Measured groundwater level at Tom's well, Tuarabu Village, Abaiang.

Date/time	Water head[cm]	Water head[m]
16/03/2013 10:30	38.4	0.384
16/03/2013 10:45	38	0.38
16/03/2013 11:00	37.2	0.372
16/03/2013 11:15	36.6	0.366
16/03/2013 11:30	35.8	0.358
16/03/2013 11:45	35.2	0.352
16/03/2013 12:00	34.2	0.342
16/03/2013 12:15	33.2	0.332
16/03/2013 12:30	32.6	0.326
16/03/2013 12:45	31.7	0.317
16/03/2013 13:00	31.2	0.312
16/03/2013 13:15	30.2	0.302
16/03/2013 13:30	29.8	0.298
16/03/2013 13:45	29	0.29
16/03/2013 14:00	28.4	0.284
16/03/2013 14:15	27.8	0.278
16/03/2013 14:30	27.4	0.274
16/03/2013 14:45	26.8	0.268
16/03/2013 15:00	26.4	0.264
16/03/2013 15:15	26.4	0.264
16/03/2013 15:30	25.8	0.258
16/03/2013 15:45	25.4	0.254
16/03/2013 16:00	26	0.26
16/03/2013 16:15	26.3	0.263
16/03/2013 16:30	26.7	0.267
16/03/2013 16:45	26.9	0.269
16/03/2013 17:00	27.7	0.277
16/03/2013 17:15	28.4	0.284
16/03/2013 17:30	29.2	0.292
16/03/2013 17:45	29.5	0.295
16/03/2013 18:00	30.1	0.301
16/03/2013 18:15	30.7	0.307
16/03/2013 18:30	31.5	0.315
16/03/2013 18:45	32	0.32
16/03/2013 19:00	32.2	0.322
16/03/2013 19:15	31.8	0.318
16/03/2013 19:30	33.8	0.338
16/03/2013 19:45	33.9	0.339
16/03/2013 20:00	34.3	0.343
16/03/2013 20:15	34.9	0.349
16/03/2013 20:30	35.2	0.352
16/03/2013 20:45	35.8	0.358
16/03/2013 21:00	35.8	0.358
16/03/2013 21:15	36	0.36
16/03/2013 21:30	35.8	0.358
16/03/2013 21:45	36.3	0.363
16/03/2013 22:00	36.3	0.363
16/03/2013 22:15	35.9	0.359
16/03/2013 22:30	35.7	0.357
16/03/2013 22:45	35.1	0.351
16/03/2013 23:00	34.7	0.347
16/03/2013 23:15	34	0.34
16/03/2013 23:30	33.3	0.333
16/03/2013 23:45	32.5	0.325
17/03/2013 0:00	32.1	0.321
17/03/2013 0:15	31.3	0.313

17/03/2013 0:30	30.7	0.307
17/03/2013 0:45	30.3	0.303
17/03/2013 1:00	29.4	0.294
17/03/2013 1:15	28.4	0.284
17/03/2013 1:30	27.7	0.277
17/03/2013 1:45	27.3	0.273
17/03/2013 2:00	26.3	0.263
17/03/2013 2:15	25.9	0.259
17/03/2013 2:30	25.5	0.255
17/03/2013 2:45	25	0.25
17/03/2013 3:00	24.8	0.248
17/03/2013 3:15	24.6	0.246
17/03/2013 3:30	24.2	0.242
17/03/2013 3:45	24.4	0.244
17/03/2013 4:00	24.4	0.244
17/03/2013 4:15	24.4	0.244
17/03/2013 4:30	24.8	0.248
17/03/2013 4:45	25.2	0.252
17/03/2013 5:00	25.8	0.258
17/03/2013 5:15	26.4	0.264
17/03/2013 5:30	27	0.27
17/03/2013 5:45	27.6	0.276
17/03/2013 6:00	28.4	0.284
17/03/2013 6:15	29	0.29
17/03/2013 6:30	29.2	0.292
17/03/2013 6:45	30.1	0.301
17/03/2013 7:00	30	0.3
17/03/2013 7:15	30.9	0.309
17/03/2013 7:30	31.5	0.315
17/03/2013 7:45	32.1	0.321
17/03/2013 8:00	32.9	0.329
17/03/2013 8:15	33.3	0.333
17/03/2013 8:30	33.3	0.333
17/03/2013 8:45	33.7	0.337
17/03/2013 9:00	33.9	0.339
17/03/2013 9:15	34.1	0.341
17/03/2013 9:30	34.5	0.345
17/03/2013 9:45	34.5	0.345
17/03/2013 10:00	34.1	0.341
17/03/2013 10:15	34.4	0.344
17/03/2013 10:30	34.2	0.342
17/03/2013 10:45	34	0.34
17/03/2013 11:00	33.4	0.334
17/03/2013 11:15	33.2	0.332
17/03/2013 11:30	32.6	0.326
17/03/2013 11:45	31.8	0.318
17/03/2013 12:00	31.1	0.311
17/03/2013 12:15	30.5	0.305
17/03/2013 12:30	29.6	0.296
17/03/2013 12:45	29.2	0.292
17/03/2013 13:00	28.6	0.286
17/03/2013 13:15	27.6	0.276
17/03/2013 13:30	27	0.27
17/03/2013 13:45	26.3	0.263
17/03/2013 14:00	25.5	0.255
17/03/2013 14:15	25.1	0.251
17/03/2013 14:30	24.6	0.246
17/03/2013 14:45	24	0.24
17/03/2013 15:00	24	0.24
17/03/2013 15:15	23.6	0.236
17/03/2013 15:30	23.4	0.234
17/03/2013 15:45	23.2	0.232
17/03/2013 16:00	23.2	0.232

17/03/2013 16:15	22.8	0.228
17/03/2013 16:30	22.8	0.228
17/03/2013 16:45	22.7	0.227
17/03/2013 17:00	23.3	0.233
17/03/2013 17:15	23.3	0.233
17/03/2013 17:30	23.7	0.237
17/03/2013 17:45	24.5	0.245
17/03/2013 18:00	25.1	0.251
17/03/2013 18:15	25.5	0.255
17/03/2013 18:30	26.3	0.263
17/03/2013 18:45	26.8	0.268
17/03/2013 19:00	26.3	0.263
17/03/2013 19:15	27.8	0.278
17/03/2013 19:30	28.6	0.286
17/03/2013 19:45	29	0.29
17/03/2013 20:00	29.4	0.294
17/03/2013 20:15	29.8	0.298
17/03/2013 20:30	30	0.3
17/03/2013 20:45	30.6	0.306
17/03/2013 21:00	31	0.31
17/03/2013 21:15	31.2	0.312
17/03/2013 21:30	31.4	0.314
17/03/2013 21:45	31.4	0.314
17/03/2013 22:00	31.2	0.312
17/03/2013 22:15	31.6	0.316
17/03/2013 22:30	31	0.31
17/03/2013 22:45	30.7	0.307
17/03/2013 23:00	30.3	0.303
17/03/2013 23:15	30.1	0.301
17/03/2013 23:30	29.7	0.297
17/03/2013 23:45	29	0.29
18/03/2013 0:00	28.2	0.282
18/03/2013 0:15	27.6	0.276
18/03/2013 0:30	27.2	0.272
18/03/2013 0:45	26.2	0.262
18/03/2013 1:00	25.8	0.258
18/03/2013 1:15	24.9	0.249
18/03/2013 1:30	23.9	0.239
18/03/2013 1:45	23.5	0.235
18/03/2013 2:00	23.1	0.231
18/03/2013 2:15	22.9	0.229
18/03/2013 2:30	22.3	0.223
18/03/2013 2:45	21.9	0.219
18/03/2013 3:00	21.7	0.217
18/03/2013 3:15	21.3	0.213
18/03/2013 3:30	21.1	0.211
18/03/2013 3:45	21	0.21
18/03/2013 4:00	20.9	0.209
18/03/2013 4:15	21.3	0.213
18/03/2013 4:30	21.1	0.211
18/03/2013 4:45	21.5	0.215
18/03/2013 5:00	21.5	0.215
18/03/2013 5:15	22.3	0.223
18/03/2013 5:30	22.3	0.223
18/03/2013 5:45	23.1	0.231
18/03/2013 6:00	23.9	0.239
18/03/2013 6:15	24.2	0.242
18/03/2013 6:30	24.8	0.248
18/03/2013 6:45	25.6	0.256
18/03/2013 7:00	25.9	0.259
18/03/2013 7:15	26.7	0.267
18/03/2013 7:30	27.9	0.279
18/03/2013 7:45	27.9	0.279
18/03/2013 8:00	28.7	0.287

18/03/2013 8:15	28.7	0.287
18/03/2013 8:30	29.4	0.294
18/03/2013 8:45	30.1	0.301
18/03/2013 9:00	30.4	0.304
18/03/2013 9:15	31.2	0.312
18/03/2013 9:30	31	0.31
18/03/2013 9:45	31.2	0.312
18/03/2013 10:00	31.2	0.312
18/03/2013 10:15	31.2	0.312
18/03/2013 10:30	31	0.31
18/03/2013 10:45	31	0.31
18/03/2013 11:00	30.8	0.308
18/03/2013 11:15	30.4	0.304
18/03/2013 11:30	30.2	0.302
18/03/2013 11:45	29.6	0.296
18/03/2013 12:00	28.9	0.289
18/03/2013 12:15	28.5	0.285
18/03/2013 12:30	28.1	0.281
18/03/2013 12:45	27.5	0.275
18/03/2013 13:00	26.7	0.267
18/03/2013 13:15	25.3	0.253
18/03/2013 13:30	25.4	0.254
18/03/2013 13:45	24.5	0.245
18/03/2013 14:00	24.4	0.244
18/03/2013 14:15	23.8	0.238
18/03/2013 14:30	23.4	0.234
18/03/2013 14:45	21.8	0.218
18/03/2013 15:00	22.4	0.224
18/03/2013 15:15	22.3	0.223
18/03/2013 15:30	22.2	0.222
18/03/2013 15:45	22	0.22
18/03/2013 16:00	21.8	0.218
18/03/2013 16:15	21.8	0.218
18/03/2013 16:30	20.7	0.207
18/03/2013 16:45	21.6	0.216
18/03/2013 17:00	21.8	0.218
18/03/2013 17:15	21.6	0.216
18/03/2013 17:30	22.4	0.224
18/03/2013 17:45	21.2	0.212
18/03/2013 18:00	22.6	0.226
18/03/2013 18:15	23	0.23
18/03/2013 18:30	23.6	0.236
18/03/2013 18:45	23.9	0.239
18/03/2013 19:00	24.9	0.249
18/03/2013 19:15	25.3	0.253
18/03/2013 19:30	25.7	0.257
18/03/2013 19:45	26.3	0.263
18/03/2013 20:00	26.6	0.266
18/03/2013 20:15	27.1	0.271
18/03/2013 20:30	27.5	0.275
18/03/2013 20:45	27.6	0.276
18/03/2013 21:00	28	0.28
18/03/2013 21:15	28.4	0.284
18/03/2013 21:30	28.4	0.284
18/03/2013 21:45	28.6	0.286
18/03/2013 22:00	28.6	0.286
18/03/2013 22:15	28.6	0.286
18/03/2013 22:30	28.6	0.286
18/03/2013 22:45	28.4	0.284
18/03/2013 23:00	28	0.28
18/03/2013 23:15	28.2	0.282
18/03/2013 23:30	27.5	0.275
18/03/2013 23:45	27	0.27

19/03/2013 0:00	26.6	0.266
19/03/2013 0:15	26.2	0.262
19/03/2013 0:30	25.4	0.254
19/03/2013 0:45	25.1	0.251
19/03/2013 1:00	24.3	0.243
19/03/2013 1:15	23.9	0.239
19/03/2013 1:30	23.7	0.237
19/03/2013 1:45	22.7	0.227
19/03/2013 2:00	21.9	0.219
19/03/2013 2:15	21.9	0.219
19/03/2013 2:30	21.2	0.212
19/03/2013 2:45	20.8	0.208
19/03/2013 3:00	20.6	0.206
19/03/2013 3:15	20.4	0.204
19/03/2013 3:30	20.4	0.204
19/03/2013 3:45	20	0.2
19/03/2013 4:00	19.8	0.198
19/03/2013 4:15	19.8	0.198
19/03/2013 4:30	19.8	0.198
19/03/2013 4:45	20	0.2
19/03/2013 5:00	19.8	0.198
19/03/2013 5:15	19.8	0.198
19/03/2013 5:30	20.2	0.202
19/03/2013 5:45	20.9	0.209
19/03/2013 6:00	21	0.21
19/03/2013 6:15	21.7	0.217
19/03/2013 6:30	22.3	0.223
19/03/2013 6:45	22.5	0.225
19/03/2013 7:00	22.9	0.229
19/03/2013 7:15	23.7	0.237
19/03/2013 7:30	23.3	0.233
19/03/2013 7:45	25	0.25
19/03/2013 8:00	25.5	0.255
19/03/2013 8:15	26.2	0.262
19/03/2013 8:30	26.8	0.268
19/03/2013 8:45	27.2	0.272
19/03/2013 9:00	27.6	0.276
19/03/2013 9:15	28	0.28
19/03/2013 9:30	28	0.28
19/03/2013 9:45	27.8	0.278
19/03/2013 10:00	28.3	0.283
19/03/2013 10:15	28.5	0.285
19/03/2013 10:30	28.5	0.285
19/03/2013 10:45	28.6	0.286
19/03/2013 11:00	28.3	0.283
19/03/2013 11:15	27.2	0.272
19/03/2013 11:30	28	0.28
19/03/2013 11:45	27.6	0.276
19/03/2013 12:00	27.6	0.276
19/03/2013 12:15	27	0.27
19/03/2013 12:30	26.6	0.266
19/03/2013 12:45	26.2	0.262
19/03/2013 13:00	25.8	0.258
19/03/2013 13:15	25.5	0.255

Table A9-5. Summary of groundwater level measurement in Aonobuaka Village, Abaiang.

Abaiang predicted tides			Taake, Aonobuaka, Abaiang				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
13/03/2013 5:16	2.58	1.89					
13/03/2013 11:23	0.69	-1.88	13/03/2013 14:00	0.28	-0.12	2:36	6%
13/03/2013 17:31	2.57	1.84	13/03/2013 20:45	0.403	0.11	3:13	6%
13/03/2013 23:38	0.73	-1.82	14/03/2013 2:45	0.30	-0.11	3:06	6%
14/03/2013 5:45	2.54	1.78	14/03/2013 8:45	0.41	0.11	2:59	6%
14/03/2013 11:53	0.76	-1.70					
14/03/2013 17:59	2.46						
Mean	1.64	0.02		0.35		2:58	6%

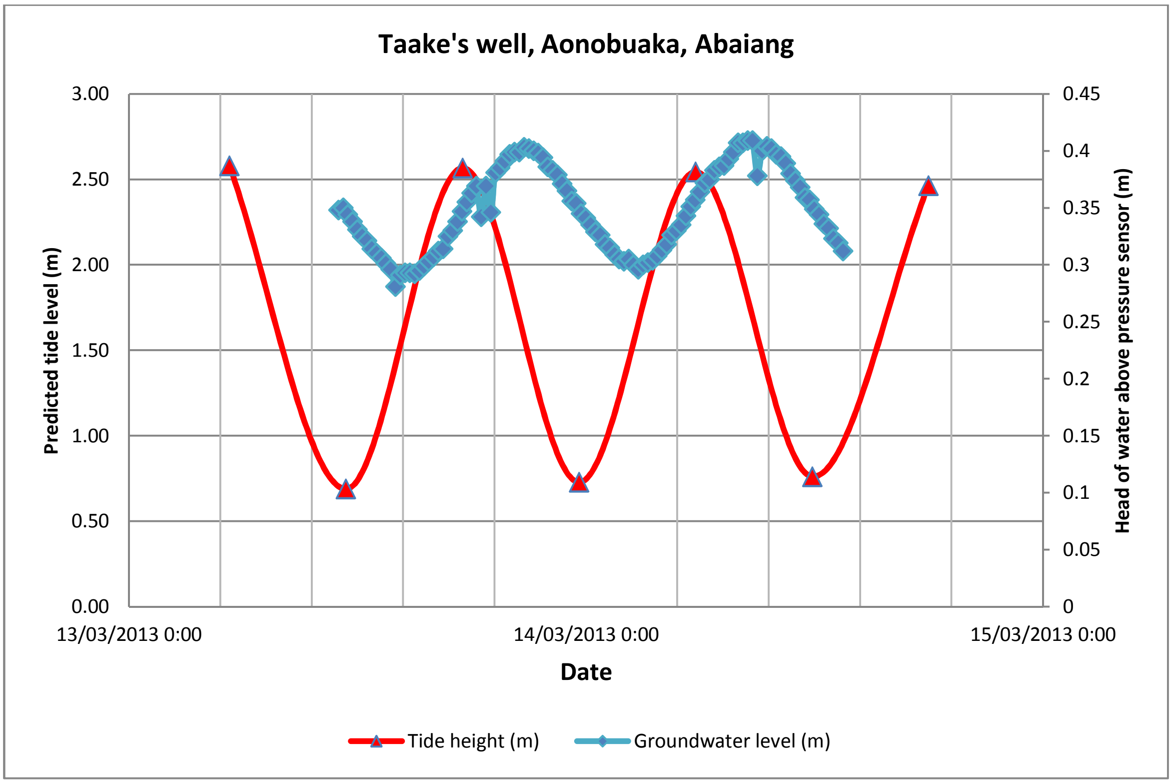


Figure A9-3. Measured groundwater level and predicted tidal data for Taake's well, Aonobuaka Village, Abaiang.

Table A9-6. Measured groundwater level for Taake's well, Aonobuaka Village, Abaiang.

Date	Water head[cm]	Head (m)
13/03/2013 11:00	34.8	0.348
13/03/2013 11:15	35	0.35
13/03/2013 11:30	34.4	0.344
13/03/2013 11:45	33.8	0.338
13/03/2013 12:00	33.1	0.331
13/03/2013 12:15	32.5	0.325
13/03/2013 12:30	32.1	0.321
13/03/2013 12:45	31.4	0.314
13/03/2013 13:00	31	0.31
13/03/2013 13:15	30.6	0.306
13/03/2013 13:30	30.1	0.301
13/03/2013 13:45	29.6	0.296
13/03/2013 14:00	28.1	0.281
13/03/2013 14:15	29.1	0.291
13/03/2013 14:30	29.3	0.293
13/03/2013 14:45	29.3	0.293
13/03/2013 15:00	29.2	0.292
13/03/2013 15:15	29.5	0.295
13/03/2013 15:30	29.9	0.299
13/03/2013 15:45	30.3	0.303
13/03/2013 16:00	30.7	0.307
13/03/2013 16:15	31.2	0.312
13/03/2013 16:30	31.4	0.314
13/03/2013 16:45	32.5	0.325

13/03/2013 17:00	33	0.33
13/03/2013 17:15	33.8	0.338
13/03/2013 17:30	34.7	0.347
13/03/2013 17:45	35.5	0.355
13/03/2013 18:00	36.3	0.363
13/03/2013 18:15	36.9	0.369
13/03/2013 18:30	34.2	0.342
13/03/2013 18:45	36.9	0.369
13/03/2013 19:00	34.6	0.346
13/03/2013 19:15	38.1	0.381
13/03/2013 19:30	38.5	0.385
13/03/2013 19:45	39.1	0.391
13/03/2013 20:00	39.7	0.397
13/03/2013 20:15	39.9	0.399
13/03/2013 20:30	39.9	0.399
13/03/2013 20:45	40.3	0.403
13/03/2013 21:00	40.2	0.402
13/03/2013 21:15	40	0.4
13/03/2013 21:30	39.8	0.398
13/03/2013 21:45	39.4	0.394
13/03/2013 22:00	38.6	0.386
13/03/2013 22:15	38.3	0.383
13/03/2013 22:30	37.9	0.379
13/03/2013 22:45	37.1	0.371
13/03/2013 23:00	36.5	0.365
13/03/2013 23:15	35.6	0.356
13/03/2013 23:30	35.4	0.354
13/03/2013 23:45	34.5	0.345
14/03/2013 0:00	34.1	0.341
14/03/2013 0:15	33.5	0.335
14/03/2013 0:30	32.9	0.329
14/03/2013 0:45	32.6	0.326
14/03/2013 1:00	31.8	0.318
14/03/2013 1:15	31.5	0.315
14/03/2013 1:30	30.9	0.309
14/03/2013 1:45	30.5	0.305
14/03/2013 2:00	30.3	0.303
14/03/2013 2:15	30.5	0.305
14/03/2013 2:30	30	0.3
14/03/2013 2:45	29.6	0.296
14/03/2013 3:00	30	0.3
14/03/2013 3:15	30.2	0.302
14/03/2013 3:30	30.4	0.304
14/03/2013 3:45	30.8	0.308
14/03/2013 4:00	31.3	0.313
14/03/2013 4:15	31.8	0.318
14/03/2013 4:30	32.6	0.326
14/03/2013 4:45	33	0.33
14/03/2013 5:00	33.5	0.335
14/03/2013 5:15	34.3	0.343
14/03/2013 5:30	35.1	0.351
14/03/2013 5:45	35.7	0.357
14/03/2013 6:00	36.4	0.364
14/03/2013 6:15	37.2	0.372
14/03/2013 6:30	37.5	0.375
14/03/2013 6:45	38.3	0.383
14/03/2013 7:00	38.6	0.386
14/03/2013 7:15	38.7	0.387
14/03/2013 7:30	39.3	0.393
14/03/2013 7:45	39.9	0.399
14/03/2013 8:00	40.7	0.407
14/03/2013 8:15	40.7	0.407
14/03/2013 8:30	40.9	0.409
14/03/2013 8:45	40.9	0.409
14/03/2013 9:00	37.8	0.378
14/03/2013 9:15	40	0.4
14/03/2013 9:30	40.4	0.404
14/03/2013 9:45	40.2	0.402
14/03/2013 10:00	39.7	0.397
14/03/2013 10:15	39.5	0.395
14/03/2013 10:30	38.9	0.389
14/03/2013 10:45	38	0.38
14/03/2013 11:00	37.4	0.374
14/03/2013 11:15	36.8	0.368
14/03/2013 11:30	35.9	0.359
14/03/2013 11:45	35.7	0.357
14/03/2013 12:00	34.9	0.349
14/03/2013 12:15	34.4	0.344
14/03/2013 12:30	33.6	0.336
14/03/2013 12:45	33.2	0.332
14/03/2013 13:00	32.3	0.323
14/03/2013 13:15	31.9	0.319
14/03/2013 13:30	31.2	0.312

Table A9-7. Summary of measured groundwater level and predicted tidal data for Amarereiti's well. Aonobuaka Village, Abaiang.

Abaiang predicted tides			**Amarereiti, Aonobuaka, Abaiang**				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
13/03/2013 5:16	2.58	1.89					
13/03/2013 11:23	0.69	-1.88	13/03/2013 14:45	1.0297	-0.03	3:21	2%
13/03/2013 17:31	2.57	1.84	13/03/2013 21:00	1.0599	0.03	3:28	1%
13/03/2013 23:38	0.73	-1.82	14/03/2013 3:15	1.03	-0.03	3:36	2%
14/03/2013 5:45	2.54	1.78					
14/03/2013 11:53	0.76	-1.70					
14/03/2013 17:59	2.46						
Mean						3:28	2%

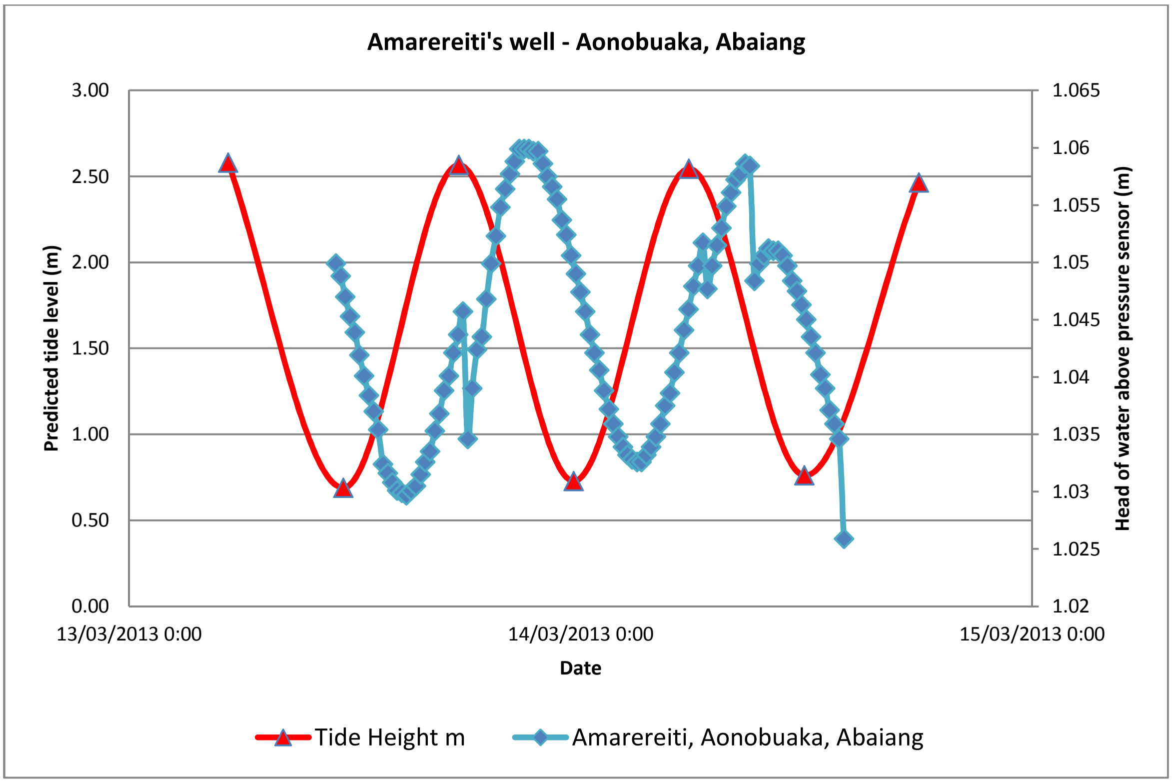


Figure A9-4. Measured groundwater level and predicted tidal data for Amerereiti's well, Aonobuaka Village, Abaiang.

Table A9-8. Measured groundwater level for Amerereiti's well, Aonobuaka Village, Abaiang.

Date/time	Pressure [cm]	Head (m)
13/03/2013 11:00	1049.9	1.0499
13/03/2013 11:15	1048.8	1.0488
13/03/2013 11:30	1047	1.047
13/03/2013 11:45	1045.3	1.0453
13/03/2013 12:00	1043.9	1.0439
13/03/2013 12:15	1041.9	1.0419
13/03/2013 12:30	1040.1	1.0401
13/03/2013 12:45	1038.4	1.0384
13/03/2013 13:00	1037	1.037
13/03/2013 13:15	1035.4	1.0354
13/03/2013 13:30	1032.4	1.0324
13/03/2013 13:45	1031.6	1.0316
13/03/2013 14:00	1030.8	1.0308
13/03/2013 14:15	1030.1	1.0301
13/03/2013 14:30	1029.9	1.0299
13/03/2013 14:45	1029.7	1.0297
13/03/2013 15:00	1030.1	1.0301
13/03/2013 15:15	1030.5	1.0305
13/03/2013 15:30	1031.5	1.0315
13/03/2013 15:45	1032.6	1.0326
13/03/2013 16:00	1033.5	1.0335
13/03/2013 16:15	1035.3	1.0353
13/03/2013 16:30	1036.8	1.0368
13/03/2013 16:45	1038.8	1.0388
13/03/2013 17:00	1040.1	1.0401
13/03/2013 17:15	1042.1	1.0421
13/03/2013 17:30	1043.7	1.0437
13/03/2013 17:45	1045.7	1.0457
13/03/2013 18:00	1034.6	1.0346
13/03/2013 18:15	1039	1.039
13/03/2013 18:30	1042.4	1.0424
13/03/2013 18:45	1043.5	1.0435
13/03/2013 19:00	1046.8	1.0468
13/03/2013 19:15	1049.9	1.0499
13/03/2013 19:30	1052.3	1.0523
13/03/2013 19:45	1054.8	1.0548
13/03/2013 20:00	1056.4	1.0564
13/03/2013 20:15	1057.7	1.0577
13/03/2013 20:30	1058.8	1.0588
13/03/2013 20:45	1059.9	1.0599
13/03/2013 21:00	1059.9	1.0599
13/03/2013 21:15	1059.9	1.0599
13/03/2013 21:30	1059.7	1.0597
13/03/2013 21:45	1059.7	1.0597
13/03/2013 22:00	1058.6	1.0586
13/03/2013 22:15	1057.5	1.0575
13/03/2013 22:30	1056.6	1.0566
13/03/2013 22:45	1055.5	1.0555
13/03/2013 23:00	1053.7	1.0537
13/03/2013 23:15	1052.4	1.0524
13/03/2013 23:30	1050.6	1.0506
13/03/2013 23:45	1049	1.049
14/03/2013 0:00	1047.4	1.0474
14/03/2013 0:15	1045.7	1.0457
14/03/2013 0:30	1043.7	1.0437
14/03/2013 0:45	1042.1	1.0421
14/03/2013 1:00	1040.6	1.0406
14/03/2013 1:15	1038.8	1.0388
14/03/2013 1:30	1037.2	1.0372

14/03/2013 1:45	1035.9	1.0359
14/03/2013 2:00	1034.8	1.0348
14/03/2013 2:15	1033.9	1.0339
14/03/2013 2:30	1033.2	1.0332
14/03/2013 2:45	1032.8	1.0328
14/03/2013 3:00	1032.6	1.0326
14/03/2013 3:15	1032.6	1.0326
14/03/2013 3:30	1033.2	1.0332
14/03/2013 3:45	1033.9	1.0339
14/03/2013 4:00	1034.8	1.0348
14/03/2013 4:15	1035.9	1.0359
14/03/2013 4:30	1037.5	1.0375
14/03/2013 4:45	1038.6	1.0386
14/03/2013 5:00	1040.4	1.0404
14/03/2013 5:15	1042.1	1.0421
14/03/2013 5:30	1044.1	1.0441
14/03/2013 5:45	1045.9	1.0459
14/03/2013 6:00	1047.9	1.0479
14/03/2013 6:15	1049.7	1.0497
14/03/2013 6:30	1051.7	1.0517
14/03/2013 6:45	1047.7	1.0477
14/03/2013 7:00	1049.7	1.0497
14/03/2013 7:15	1051.5	1.0515
14/03/2013 7:30	1053	1.053
14/03/2013 7:45	1054.9	1.0549
14/03/2013 8:00	1056.1	1.0561
14/03/2013 8:15	1057.2	1.0572
14/03/2013 8:30	1057.7	1.0577
14/03/2013 8:45	1058.6	1.0586
14/03/2013 9:00	1058.4	1.0584
14/03/2013 9:15	1048.4	1.0484
14/03/2013 9:30	1049.9	1.0499
14/03/2013 9:45	1050.6	1.0506
14/03/2013 10:00	1051.2	1.0512
14/03/2013 10:15	1051	1.051
14/03/2013 10:30	1051	1.051
14/03/2013 10:45	1050.6	1.0506
14/03/2013 11:00	1049.7	1.0497
14/03/2013 11:15	1048.4	1.0484
14/03/2013 11:30	1047.5	1.0475
14/03/2013 11:45	1046.3	1.0463
14/03/2013 12:00	1045	1.045
14/03/2013 12:15	1043.5	1.0435
14/03/2013 12:30	1042.1	1.0421
14/03/2013 12:45	1040.2	1.0402
14/03/2013 13:00	1039	1.039
14/03/2013 13:15	1037.1	1.0371
14/03/2013 13:30	1035.9	1.0359
14/03/2013 13:45	1034.6	1.0346
14/03/2013 14:00	1025.9	1.0259

Table A9-9. Summary of measured groundwater level and predicted tidal data for Bwaatake's well, Tebunginako, Abaiang.

Abaiang predicted tides			**Bwaatake, Tebunginako - Abaiang**				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
11/03/2013 4:13	2.52	1.83					
11/03/2013 10:18	0.69	-1.96	11/03/2013 13:00	0.25	-0.28	2:41	14%
11/03/2013 16:29	2.65	1.99	11/03/2013 19:30	0.53	0.26	3:00	13%
11/03/2013 22:40	0.67	-1.90	12/03/2013 1:45	0.27	-0.23	3:04	12%
12/03/2013 4:46	2.57	1.91	12/03/2013 7:15	0.50	-41344.86	2:28	
Mean						2:51	13%

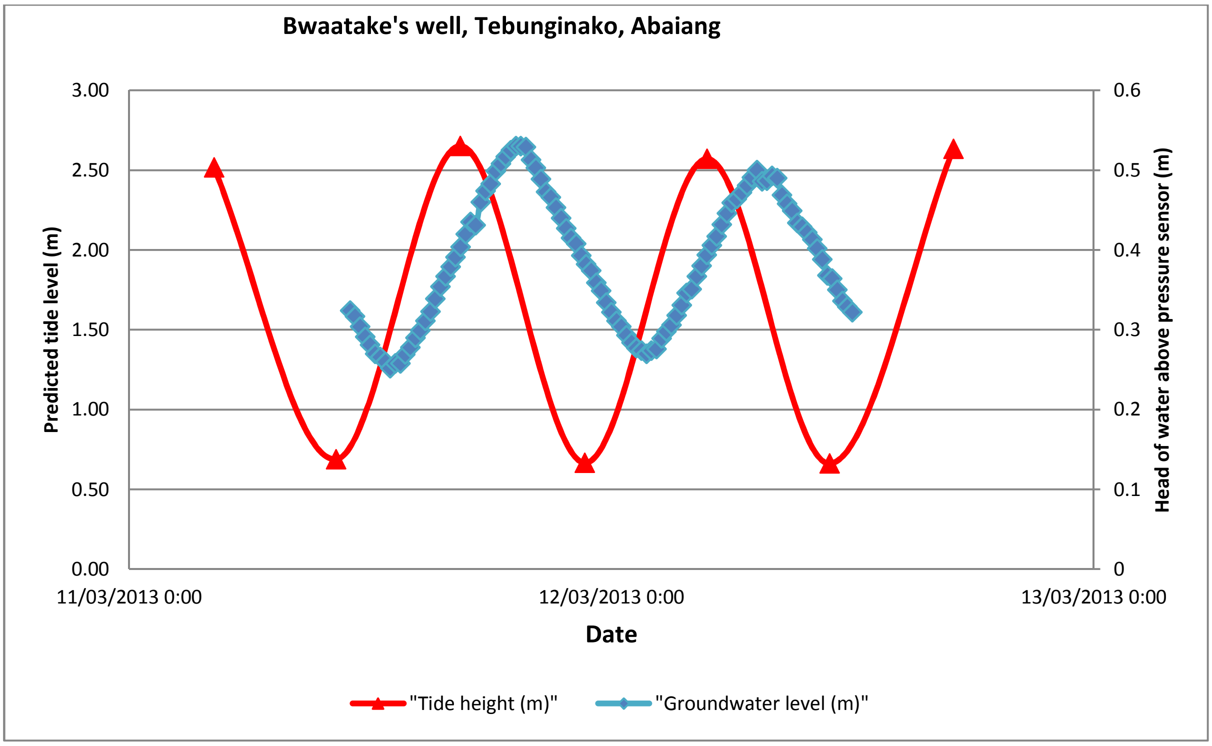


Figure A9-5. Measured groundwater level and predicted tidal data for Bwaatake's well, Tebunginako Village, Abaiang.

Table A9-10. Measured groundwater level for Bwaatake's well, Tebunginako Village, Abaiang.

Date/time	Water head[cm]	Head (m)
11/03/2013 11:00	32.4	0.324
11/03/2013 11:15	31.7	0.317
11/03/2013 11:30	30.4	0.304
11/03/2013 11:45	29.1	0.291
11/03/2013 12:00	28.1	0.281
11/03/2013 12:15	27	0.27
11/03/2013 12:30	26.6	0.266
11/03/2013 12:45	26	0.26
11/03/2013 13:00	25.2	0.252
11/03/2013 13:15	25.8	0.258
11/03/2013 13:30	25.8	0.258
11/03/2013 13:45	26.9	0.269
11/03/2013 14:00	27.8	0.278
11/03/2013 14:15	29	0.29
11/03/2013 14:30	29.9	0.299
11/03/2013 14:45	31.1	0.311
11/03/2013 15:00	32.3	0.323
11/03/2013 15:15	33.9	0.339
11/03/2013 15:30	35.4	0.354
11/03/2013 15:45	36.7	0.367
11/03/2013 16:00	37.9	0.379
11/03/2013 16:15	39.1	0.391
11/03/2013 16:30	40.4	0.404
11/03/2013 16:45	42	0.42
11/03/2013 17:00	43.5	0.435
11/03/2013 17:15	43.1	0.431
11/03/2013 17:30	46	0.46
11/03/2013 17:45	47.4	0.474
11/03/2013 18:00	48.3	0.483
11/03/2013 18:15	49.9	0.499
11/03/2013 18:30	50.8	0.508
11/03/2013 18:45	51.7	0.517
11/03/2013 19:00	52.5	0.525
11/03/2013 19:15	53	0.53
11/03/2013 19:30	53	0.53
11/03/2013 19:45	52.9	0.529
11/03/2013 20:00	51.3	0.513
11/03/2013 20:15	50.3	0.503
11/03/2013 20:30	48.9	0.489
11/03/2013 20:45	47.3	0.473
11/03/2013 21:00	46.6	0.466
11/03/2013 21:15	45.3	0.453
11/03/2013 21:30	44	0.44
11/03/2013 21:45	42.7	0.427
11/03/2013 22:00	41.5	0.415
11/03/2013 22:15	40.8	0.408
11/03/2013 22:30	39.3	0.393
11/03/2013 22:45	38.2	0.382
11/03/2013 23:00	37.4	0.374
11/03/2013 23:15	35.9	0.359
11/03/2013 23:30	34.9	0.349
11/03/2013 23:45	33.4	0.334
12/03/2013 0:00	32.2	0.322
12/03/2013 0:15	31.1	0.311
12/03/2013 0:30	30.4	0.304
12/03/2013 0:45	29.3	0.293
12/03/2013 1:00	28.4	0.284
12/03/2013 1:15	27.7	0.277
12/03/2013 1:30	27.4	0.274
12/03/2013 1:45	27	0.27

12/03/2013 2:00	27.4	0.274
12/03/2013 2:15	27.6	0.276
12/03/2013 2:30	28.9	0.289
12/03/2013 2:45	29.8	0.298
12/03/2013 3:00	30.6	0.306
12/03/2013 3:15	31.8	0.318
12/03/2013 3:30	33.1	0.331
12/03/2013 3:45	34.6	0.346
12/03/2013 4:00	35.1	0.351
12/03/2013 4:15	36.7	0.367
12/03/2013 4:30	38	0.38
12/03/2013 4:45	39.4	0.394
12/03/2013 5:00	40.6	0.406
12/03/2013 5:15	41.7	0.417
12/03/2013 5:30	43.2	0.432
12/03/2013 5:45	44.6	0.446
12/03/2013 6:00	45.9	0.459
12/03/2013 6:15	46.4	0.464
12/03/2013 6:30	47.2	0.472
12/03/2013 6:45	48.1	0.481
12/03/2013 7:00	49.1	0.491
12/03/2013 7:15	50	0.5
12/03/2013 7:30	48.6	0.486
12/03/2013 7:45	48.7	0.487
12/03/2013 8:00	49.3	0.493
12/03/2013 8:15	49	0.49
12/03/2013 8:30	46.9	0.469
12/03/2013 8:45	45.8	0.458
12/03/2013 9:00	44.9	0.449
12/03/2013 9:15	43.4	0.434
12/03/2013 9:30	42.9	0.429
12/03/2013 9:45	42.2	0.422
12/03/2013 10:00	41.3	0.413
12/03/2013 10:15	40.2	0.402
12/03/2013 10:30	38.8	0.388
12/03/2013 10:45	36.8	0.368
12/03/2013 11:00	36.4	0.364
12/03/2013 11:15	35	0.35
12/03/2013 11:30	33.6	0.336
12/03/2013 11:45	32.9	0.329
12/03/2013 12:00	32.2	0.322

Table A9-11. Summary of meared groundwater level and predicted tidal data for Etueti's well in Tebunginako Village, Abaiang.

Abaiang predicted tides			**Etueti, Tebunginako - Abaiang**				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
11/03/2013 4:13	2.52	1.83					
11/03/2013 10:18	0.69	-1.96					
11/03/2013 16:29	2.65	1.99	11/03/2013 19:00	0.38	0.19	2:30	10%
11/03/2013 22:40	0.67	-1.90	12/03/2013 1:30	0.19	0.19	2:49	-10%
12/03/2013 4:46	2.57	1.91	12/03/2013 7:00	0.28	0.09	2:13	-4%
12/03/2013 10:51	0.66	-1.97					
Mean						2:31	-7%

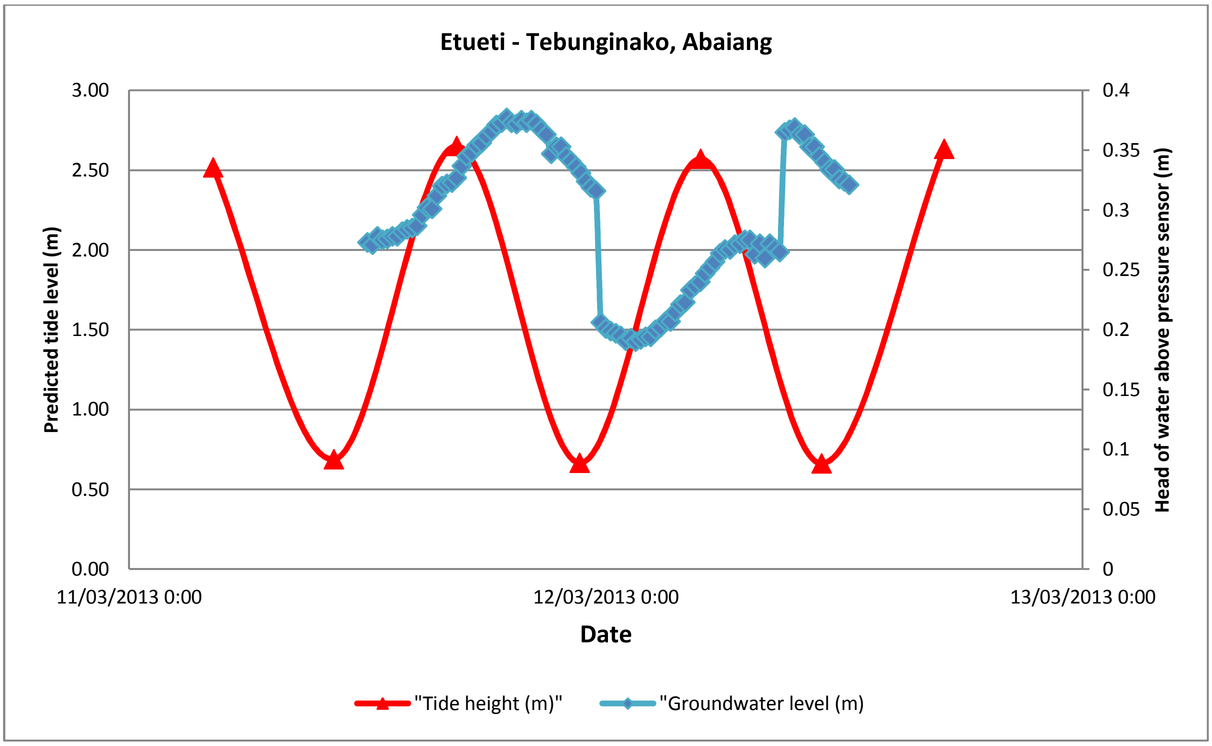


Figure A9-6. Measured groundwater level and predicted tidal data for Etueti's well, Tebunginako Village, Abaiang.

Table A9-12. Measured groundwater level for Etueti's well, Tebunginako Village, Abaiang.

Date/time	Water head[cm]	Head (m)
11/03/2013 12:00	27.3	0.273
11/03/2013 12:15	27.1	0.271
11/03/2013 12:30	27.8	0.278
11/03/2013 12:45	27.5	0.275
11/03/2013 13:00	27.6	0.276
11/03/2013 13:15	27.8	0.278
11/03/2013 13:30	27.8	0.278
11/03/2013 13:45	28.2	0.282
11/03/2013 14:00	28.4	0.284
11/03/2013 14:15	28.5	0.285
11/03/2013 14:30	28.7	0.287
11/03/2013 14:45	29.6	0.296
11/03/2013 15:00	30.2	0.302
11/03/2013 15:15	30.1	0.301
11/03/2013 15:30	31.2	0.312
11/03/2013 15:45	32	0.32
11/03/2013 16:00	32.2	0.322
11/03/2013 16:15	32.3	0.323
11/03/2013 16:30	32.7	0.327
11/03/2013 16:45	33.7	0.337
11/03/2013 17:00	34.5	0.345
11/03/2013 17:15	34.8	0.348
11/03/2013 17:30	35.4	0.354
11/03/2013 17:45	35.6	0.356
11/03/2013 18:00	36.2	0.362
11/03/2013 18:15	36.6	0.366
11/03/2013 18:30	37.1	0.371
11/03/2013 18:45	37.3	0.373
11/03/2013 19:00	37.7	0.377
11/03/2013 19:15	37.3	0.373
11/03/2013 19:30	37.2	0.372
11/03/2013 19:45	37.5	0.375
11/03/2013 20:00	37.3	0.373
11/03/2013 20:15	37.5	0.375
11/03/2013 20:30	37.2	0.372
11/03/2013 20:45	36.7	0.367
11/03/2013 21:00	36.3	0.363
11/03/2013 21:15	34.7	0.347
11/03/2013 21:30	35.3	0.353
11/03/2013 21:45	35.3	0.353
11/03/2013 22:00	34.5	0.345
11/03/2013 22:15	34.1	0.341
11/03/2013 22:30	33.6	0.336
11/03/2013 22:45	33.1	0.331
11/03/2013 23:00	32.4	0.324
11/03/2013 23:15	31.9	0.319
11/03/2013 23:30	31.6	0.316
11/03/2013 23:45	20.6	0.206
12/03/2013 0:00	20.1	0.201
12/03/2013 0:15	19.9	0.199
12/03/2013 0:30	19.7	0.197
12/03/2013 0:45	19.5	0.195
12/03/2013 1:00	19.1	0.191
12/03/2013 1:15	19.3	0.193

12/03/2013 1:30	19	0.19
12/03/2013 1:45	19.2	0.192
12/03/2013 2:00	19.4	0.194
12/03/2013 2:15	19.4	0.194
12/03/2013 2:30	20	0.2
12/03/2013 2:45	20.2	0.202
12/03/2013 3:00	20.7	0.207
12/03/2013 3:15	20.7	0.207
12/03/2013 3:30	21.5	0.215
12/03/2013 3:45	22.1	0.221
12/03/2013 4:00	22.3	0.223
12/03/2013 4:15	23.3	0.233
12/03/2013 4:30	23.7	0.237
12/03/2013 4:45	24	0.24
12/03/2013 5:00	24.7	0.247
12/03/2013 5:15	25.2	0.252
12/03/2013 5:30	25.7	0.257
12/03/2013 5:45	26.4	0.264
12/03/2013 6:00	26.7	0.267
12/03/2013 6:15	26.7	0.267
12/03/2013 6:30	27.1	0.271
12/03/2013 6:45	27.2	0.272
12/03/2013 7:00	27.5	0.275
12/03/2013 7:15	27.5	0.275
12/03/2013 7:30	26.3	0.263
12/03/2013 7:45	27.2	0.272
12/03/2013 8:00	26	0.26
12/03/2013 8:15	27.2	0.272
12/03/2013 8:30	26.8	0.268
12/03/2013 8:45	26.5	0.265
12/03/2013 9:00	36.5	0.365
12/03/2013 9:15	36.7	0.367
12/03/2013 9:30	36.9	0.369
12/03/2013 9:45	36.3	0.363
12/03/2013 10:00	36.3	0.363
12/03/2013 10:15	35.3	0.353
12/03/2013 10:30	35.3	0.353
12/03/2013 10:45	34.5	0.345
12/03/2013 11:00	34	0.34
12/03/2013 11:15	33.4	0.334
12/03/2013 11:30	33.4	0.334
12/03/2013 11:45	32.6	0.326
12/03/2013 12:00	32.4	0.324
12/03/2013 12:15	32.1	0.321

Table A9-13. Summary of measured groundwater level and predicted tidal data for Councillor's well, Ribono islet, Abaiang.

Abaiang predicted tides			**Concilor, Ribono - Abaiang**				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
8/03/2013 2:11	2.11	1.06					
8/03/2013 8:10	1.06	-1.34					
8/03/2013 14:30	2.39	1.49	8/03/2013 18:30	0.233	0.02	3:59	1%
8/03/2013 20:53	0.91	-1.37	9/03/2013 0:15	0.21	0.00	3:21	0%
9/03/2013 2:59	2.28	1.38	9/03/2013 0:30	0.22	0.22	#######	16%
9/03/2013 9:00	0.90	-1.63					
9/03/2013 15:15	2.53	2.53					
Mean						1:37	6%

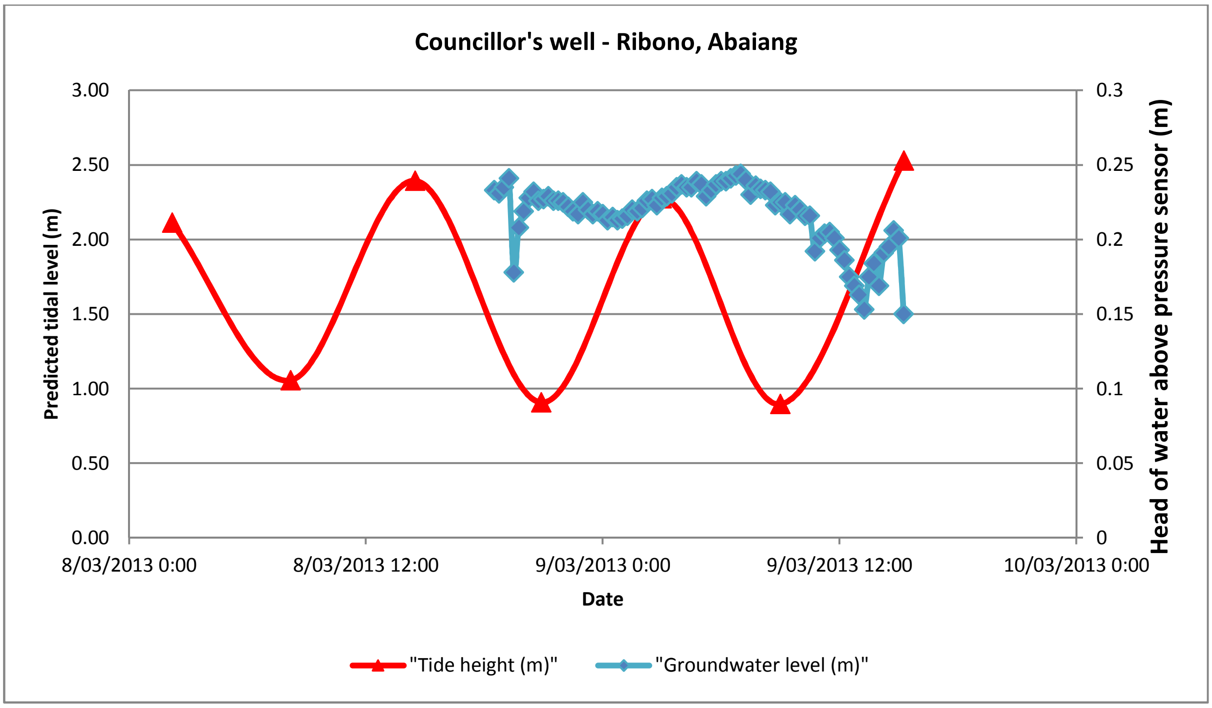


Figure A9-7. Measured groundwater levels with predicted tidal data at the Councillor's house, Ribono islet, Abaiang.

Table A9-14. Measured groundwater level at the Councillor's house, Ribono islet, Abaiang.

Date/time	Water head[cm]	Head (m)
8/03/2013 18:30	23.3	0.233
8/03/2013 18:45	23.1	0.231
8/03/2013 19:00	23.5	0.235
8/03/2013 19:15	24.1	0.241
8/03/2013 19:30	17.8	0.178
8/03/2013 19:45	20.8	0.208
8/03/2013 20:00	21.9	0.219
8/03/2013 20:15	22.8	0.228
8/03/2013 20:30	23.2	0.232
8/03/2013 20:45	22.6	0.226
8/03/2013 21:00	22.7	0.227
8/03/2013 21:15	22.9	0.229
8/03/2013 21:30	22.6	0.226
8/03/2013 21:45	22.6	0.226
8/03/2013 22:00	22.5	0.225
8/03/2013 22:15	22.2	0.222
8/03/2013 22:30	21.9	0.219
8/03/2013 22:45	21.7	0.217
8/03/2013 23:00	22.5	0.225
8/03/2013 23:15	22	0.22
8/03/2013 23:30	21.7	0.217
8/03/2013 23:45	21.9	0.219
9/03/2013 0:00	21.7	0.217
9/03/2013 0:15	21.3	0.213
9/03/2013 0:30	21.5	0.215
9/03/2013 0:45	21.3	0.213
9/03/2013 1:00	21.4	0.214
9/03/2013 1:15	21.6	0.216
9/03/2013 1:30	22	0.22
9/03/2013 1:45	21.9	0.219
9/03/2013 2:00	22.1	0.221
9/03/2013 2:15	22.6	0.226
9/03/2013 2:30	22.7	0.227
9/03/2013 2:45	22.3	0.223
9/03/2013 3:00	22.8	0.228
9/03/2013 3:15	22.9	0.229
9/03/2013 3:30	23.1	0.231
9/03/2013 3:45	23.5	0.235
9/03/2013 4:00	23.7	0.237
9/03/2013 4:15	23.5	0.235
9/03/2013 4:30	23.5	0.235
9/03/2013 4:45	23.9	0.239
9/03/2013 5:00	23.7	0.237
9/03/2013 5:15	22.9	0.229
9/03/2013 5:30	23.3	0.233
9/03/2013 5:45	23.7	0.237
9/03/2013 6:00	23.9	0.239
9/03/2013 6:15	23.9	0.239
9/03/2013 6:30	24.1	0.241
9/03/2013 6:45	24.3	0.243
9/03/2013 7:00	24.4	0.244
9/03/2013 7:15	24	0.24
9/03/2013 7:30	23	0.23
9/03/2013 7:45	23.6	0.236

9/03/2013 8:00	23.4	0.234
9/03/2013 8:15	23.3	0.233
9/03/2013 8:30	23.2	0.232
9/03/2013 8:45	22.3	0.223
9/03/2013 9:00	22.5	0.225
9/03/2013 9:15	22.5	0.225
9/03/2013 9:30	21.7	0.217
9/03/2013 9:45	22.3	0.223
9/03/2013 10:00	22	0.22
9/03/2013 10:15	21.6	0.216
9/03/2013 10:30	21.6	0.216
9/03/2013 10:45	19.2	0.192
9/03/2013 11:00	20.1	0.201
9/03/2013 11:15	20.4	0.204
9/03/2013 11:30	20.5	0.205
9/03/2013 11:45	20.1	0.201
9/03/2013 12:00	19.3	0.193
9/03/2013 12:15	18.6	0.186
9/03/2013 12:30	17.5	0.175
9/03/2013 12:45	16.9	0.169
9/03/2013 13:00	16.3	0.163
9/03/2013 13:15	15.3	0.153
9/03/2013 13:30	17.5	0.175
9/03/2013 13:45	18.4	0.184
9/03/2013 14:00	16.9	0.169
9/03/2013 14:15	19.1	0.191
9/03/2013 14:30	19.5	0.195
9/03/2013 14:45	20.6	0.206
9/03/2013 15:00	20.1	0.201
9/03/2013 15:15	15	0.15

Table A9-15. Summary of measured groundwater level and predicted tidal data for Itinimarawa's well, Ribono islet, Abaiang.

Abaiang predicted tides			**Itinimarawa, Ribono - Abaiang**				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
8/03/2013 2:11	2.11	1.06					
8/03/2013 8:10	1.06	-1.34					
8/03/2013 14:30	2.39	1.49					
8/03/2013 20:53	0.91	-1.37	9/03/2013 0:00	0.11	-0.04	3:06	3%
9/03/2013 2:59	2.28	1.38	9/03/2013 5:15	0.16	0.06	2:15	4%
9/03/2013 9:00	0.90	-1.63	9/03/2013 11:15	0.10	0.10	2:14	6%
9/03/2013 15:15	2.53	2.53					
Mean						2:32	4%

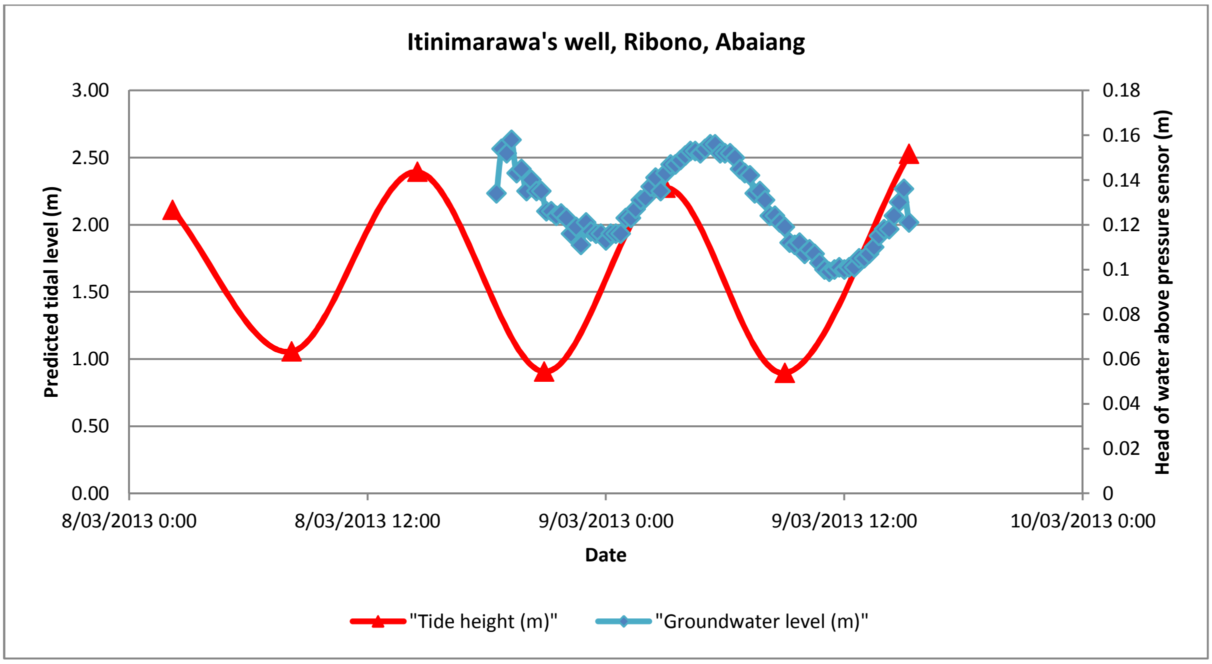


Figure A9-8. Measured groundwater level and predicted tidal data for Itinimarawa's well, Ribono islet, Abaiang.

Table A9-16. Measured groundwater level for Itinimarawa's well, Ribono islet, Abaiang.

Date/time	Water head[cm]	Head (m)
8/03/2013 18:30	13.4	0.134
8/03/2013 18:45	15.4	0.154
8/03/2013 19:00	15.2	0.152
8/03/2013 19:15	15.8	0.158
8/03/2013 19:30	14.3	0.143
8/03/2013 19:45	14.5	0.145
8/03/2013 20:00	13.5	0.135
8/03/2013 20:15	14	0.14
8/03/2013 20:30	13.5	0.135
8/03/2013 20:45	13.5	0.135
8/03/2013 21:00	12.6	0.126
8/03/2013 21:15	12.6	0.126
8/03/2013 21:30	12.4	0.124
8/03/2013 21:45	12.5	0.125
8/03/2013 22:00	12.3	0.123
8/03/2013 22:15	11.6	0.116
8/03/2013 22:30	11.9	0.119
8/03/2013 22:45	11.1	0.111
8/03/2013 23:00	12.1	0.121
8/03/2013 23:15	11.7	0.117
8/03/2013 23:30	11.6	0.116
8/03/2013 23:45	11.6	0.116
9/03/2013 0:00	11.3	0.113
9/03/2013 0:15	11.6	0.116
9/03/2013 0:30	11.6	0.116
9/03/2013 0:45	11.6	0.116
9/03/2013 1:00	12.3	0.123
9/03/2013 1:15	12.3	0.123

9/03/2013 1:30	12.7	0.127
9/03/2013 1:45	13.1	0.131
9/03/2013 2:00	13.2	0.132
9/03/2013 2:15	13.7	0.137
9/03/2013 2:30	14.1	0.141
9/03/2013 2:45	13.5	0.135
9/03/2013 3:00	14.3	0.143
9/03/2013 3:15	14.7	0.147
9/03/2013 3:30	14.7	0.147
9/03/2013 3:45	14.9	0.149
9/03/2013 4:00	15.1	0.151
9/03/2013 4:15	15.3	0.153
9/03/2013 4:30	15.3	0.153
9/03/2013 4:45	15.2	0.152
9/03/2013 5:00	15.4	0.154
9/03/2013 5:15	15.6	0.156
9/03/2013 5:30	15.6	0.156
9/03/2013 5:45	15.2	0.152
9/03/2013 6:00	15.2	0.152
9/03/2013 6:15	15.2	0.152
9/03/2013 6:30	15	0.15
9/03/2013 6:45	14.5	0.145
9/03/2013 7:00	14.3	0.143
9/03/2013 7:15	14.2	0.142
9/03/2013 7:30	13.4	0.134
9/03/2013 7:45	13.5	0.135
9/03/2013 8:00	13.1	0.131
9/03/2013 8:15	12.4	0.124
9/03/2013 8:30	12.4	0.124
9/03/2013 8:45	12.1	0.121

9/03/2013 9:00	11.9	0.119
9/03/2013 9:15	11.2	0.112
9/03/2013 9:30	11.1	0.111
9/03/2013 9:45	11.2	0.112
9/03/2013 10:00	10.7	0.107
9/03/2013 10:15	10.9	0.109
9/03/2013 10:30	10.7	0.107
9/03/2013 10:45	10.3	0.103
9/03/2013 11:00	10	0.1
9/03/2013 11:15	9.9	0.099
9/03/2013 11:30	10	0.1
9/03/2013 11:45	10.1	0.101
9/03/2013 12:00	10	0.1
9/03/2013 12:15	10.1	0.101
9/03/2013 12:30	10.1	0.101
9/03/2013 12:45	10.5	0.105
9/03/2013 13:00	10.5	0.105
9/03/2013 13:15	10.7	0.107
9/03/2013 13:30	11	0.11
9/03/2013 13:45	11.5	0.115
9/03/2013 14:00	11.8	0.118
9/03/2013 14:15	11.8	0.118
9/03/2013 14:30	12.4	0.124
9/03/2013 14:45	13	0.13
9/03/2013 15:00	13.6	0.136
9/03/2013 15:15	12.1	0.121

Table A9-17. Summary of measured groundwater levels and predicted tidal height for Living Water AOG well, Ewena, Abaiang.

Abaiang predicted tides			**Living Water AOG, Ewena - Abaiang**				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
15/03/2013 0:04	0.81	-1.66					
15/03/2013 6:13	2.47	1.60					
15/03/2013 12:23	0.87	-1.47	15/03/2013 15:30	0.23	-0.16	3:06	11%
15/03/2013 18:26	2.34	1.42	15/03/2013 21:15	0.39	0.16	2:48	11%
16/03/2013 0:29	0.92	-1.46	16/03/2013 2:45	0.23	-0.16	2:15	11%
16/03/2013 6:41	2.37	1.37					
16/03/2013 12:52	1.00	1.00					
Mean						2:43	11%

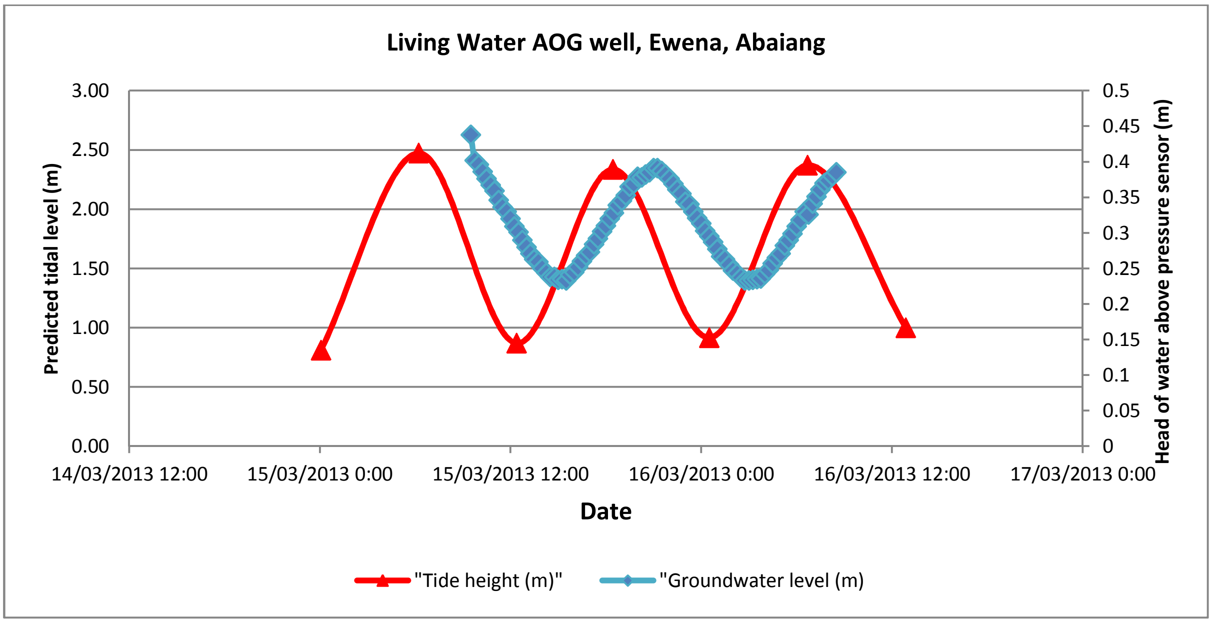


Figure A9-9. Measured groundwater levels and predicted tidal height for Living Water AOG well, Ewena, Abaiang.

Table A9-18. Measured groundwater level at Living Water AOG well, Ewena, Abaiang.

Date/time	Water head[cm]	Head (m)
15/03/2013 9:30	43.8	0.438
15/03/2013 9:45	40.2	0.402
15/03/2013 10:00	39.6	0.396
15/03/2013 10:15	38.6	0.386
15/03/2013 10:30	37.6	0.376
15/03/2013 10:45	36.7	0.367
15/03/2013 11:00	35.9	0.359
15/03/2013 11:15	34.6	0.346
15/03/2013 11:30	33.6	0.336
15/03/2013 11:45	33	0.33
15/03/2013 12:00	32	0.32
15/03/2013 12:15	30.9	0.309
15/03/2013 12:30	30.1	0.301
15/03/2013 12:45	29	0.29
15/03/2013 13:00	28	0.28
15/03/2013 13:15	27.1	0.271
15/03/2013 13:30	26.3	0.263
15/03/2013 13:45	25.9	0.259
15/03/2013 14:00	25	0.25
15/03/2013 14:15	24.4	0.244
15/03/2013 14:30	23.8	0.238
15/03/2013 14:45	23.8	0.238
15/03/2013 15:00	23.4	0.234
15/03/2013 15:15	23.5	0.235
15/03/2013 15:30	23.3	0.233
15/03/2013 15:45	24.1	0.241
15/03/2013 16:00	24.5	0.245
15/03/2013 16:15	25.2	0.252
15/03/2013 16:30	26	0.26
15/03/2013 16:45	26.8	0.268
15/03/2013 17:00	27.3	0.273
15/03/2013 17:15	28.4	0.284
15/03/2013 17:30	29.2	0.292
15/03/2013 17:45	30.2	0.302
15/03/2013 18:00	31	0.31
15/03/2013 18:15	32	0.32
15/03/2013 18:30	32.8	0.328
15/03/2013 18:45	33.9	0.339
15/03/2013 19:00	34.5	0.345
15/03/2013 19:15	35.3	0.353
15/03/2013 19:30	36.5	0.365
15/03/2013 19:45	36.9	0.369
15/03/2013 20:00	37.9	0.379
15/03/2013 20:15	37.8	0.378
15/03/2013 20:30	38.2	0.382
15/03/2013 20:45	38.5	0.385
15/03/2013 21:00	39.1	0.391
15/03/2013 21:15	39.1	0.391
15/03/2013 21:30	38.7	0.387
15/03/2013 21:45	38.2	0.382
15/03/2013 22:00	37.6	0.376
15/03/2013 22:15	36.9	0.369
15/03/2013 22:30	36.1	0.361
15/03/2013 22:45	35.5	0.355
15/03/2013 23:00	34.4	0.344
15/03/2013 23:15	34	0.34
15/03/2013 23:30	33	0.33
15/03/2013 23:45	32.1	0.321
16/03/2013 0:00	31.3	0.313
16/03/2013 0:15	30.3	0.303
16/03/2013 0:30	29.5	0.295
16/03/2013 0:45	28.7	0.287
16/03/2013 1:00	27.7	0.277
16/03/2013 1:15	26.7	0.267
16/03/2013 1:30	26.3	0.263
16/03/2013 1:45	25.5	0.255
16/03/2013 2:00	24.7	0.247
16/03/2013 2:15	24.3	0.243
16/03/2013 2:30	23.7	0.237
16/03/2013 2:45	23.3	0.233
16/03/2013 3:00	23.3	0.233
16/03/2013 3:15	23.4	0.234
16/03/2013 3:30	23.5	0.235
16/03/2013 3:45	23.6	0.236
16/03/2013 4:00	24.2	0.242
16/03/2013 4:15	24.8	0.248
16/03/2013 4:30	25.7	0.257
16/03/2013 4:45	26.5	0.265
16/03/2013 5:00	27.1	0.271
16/03/2013 5:15	28.2	0.282
16/03/2013 5:30	29	0.29
16/03/2013 5:45	29.9	0.299
16/03/2013 6:00	30.9	0.309
16/03/2013 6:15	31.8	0.318
16/03/2013 6:30	33	0.33
16/03/2013 6:45	32.6	0.326
16/03/2013 7:00	34.1	0.341
16/03/2013 7:15	35.1	0.351
16/03/2013 7:30	36.1	0.361
16/03/2013 7:45	37	0.37
16/03/2013 8:00	37.4	0.374
16/03/2013 8:15	38	0.38
16/03/2013 8:30	38.5	0.385

Table A9-19. Summary of measured groundwater levels and predicted tidal height for Rubataiti's well, Taniau (Tebwanga) Village, Abaiang.

Abaiang predicted tides			Rubataiti's well, Taniau - Abaiang				
Date and time	Tide Height m	Tidal range m	Date and time	Tide Height m	Tidal range m	Tidal lag	Tidal efficiency
20/03/2013 2:47	1.45	-0.42					
20/03/2013 9:59	1.87	0.37	20/03/2013 11:15	0.29	0.08	1:15	20%
20/03/2013 17:29	1.49	-0.20	20/03/2013 18:45	0.22	-0.02	1:15	11%
20/03/2013 23:46	1.69	0.19	21/03/2013 0:30	0.24	0.03	0:43	18%
21/03/2013 5:38	1.50	-0.40	21/03/2013 5:45	0.21	-0.03	0:06	8%
21/03/2013 12:33	1.90	0.53					
21/03/2013 19:27	1.37	1.37					
Mean						0:42	13%

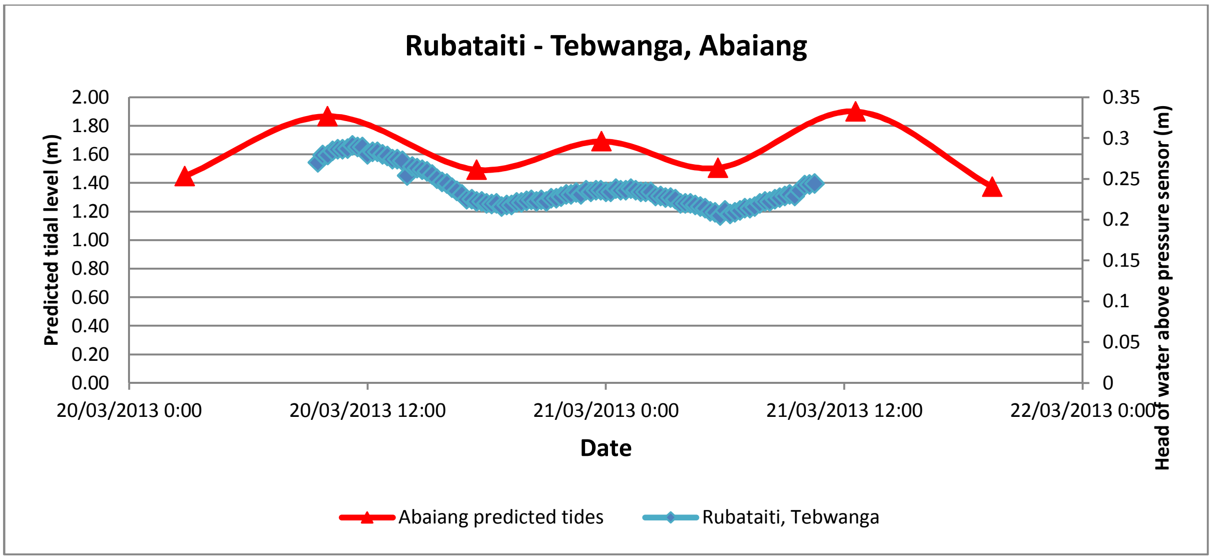


Figure A9-10. Measured groundwater levels and predicted tidal height for Rubataiti's well, Taniau Village, Abaiang.

Table A9-20. Measured groundwater level at Rubataiti's well in Taniau Village.

Date/time	Water head [cm]	Head (m)
20/03/2013 9:30	27	0.27
20/03/2013 9:45	27.9	0.279
20/03/2013 10:00	27.9	0.279
20/03/2013 10:15	28.4	0.284
20/03/2013 10:30	28.6	0.286
20/03/2013 10:45	28.6	0.286
20/03/2013 11:00	28.7	0.287

20/03/2013 11:15	29.1	0.291
20/03/2013 11:30	28.9	0.289
20/03/2013 11:45	28.9	0.289
20/03/2013 12:00	28	0.28
20/03/2013 12:15	28.3	0.283
20/03/2013 12:30	28.3	0.283
20/03/2013 12:45	28	0.28
20/03/2013 13:00	27.8	0.278
20/03/2013 13:15	27.4	0.274
20/03/2013 13:30	27.4	0.274
20/03/2013 13:45	27.2	0.272
20/03/2013 14:00	25.4	0.254
20/03/2013 14:15	26.5	0.265
20/03/2013 14:30	26.3	0.263
20/03/2013 14:45	26.1	0.261
20/03/2013 15:00	25.9	0.259
20/03/2013 15:15	25.5	0.255
20/03/2013 15:30	25	0.25
20/03/2013 15:45	24.6	0.246
20/03/2013 16:00	24.4	0.244
20/03/2013 16:15	23.9	0.239
20/03/2013 16:30	23.5	0.235
20/03/2013 16:45	23.1	0.231
20/03/2013 17:00	22.5	0.225
20/03/2013 17:15	22.5	0.225
20/03/2013 17:30	22.2	0.222
20/03/2013 17:45	22.2	0.222
20/03/2013 18:00	22	0.22
20/03/2013 18:15	21.9	0.219
20/03/2013 18:30	22	0.22
20/03/2013 18:45	21.6	0.216
20/03/2013 19:00	21.8	0.218
20/03/2013 19:15	21.8	0.218
20/03/2013 19:30	22.1	0.221
20/03/2013 19:45	22.1	0.221
20/03/2013 20:00	22.3	0.223
20/03/2013 20:15	22.4	0.224
20/03/2013 20:30	22.2	0.222
20/03/2013 20:45	22.4	0.224
20/03/2013 21:00	22.2	0.222
20/03/2013 21:15	22.6	0.226
20/03/2013 21:30	22.6	0.226
20/03/2013 21:45	22.8	0.228
20/03/2013 22:00	23.1	0.231
20/03/2013 22:15	23.1	0.231
20/03/2013 22:30	23.3	0.233
20/03/2013 22:45	23.1	0.231
20/03/2013 23:00	23.6	0.236
20/03/2013 23:15	23.4	0.234
20/03/2013 23:30	23.6	0.236
20/03/2013 23:45	23.6	0.236
21/03/2013 0:00	23.4	0.234
21/03/2013 0:15	23.4	0.234

21/03/2013 0:30	23.8	0.238
21/03/2013 0:45	23.6	0.236
21/03/2013 1:00	23.6	0.236
21/03/2013 1:15	23.8	0.238
21/03/2013 1:30	23.6	0.236
21/03/2013 1:45	23.4	0.234
21/03/2013 2:00	23.4	0.234
21/03/2013 2:15	23.4	0.234
21/03/2013 2:30	22.9	0.229
21/03/2013 2:45	22.9	0.229
21/03/2013 3:00	22.7	0.227
21/03/2013 3:15	22.7	0.227
21/03/2013 3:30	22.5	0.225
21/03/2013 3:45	22	0.22
21/03/2013 4:00	22	0.22
21/03/2013 4:15	22	0.22
21/03/2013 4:30	21.8	0.218
21/03/2013 4:45	21.6	0.216
21/03/2013 5:00	21.4	0.214
21/03/2013 5:15	21	0.21
21/03/2013 5:30	20.9	0.209
21/03/2013 5:45	20.5	0.205
21/03/2013 6:00	21.1	0.211
21/03/2013 6:15	20.7	0.207
21/03/2013 6:30	20.9	0.209
21/03/2013 6:45	21.1	0.211
21/03/2013 7:00	21.4	0.214
21/03/2013 7:15	21.4	0.214
21/03/2013 7:30	21.6	0.216
21/03/2013 7:45	22	0.22
21/03/2013 8:00	22.2	0.222
21/03/2013 8:15	22.2	0.222
21/03/2013 8:30	22.5	0.225
21/03/2013 8:45	22.7	0.227
21/03/2013 9:00	22.9	0.229
21/03/2013 9:15	23.1	0.231
21/03/2013 9:30	22.9	0.229
21/03/2013 9:45	23.6	0.236
21/03/2013 10:00	24.2	0.242
21/03/2013 10:15	24.3	0.243
21/03/2013 10:30	24.4	0.244

Annex 10

Rainwater Harvesting Analysis Calculator & Abaiang Results

This annex presents the analysis of potential rainwater harvesting centres in each target village on Abaiang atoll. This analysis uses White's (2010) rainfall calculator spreadsheet (Table A10-2) and the historical monthly rainfall for Abaiang Island from November 1904 to May 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 A10-1, which considers the collecting roof area and guttering condition to determine the capture efficiency for each building.

Table A10-1. 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 ≤ C ≤ 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 A10-2. Rainwater calculator created by White (2010) and uses Abaiang's long-term and discontinuous monthly rainfall from November 1904 to May 2014.

INPUTS				RESULTS					
				Length of record			**Overflow**		
catchment area	A	50	m^2	months	677		average monthly overflow	1834	litres
runoff C	C	1	0.95-0.7	years	56				
tank vol	S	50,000	litres						
demand	D	5	L/p/d	**Reliability**		(at end of month t)	**Satisfaction**		
users	N	50		% (months) empty	13.6%		93%	of monthly demand met on average	
month days	dt	30.4333		% of months demand met	86.4%		longest	17	months in a row where less than 100% demand is met
				% tank full	23.2%		dry spell	10	months in a row where less than 60% of demand is met
initial tank volume		0							

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

Abaiang rain Nov-1904 to May-2014 (with gaps)					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
Nov-04	78.7	3935	3935	7608	-3673	0	0	52%	0	0	0	0
Dec-04	247.7	12385	12385	7608	4777	4777	0	100%	1	0	1	0
Jan-05	371.9	18595	23372	7608	15763	15763	0	100%	1	0	1	0
Feb-05	378.7	18935	34698	7608	27090	27090	0	100%	1	0	1	0
Mar-05	521.0	26050	53140	7608	45532	45532	0	100%	1	0	1	0
Apr-05	589.3	29465	74997	7608	67388	50000	17388	100%	1	0	1	0
May-05	459.0	22950	72950	7608	65342	50000	15342	100%	1	0	1	0
Jun-05	320.8	16040	66040	7608	58432	50000	8432	100%	1	0	1	0
Jul-05	335.3	16765	66765	7608	59157	50000	9157	100%	1	0	1	0
Aug-05	145.3	7265	57265	7608	49657	49657	0	100%	1	0	1	0
Sep-05	147.3	7365	57022	7608	49413	49413	0	100%	1	0	1	0
Oct-05	613.4	30670	80083	7608	72475	50000	22475	100%	1	0	1	0
Nov-05	206.5	10325	60325	7608	52717	50000	2717	100%	1	0	1	0

Dec-05	232.7	11635	61635	7608	54027	50000	4027	100%	1	0	1	0
Jan-06	538.0	26900	76900	7608	69292	50000	19292	100%	1	0	1	0
Feb-06	19.8	990	50990	7608	43382	43382	0	100%	1	0	1	0
Mar-06	130.3	6515	49897	7608	42288	42288	0	100%	1	0	1	0
Apr-06	148.8	7440	49728	7608	42120	42120	0	100%	1	0	1	0
May-06	32.3	1615	43735	7608	36127	36127	0	100%	1	0	1	0
Jun-06	90.9	4545	40672	7608	33063	33063	0	100%	1	0	1	0
Jul-06	25.1	1255	34318	7608	26710	26710	0	100%	1	0	1	0
Aug-06	24.9	1245	27955	7608	20347	20347	0	100%	1	0	1	0
Sep-06	28.7	1435	21782	7608	14173	14173	0	100%	1	0	1	0
Oct-06	21.6	1080	15253	7608	7645	7645	0	100%	1	0	1	0
Nov-06	5.1	255	7900	7608	292	292	0	100%	1	0	1	0
Dec-06	225.0	11250	11542	7608	3933	3933	0	100%	1	0	1	0
Jan-07	103.9	5195	9128	7608	1520	1520	0	100%	1	0	1	0
Feb-07	47.2	2360	3880	7608	-3728	0	0	51%	0	1	0	1
Mar-07	22.4	1120	1120	7608	-6488	0	0	15%	0	2	0	2
Apr-07	65.8	3290	3290	7608	-4318	0	0	43%	0	3	0	3
May-07	9.9	495	495	7608	-7113	0	0	7%	0	4	0	4
Jun-07	135.6	6780	6780	7608	-828	0	0	89%	0	5	1	0
Jul-07	123.2	6160	6160	7608	-1448	0	0	81%	0	6	1	0
Aug-07	54.4	2720	2720	7608	-4888	0	0	36%	0	7	0	1
Sep-07	14.0	700	700	7608	-6908	0	0	9%	0	8	0	2
Oct-07	227.6	11380	11380	7608	3772	3772	0	100%	1	0	1	0
Nov-07	156.5	7825	11597	7608	3988	3988	0	100%	1	0	1	0
Dec-07	153.4	7670	11658	7608	4050	4050	0	100%	1	0	1	0
Jul-31	22.4	1120	5170	7608	-2438	0	0	68%	0	1	1	0
Aug-31	23.6	1180	1180	7608	-6428	0	0	16%	0	2	0	1
Sep-31	3.6	180	180	7608	-7428	0	0	2%	0	3	0	2
Oct-31	22.1	1105	1105	7608	-6503	0	0	15%	0	4	0	3
Nov-31	48.0	2400	2400	7608	-5208	0	0	32%	0	5	0	4
Dec-31	0.0	0	0	7608	-7608	0	0	0%	0	6	0	5
Jan-32	62.0	3100	3100	7608	-4508	0	0	41%	0	7	0	6
Feb-32	111.3	5565	5565	7608	-2043	0	0	73%	0	8	1	0
Mar-32	470.2	23510	23510	7608	15902	15902	0	100%	1	0	1	0
Apr-32	613.7	30685	46587	7608	38978	38978	0	100%	1	0	1	0
May-32	213.9	10695	49673	7608	42065	42065	0	100%	1	0	1	0
Jun-32	126.7	6335	48400	7608	40792	40792	0	100%	1	0	1	0
Jul-32	172.2	8610	49402	7608	41793	41793	0	100%	1	0	1	0

Aug-32	30.0	1500	43293	7608	35685	35685	0	100%	1	0	1	0
Sep-32	6.9	345	36030	7608	28422	28422	0	100%	1	0	1	0
Oct-32	0.0	0	28422	7608	20813	20813	0	100%	1	0	1	0
Nov-32	4.1	205	21018	7608	13410	13410	0	100%	1	0	1	0
Dec-32	2.5	125	13535	7608	5927	5927	0	100%	1	0	1	0
Jan-33	115.1	5755	11682	7608	4073	4073	0	100%	1	0	1	0
Feb-33	113.3	5665	9738	7608	2130	2130	0	100%	1	0	1	0
Mar-33	87.9	4395	6525	7608	-1083	0	0	86%	0	1	1	0
Apr-33	327.7	16385	16385	7608	8777	8777	0	100%	1	0	1	0
May-33	63.5	3175	11952	7608	4343	4343	0	100%	1	0	1	0
Jun-33	85.1	4255	8598	7608	990	990	0	100%	1	0	1	0
Jan-34	53.6	2680	3670	7608	-3938	0	0	48%	0	1	0	1
Feb-34	227.3	11365	11365	7608	3757	3757	0	100%	1	0	1	0
Mar-34	65.5	3275	7032	7608	-577	0	0	92%	0	1	1	0
Apr-34	36.6	1830	1830	7608	-5778	0	0	24%	0	2	0	1
May-34	120.4	6020	6020	7608	-1588	0	0	79%	0	3	1	0
Jun-34	227.3	11365	11365	7608	3757	3757	0	100%	1	0	1	0
Jul-34	79.0	3950	7707	7608	98	98	0	100%	1	0	1	0
Aug-34	103.9	5195	5293	7608	-2315	0	0	70%	0	1	1	0
Sep-34	57.7	2885	2885	7608	-4723	0	0	38%	0	2	0	1
Oct-34	23.9	1195	1195	7608	-6413	0	0	16%	0	3	0	2
Nov-34	191.8	9590	9590	7608	1982	1982	0	100%	1	0	1	0
Dec-34	82.6	4130	6112	7608	-1497	0	0	80%	0	1	1	0
Jan-35	137.9	6895	6895	7608	-713	0	0	91%	0	2	1	0
Feb-35	95.3	4765	4765	7608	-2843	0	0	63%	0	3	1	0
Mar-35	40.6	2030	2030	7608	-5578	0	0	27%	0	4	0	1
Apr-35	101.9	5095	5095	7608	-2513	0	0	67%	0	5	1	0
May-35	84.8	4240	4240	7608	-3368	0	0	56%	0	6	0	1
Jun-35	237.7	11885	11885	7608	4277	4277	0	100%	1	0	1	0
Jul-35	118.4	5920	10197	7608	2588	2588	0	100%	1	0	1	0
Aug-35	119.4	5970	8558	7608	950	950	0	100%	1	0	1	0
Sep-35	138.2	6910	7860	7608	252	252	0	100%	1	0	1	0
Oct-35	23.1	1155	1407	7608	-6202	0	0	18%	0	1	0	1
Nov-35	158.2	7910	7910	7608	302	302	0	100%	1	3330	1	0
Dec-35	243.3	12165	12467	7608	4858	4858	0	100%	1	0	1	0
Jan-36	372.6	18630	23488	7608	15880	15880	0	100%	1	0	1	0
Feb-36	230.1	11505	27385	7608	19777	19777	0	100%	1	0	1	0
Mar-36	244.3	12215	31992	7608	24383	24383	0	100%	1	0	1	0

Apr-36	263.1	13155	37538	7608	29930	29930	0	100%	1	0	1	0
May-36	230.1	11505	41435	7608	33827	33827	0	100%	1	0	1	0
Jun-36	205.7	10285	44112	7608	36503	36503	0	100%	1	0	1	0
Jul-36	181.6	9080	45583	7608	37975	37975	0	100%	1	0	1	0
Aug-36	130.8	6540	44515	7608	36907	36907	0	100%	1	0	1	0
Sep-36	28.4	1420	38327	7608	30718	30718	0	100%	1	0	1	0
Oct-36	91.2	4560	35278	7608	27670	27670	0	100%	1	0	1	0
Nov-36	301.0	15050	42720	7608	35112	35112	0	100%	1	0	1	0
Dec-36	164.6	8230	43342	7608	35733	35733	0	100%	1	0	1	0
Jan-37	178.6	8930	44663	7608	37055	37055	0	100%	1	0	1	0
Feb-37	93.2	4660	41715	7608	34107	34107	0	100%	1	0	1	0
Mar-37	166.1	8305	42412	7608	34803	34803	0	100%	1	0	1	0
Apr-37	185.9	9295	44098	7608	36490	36490	0	100%	1	0	1	0
May-37	21.6	1080	37570	7608	29962	29962	0	100%	1	0	1	0
Jun-37	47.0	2350	32312	7608	24704	24704	0	100%	1	0	1	0
Jul-37	58.4	2920	27624	7608	20015	20015	0	100%	1	0	1	0
Aug-37	42.4	2120	22135	7608	14527	14527	0	100%	1	0	1	0
Sep-37	44.5	2225	16752	7608	9144	9144	0	100%	1	0	1	0
Oct-37	20.8	1040	10184	7608	2575	2575	0	100%	1	0	1	0
Nov-37	149.1	7455	10030	7608	2422	2422	0	100%	1	0	1	0
Dec-37	56.6	2830	5252	7608	-2356	0	0	69%	0	1	1	0
Jan-38	110.0	5500	5500	7608	-2108	0	0	72%	0	2	1	0
Feb-38	137.4	6870	6870	7608	-738	0	0	90%	0	3	1	0
Mar-38	12.2	610	610	7608	-6998	0	0	8%	0	4	0	1
Apr-38	87.1	4355	4355	7608	-3253	0	0	57%	0	5	0	2
May-38	7.1	355	355	7608	-7253	0	0	5%	0	6	0	3
Jun-38	30.0	1500	1500	7608	-6108	0	0	20%	0	7	0	4
Jul-38	22.1	1105	1105	7608	-6503	0	0	15%	0	8	0	5
Aug-38	50.8	2540	2540	7608	-5068	0	0	33%	0	9	0	6
May-47	160.8	8040	8040	7608	432	432	0	100%	1	0	1	0
Jun-47	175.8	8790	9222	7608	1613	1613	0	100%	1	0	1	0
Jul-47	88.6	4430	6043	7608	-1565	0	0	79%	0	1	1	0
Aug-47	68.8	3440	3440	7608	-4168	0	0	45%	0	2	0	1
Sep-47	14.0	700	700	7608	-6908	0	0	9%	0	3	0	2
Oct-47	142.7	7135	7135	7608	-473	0	0	94%	0	4	1	0
Nov-47	147.6	7380	7380	7608	-228	0	0	97%	0	5	1	0
Dec-47	227.8	11390	11390	7608	3782	3782	0	100%	1	0	1	0
Jan-48	421.1	21055	24837	7608	17228	17228	0	100%	1	0	1	0

Feb-48	167.1	8355	25583	7608		17975	17975	0	100%	1	0	1	0
Mar-48	424.2	21210	39185	7608		31577	31577	0	100%	1	0	1	0
Apr-48	409.2	20460	52037	7608		44428	44428	0	100%	1	0	1	0
May-48	313.9	15695	60123	7608		52515	50000	2515	100%	1	0	1	0
Jun-48	208.8	10440	60440	7608		52832	50000	2832	100%	1	0	1	0
Jul-48	244.9	12245	62245	7608		54637	50000	4637	100%	1	0	1	0
Aug-48	82.0	4100	54100	7608		46492	46492	0	100%	1	0	1	0
Sep-48	24.4	1220	47712	7608		40103	40103	0	100%	1	0	1	0
Oct-48	62.5	3125	43228	7608		35620	35620	0	100%	1	0	1	0
Nov-48	117.6	5880	41500	7608		33892	33892	0	100%	1	0	1	0
Dec-48	327.2	16360	50252	7608		42643	42643	0	100%	1	0	1	0
Jan-49	535.9	26795	69438	7608		61830	50000	11830	100%	1	0	1	0
Feb-49	172.5	8625	58625	7608		51017	50000	1017	100%	1	0	1	0
Mar-49	236.0	11800	61800	7608		54192	50000	4192	100%	1	0	1	0
Apr-49	337.6	16880	66880	7608		59272	50000	9272	100%	1	0	1	0
May-49	145.8	7290	57290	7608		49682	49682	0	100%	1	0	1	0
Jun-49	75.9	3795	53477	7608		45868	45868	0	100%	1	0	1	0
Jul-49	222.0	11100	56968	7608		49360	49360	0	100%	1	0	1	0
Sep-49	41.4	2070	51430	7608		43822	43822	0	100%	1	0	1	0
Oct-49	28.4	1420	45242	7608		37633	37633	0	100%	1	0	1	0
Nov-49	12.4	620	38253	7608		30645	30645	0	100%	1	0	1	0
Dec-49	16.0	800	31445	7608		23837	23837	0	100%	1	0	1	0
Aug-50	90.0	4500	28337	7608		20728	20728	0	100%	1	0	1	0
Sep-50	84.0	4200	24928	7608		17320	17320	0	100%	1	0	1	0
Oct-50	35.0	1750	19070	7608		11462	11462	0	100%	1	0	1	0
Nov-50	36.0	1800	13262	7608		5653	5653	0	100%	1	0	1	0
Dec-50	65.0	3250	8903	7608		1295	1295	0	100%	1	0	1	0
Jan-51	105.0	5250	6545	7608		-1063	0	0	86%	0	1	1	0
Feb-51	44.0	2200	2200	7608		-5408	0	0	29%	0	2	0	1
Mar-51	96.0	4800	4800	7608		-2808	0	0	63%	0	3	1	0
Apr-51	78.0	3900	3900	7608		-3708	0	0	51%	0	4	0	1
May-51	229.0	11450	11450	7608		3842	3842	0	100%	1	0	1	0
Jun-51	336.0	16800	20642	7608		13033	13033	0	100%	1	0	1	0
Jul-51	327.0	16350	29383	7608		21775	21775	0	100%	1	0	1	0
Aug-51	291.0	14550	36325	7608		28717	28717	0	100%	1	0	1	0
Sep-51	227.0	11350	40067	7608		32458	32458	0	100%	1	0	1	0
Oct-51	95.0	4750	37208	7608		29600	29600	0	100%	1	0	1	0
Nov-51	106.0	5300	34900	7608		27292	27292	0	100%	1	0	1	0

Dec-51	283.0	14150	41442	7608	33833	33833	0	100%	1	0	1	0
Jan-52	675.0	33750	67583	7608	59975	50000	9975	100%	1	0	1	0
Feb-52	232.0	11600	61600	7608	53992	50000	3992	100%	1	0	1	0
Mar-52	274.0	13700	63700	7608	56092	50000	6092	100%	1	0	1	0
Apr-52	113.0	5650	55650	7608	48042	48042	0	100%	1	0	1	0
May-52	180.0	9000	57042	7608	49433	49433	0	100%	1	0	1	0
Jun-52	134.0	6700	56133	7608	48525	48525	0	100%	1	0	1	0
Jul-52	74.0	3700	52225	7608	44617	44617	0	100%	1	0	1	0
Aug-52	130.0	6500	51117	7608	43508	43508	0	100%	1	0	1	0
Sep-52	33.0	1650	45158	7608	37550	37550	0	100%	1	0	1	0
Oct-52	32.0	1600	39150	7608	31542	31542	0	100%	1	0	1	0
Nov-52	204.0	10200	41742	7608	34133	34133	0	100%	1	0	1	0
Dec-52	421.0	21050	55183	7608	47575	47575	0	100%	1	0	1	0
Jan-53	323.0	16150	63725	7608	56117	50000	6117	100%	1	0	1	0
Feb-53	560.0	28000	78000	7608	70392	50000	20392	100%	1	0	1	0
Mar-53	218.0	10900	60900	7608	53292	50000	3292	100%	1	0	1	0
Apr-53	399.0	19950	69950	7608	62342	50000	12342	100%	1	0	1	0
May-53	241.0	12050	62050	7608	54442	50000	4442	100%	1	0	1	0
Jun-53	137.0	6850	56850	7608	49242	49242	0	100%	1	0	1	0
Jul-53	217.0	10850	60092	7608	52483	50000	2483	100%	1	0	1	0
Sep-53	469.0	23450	73450	7608	65842	50000	15842	100%	1	0	1	0
Oct-53	115.0	5750	55750	7608	48142	48142	0	100%	1	0	1	0
Nov-53	180.0	9000	57142	7608	49533	49533	0	100%	1	0	1	0
Dec-53	507.0	25350	74883	7608	67275	50000	17275	100%	1	0	1	0
Jan-54	379.0	18950	68950	7608	61342	50000	11342	100%	1	0	1	0
Feb-54	217.0	10850	60850	7608	53242	50000	3242	100%	1	0	1	0
Mar-54	235.0	11750	61750	7608	54142	50000	4142	100%	1	0	1	0
Apr-54	198.0	9900	59900	7608	52292	50000	2292	100%	1	0	1	0
May-54	48.0	2400	52400	7608	44792	44792	0	100%	1	0	1	0
Jun-54	16.0	800	45592	7608	37983	37983	0	100%	1	0	1	0
Jul-54	99.0	4950	42933	7608	35325	35325	0	100%	1	0	1	0
Aug-54	321.0	16050	51375	7608	43767	43767	0	100%	1	0	1	0
Sep-54	70.0	3500	47267	7608	39658	39658	0	100%	1	0	1	0
Oct-54	23.0	1150	40808	7608	33200	33200	0	100%	1	0	1	0
Nov-54	49.0	2450	35650	7608	28042	28042	0	100%	1	0	1	0
Dec-54	151.0	7550	35592	7608	27983	27983	0	100%	1	0	1	0
Jan-55	104.0	5200	33183	7608	25575	25575	0	100%	1	0	1	0
Feb-55	10.0	500	26075	7608	18467	18467	0	100%	1	0	1	0

Mar-55	47.0	2350	20817	7608	13208	13208	0	100%	1	0	1	0
Apr-55	165.0	8250	21458	7608	13850	13850	0	100%	1	0	1	0
May-55	53.0	2650	16500	7608	8892	8892	0	100%	1	0	1	0
Jun-55	60.0	3000	11892	7608	4283	4283	0	100%	1	0	1	0
Jul-55	68.0	3400	7683	7608	75	75	0	100%	1	0	1	0
Aug-55	31.0	1550	1625	7608	-5983	0	0	21%	0	1	0	1
Sep-55	121.0	6050	6050	7608	-1558	0	0	80%	0	2	1	0
Oct-55	10.0	500	500	7608	-7108	0	0	7%	0	3	0	1
Nov-55	7.0	350	350	7608	-7258	0	0	5%	0	4	0	2
Dec-55	173.0	8650	8650	7608	1042	1042	0	100%	1	0	1	0
Jan-56	94.0	4700	5742	7608	-1867	0	0	75%	0	1	1	0
Feb-56	112.0	5600	5600	7608	-2008	0	0	74%	0	2	1	0
Mar-56	55.0	2750	2750	7608	-4858	0	0	36%	0	3	0	1
Apr-56	167.0	8350	8350	7608	742	742	0	100%	1	0	1	0
May-56	89.0	4450	5192	7608	-2417	0	0	68%	0	1	1	0
Jun-56	100.0	5000	5000	7608	-2608	0	0	66%	0	2	1	0
Jul-56	198.0	9900	9900	7608	2292	2292	0	100%	1	0	1	0
Aug-56	56.0	2800	5092	7608	-2517	0	0	67%	0	1	1	0
Sep-56	55.0	2750	2750	7608	-4858	0	0	36%	0	2	0	1
Oct-56	66.0	3300	3300	7608	-4308	0	0	43%	0	3	0	2
Nov-56	74.0	3700	3700	7608	-3908	0	0	49%	0	4	0	3
Dec-56	188.0	9400	9400	7608	1792	1792	0	100%	1	0	1	0
Jan-57	172.0	8600	10392	7608	2783	2783	0	100%	1	0	1	0
Feb-57	176.0	8800	11583	7608	3975	3975	0	100%	1	0	1	0
Mar-57	411.0	20550	24525	7608	16917	16917	0	100%	1	0	1	0
Apr-57	242.0	12100	29017	7608	21408	21408	0	100%	1	0	1	0
May-57	218.0	10900	32308	7608	24700	24700	0	100%	1	0	1	0
Jun-57	270.0	13500	38200	7608	30592	30592	0	100%	1	0	1	0
Jul-57	266.0	13300	43892	7608	36283	36283	0	100%	1	0	1	0
Aug-57	71.0	3550	39833	7608	32225	32225	0	100%	1	0	1	0
Sep-57	203.0	10150	42375	7608	34767	34767	0	100%	1	0	1	0
Oct-57	341.0	17050	51817	7608	44208	44208	0	100%	1	0	1	0
Nov-57	289.0	14450	58658	7608	51050	50000	1050	100%	1	0	1	0
Dec-57	185.0	9250	59250	7608	51642	50000	1642	100%	1	0	1	0
Jan-58	65.0	3250	53250	7608	45642	45642	0	100%	1	0	1	0
Feb-58	107.0	5350	50992	7608	43383	43383	0	100%	1	0	1	0
Mar-58	318.0	15900	59283	7608	51675	50000	1675	100%	1	0	1	0
Apr-58	513.0	25650	75650	7608	68042	50000	18042	100%	1	0	1	0

May-58	171.0	8550	58550	7608	50942	50000	942	100%	1	0	1	0
Jun-58	213.0	10650	60650	7608	53042	50000	3042	100%	1	0	1	0
Jul-58	421.0	21050	71050	7608	63442	50000	13442	100%	1	0	1	0
Aug-58	183.0	9150	59150	7608	51542	50000	1542	100%	1	0	1	0
Sep-58	11.0	550	50550	7608	42942	42942	0	100%	1	0	1	0
Oct-58	55.0	2750	45692	7608	38083	38083	0	100%	1	0	1	0
Nov-58	222.0	11100	49183	7608	41575	41575	0	100%	1	0	1	0
Dec-58	233.0	11650	53225	7608	45617	45617	0	100%	1	0	1	0
Jan-59	234.0	11700	57317	7608	49708	49708	0	100%	1	0	1	0
Feb-59	471.0	23550	73258	7608	65650	50000	15650	100%	1	0	1	0
Mar-59	203.0	10150	60150	7608	52542	50000	2542	100%	1	0	1	0
Apr-59	320.0	16000	66000	7608	58392	50000	8392	100%	1	0	1	0
May-59	269.0	13450	63450	7608	55842	50000	5842	100%	1	0	1	0
Jun-59	104.0	5200	55200	7608	47592	47592	0	100%	1	0	1	0
Jul-59	193.0	9650	57242	7608	49633	49633	0	100%	1	0	1	0
Aug-59	217.0	10850	60483	7608	52875	50000	2875	100%	1	0	1	0
Sep-59	56.0	2800	52800	7608	45192	45192	0	100%	1	0	1	0
Oct-59	204.0	10200	55392	7608	47783	47783	0	100%	1	0	1	0
Nov-59	56.0	2800	50583	7608	42975	42975	0	100%	1	0	1	0
Dec-59	216.0	10800	53775	7608	46167	46167	0	100%	1	0	1	0
Jan-60	474.0	23700	69867	7608	62258	50000	12258	100%	1	0	1	0
Feb-60	369.0	18450	68450	7608	60842	50000	10842	100%	1	0	1	0
Mar-60	183.0	9150	59150	7608	51542	50000	1542	100%	1	0	1	0
Apr-60	179.0	8950	58950	7608	51342	50000	1342	100%	1	0	1	0
May-60	125.0	6250	56250	7608	48642	48642	0	100%	1	0	1	0
Jun-60	144.0	7200	55842	7608	48233	48233	0	100%	1	0	1	0
Jul-60	93.0	4650	52883	7608	45275	45275	0	100%	1	0	1	0
Aug-60	80.0	4000	49275	7608	41667	41667	0	100%	1	0	1	0
Sep-60	61.0	3050	44717	7608	37108	37108	0	100%	1	0	1	0
Oct-60	0.0	0	37108	7608	29500	29500	0	100%	1	0	1	0
Nov-60	80.0	4000	33500	7608	25892	25892	0	100%	1	0	1	0
Dec-60	193.0	9650	35542	7608	27933	27933	0	100%	1	0	1	0
Jan-61	290.0	14500	42433	7608	34825	34825	0	100%	1	0	1	0
Feb-61	291.0	14550	49375	7608	41767	41767	0	100%	1	0	1	0
Mar-61	113.0	5650	47417	7608	39808	39808	0	100%	1	0	1	0
Apr-61	155.0	7750	47558	7608	39950	39950	0	100%	1	0	1	0
May-61	212.0	10600	50550	7608	42942	42942	0	100%	1	0	1	0
Jun-61	157.0	7850	50792	7608	43183	43183	0	100%	1	0	1	0

Jul-61	213.0	10650	53833	7608	46225	46225	0	100%	1	0	1	0
Aug-61	279.0	13950	60175	7608	52567	50000	2567	100%	1	0	1	0
Sep-61	34.0	1700	51700	7608	44092	44092	0	100%	1	0	1	0
Oct-61	93.0	4650	48742	7608	41133	41133	0	100%	1	0	1	0
Nov-61	50.0	2500	43633	7608	36025	36025	0	100%	1	0	1	0
Dec-61	135.0	6750	42775	7608	35167	35167	0	100%	1	0	1	0
Jan-62	153.0	7650	42817	7608	35208	35208	0	100%	1	0	1	0
Feb-62	27.0	1350	36558	7608	28950	28950	0	100%	1	0	1	0
Mar-62	171.0	8550	37500	7608	29892	29892	0	100%	1	0	1	0
Apr-62	228.0	11400	41292	7608	33683	33683	0	100%	1	0	1	0
May-62	110.0	5500	39183	7608	31575	31575	0	100%	1	0	1	0
Jun-62	124.0	6200	37775	7608	30167	30167	0	100%	1	0	1	0
Jul-62	311.0	15550	45717	7608	38108	38108	0	100%	1	0	1	0
Aug-62	178.0	8900	47008	7608	39400	39400	0	100%	1	0	1	0
Sep-62	165.0	8250	47650	7608	40042	40042	0	100%	1	0	1	0
Oct-62	17.0	850	40892	7608	33283	33283	0	100%	1	0	1	0
Nov-62	32.0	1600	34883	7608	27275	27275	0	100%	1	0	1	0
Dec-62	284.0	14200	41475	7608	33867	33867	0	100%	1	0	1	0
Jan-63	196.0	9800	43667	7608	36058	36058	0	100%	1	0	1	0
Feb-63	25.0	1250	37308	7608	29700	29700	0	100%	1	0	1	0
Mar-63	125.0	6250	35950	7608	28342	28342	0	100%	1	0	1	0
Apr-63	63.0	3150	31492	7608	23884	23884	0	100%	1	0	1	0
May-63	145.0	7250	31134	7608	23525	23525	0	100%	1	0	1	0
Jun-63	142.0	7100	30625	7608	23017	23017	0	100%	1	0	1	0
Jul-63	156.0	7800	30817	7608	23209	23209	0	100%	1	0	1	0
Aug-63	200.0	10000	33209	7608	25600	25600	0	100%	1	0	1	0
Sep-63	157.0	7850	33450	7608	25842	25842	0	100%	1	0	1	0
Oct-63	310.0	15500	41342	7608	33734	33734	0	100%	1	0	1	0
Nov-63	300.0	15000	48734	7608	41125	41125	0	100%	1	0	1	0
Dec-63	345.0	17250	58375	7608	50767	50000	767	100%	1	0	1	0
Jan-64	514.0	25700	75700	7608	68092	50000	18092	100%	1	0	1	0
Feb-64	375.0	18750	68750	7608	61142	50000	11142	100%	1	0	1	0
Mar-64	178.0	8900	58900	7608	51292	50000	1292	100%	1	0	1	0
Apr-64	68.0	3400	53400	7608	45792	45792	0	100%	1	0	1	0
May-64	10.0	500	46292	7608	38683	38683	0	100%	1	0	1	0
Jun-64	114.0	5700	44383	7608	36775	36775	0	100%	1	0	1	0
Jul-64	55.0	2750	39525	7608	31917	31917	0	100%	1	0	1	0
Aug-64	91.0	4550	36467	7608	28858	28858	0	100%	1	0	1	0

Sep-64	31.0	1550	30408	7608	22800	22800	0	100%	1	0	1	0
Oct-64	3.0	150	22950	7608	15342	15342	0	100%	1	0	1	0
Nov-64	89.0	4450	19792	7608	12183	12183	0	100%	1	0	1	0
Dec-64	17.0	850	13033	7608	5425	5425	0	100%	1	0	1	0
Jan-65	348.0	17400	22825	7608	15217	15217	0	100%	1	0	1	0
Feb-65	425.0	21250	36467	7608	28858	28858	0	100%	1	0	1	0
Mar-65	39.0	1950	30808	7608	23200	23200	0	100%	1	0	1	0
Apr-65	345.0	17250	40450	7608	32842	32842	0	100%	1	0	1	0
May-65	62.0	3100	35942	7608	28333	28333	0	100%	1	0	1	0
Jun-65	458.0	22900	51233	7608	43625	43625	0	100%	1	0	1	0
Jul-65	532.0	26600	70225	7608	62617	50000	12617	100%	1	0	1	0
Aug-65	56.0	2800	52800	7608	45192	45192	0	100%	1	0	1	0
Sep-65	186.0	9300	54492	7608	46883	46883	0	100%	1	0	1	0
Oct-65	372.0	18600	65483	7608	57875	50000	7875	100%	1	0	1	0
Nov-65	249.0	12450	62450	7608	54842	50000	4842	100%	1	0	1	0
Dec-65	502.0	25100	75100	7608	67492	50000	17492	100%	1	0	1	0
Jan-66	416.0	20800	70800	7608	63192	50000	13192	100%	1	0	1	0
Feb-66	388.0	19400	69400	7608	61792	50000	11792	100%	1	0	1	0
Mar-66	384.0	19200	69200	7608	61592	50000	11592	100%	1	0	1	0
Apr-66	384.0	19200	69200	7608	61592	50000	11592	100%	1	0	1	0
May-66	380.0	19000	69000	7608	61392	50000	11392	100%	1	0	1	0
Jun-66	15.0	750	50750	7608	43142	43142	0	100%	1	0	1	0
Jul-66	350.0	17500	60642	7608	53033	50000	3033	100%	1	0	1	0
Aug-66	28.0	1400	51400	7608	43792	43792	0	100%	1	0	1	0
Sep-66	125.0	6250	50042	7608	42433	42433	0	100%	1	0	1	0
Oct-66	229.0	11450	53883	7608	46275	46275	0	100%	1	0	1	0
Nov-66	257.0	12850	59125	7608	51517	50000	1517	100%	1	0	1	0
Dec-66	165.0	8250	58250	7608	50642	50000	642	100%	1	0	1	0
Jan-67	334.0	16700	66700	7608	59092	50000	9092	100%	1	0	1	0
Feb-67	132.0	6600	56600	7608	48992	48992	0	100%	1	0	1	0
Mar-67	137.0	6850	55842	7608	48233	48233	0	100%	1	0	1	0
Apr-67	204.0	10200	58433	7608	50825	50000	825	100%	1	0	1	0
May-67	33.0	1650	51650	7608	44042	44042	0	100%	1	0	1	0
Jun-67	106.0	5300	49342	7608	41733	41733	0	100%	1	0	1	0
Jul-67	156.0	7800	49533	7608	41925	41925	0	100%	1	0	1	0
Aug-67	42.0	2100	44025	7608	36417	36417	0	100%	1	0	1	0
Sep-67	119.0	5950	42367	7608	34758	34758	0	100%	1	0	1	0
Oct-67	66.0	3300	38058	7608	30450	30450	0	100%	1	0	1	0

Nov-67	24.0	1200	31650	7608	24042	24042	0	100%	1	0	1	0
Dec-67	224.0	11200	35242	7608	27633	27633	0	100%	1	0	1	0
Jan-68	212.0	10600	38233	7608	30625	30625	0	100%	1	0	1	0
Feb-68	262.0	13100	43725	7608	36117	36117	0	100%	1	0	1	0
Mar-68	21.0	1050	37167	7608	29558	29558	0	100%	1	0	1	0
Apr-68	9.0	450	30008	7608	22400	22400	0	100%	1	0	1	0
May-68	6.0	300	22700	7608	15092	15092	0	100%	1	0	1	0
Jun-68	12.0	600	15692	7608	8083	8083	0	100%	1	0	1	0
Jul-68	129.0	6450	14533	7608	6925	6925	0	100%	1	0	1	0
Aug-68	73.0	3650	10575	7608	2967	2967	0	100%	1	0	1	0
Sep-68	421.0	21050	24017	7608	16408	16408	0	100%	1	0	1	0
Oct-68	78.0	3900	20308	7608	12700	12700	0	100%	1	0	1	0
Nov-68	125.0	6250	18950	7608	11342	11342	0	100%	1	0	1	0
Dec-68	267.0	13350	24692	7608	17084	17084	0	100%	1	0	1	0
Jan-69	339.0	16950	34034	7608	26425	26425	0	100%	1	0	1	0
Feb-69	700.0	35000	61425	7608	53817	50000	3817	100%	1	0	1	0
Mar-69	500.0	25000	75000	7608	67392	50000	17392	100%	1	0	1	0
Apr-69	350.0	17500	67500	7608	59892	50000	9892	100%	1	0	1	0
May-69	324.0	16200	66200	7608	58592	50000	8592	100%	1	0	1	0
Jun-69	488.0	24400	74400	7608	66792	50000	16792	100%	1	0	1	0
Jul-69	587.0	29350	79350	7608	71742	50000	21742	100%	1	0	1	0
Aug-69	351.0	17550	67550	7608	59942	50000	9942	100%	1	0	1	0
Sep-69	51.0	2550	52550	7608	44942	44942	0	100%	1	0	1	0
Oct-69	0.0	0	44942	7608	37333	37333	0	100%	1	0	1	0
Nov-69	92.0	4600	41933	7608	34325	34325	0	100%	1	0	1	0
Dec-69	761.0	38050	72375	7608	64767	50000	14767	100%	1	0	1	0
Jan-70	286.0	14300	64300	7608	56692	50000	6692	100%	1	0	1	0
Feb-70	305.0	15250	65250	7608	57642	50000	7642	100%	1	0	1	0
Mar-70	284.0	14200	64200	7608	56592	50000	6592	100%	1	0	1	0
Apr-70	111.0	5550	55550	7608	47942	47942	0	100%	1	0	1	0
May-70	128.0	6400	54342	7608	46733	46733	0	100%	1	0	1	0
Jun-70	128.0	6400	53133	7608	45525	45525	0	100%	1	0	1	0
Jan-72	241.0	12050	57575	7608	49967	49967	0	100%	1	0	1	0
Feb-72	53.0	2650	52617	7608	45008	45008	0	100%	1	0	1	0
Mar-72	61.0	3050	48058	7608	40450	40450	0	100%	1	0	1	0
Apr-72	49.0	2450	42900	7608	35292	35292	0	100%	1	0	1	0
May-72	237.0	11850	47142	7608	39533	39533	0	100%	1	0	1	0
Jun-72	202.0	10100	49633	7608	42025	42025	0	100%	1	0	1	0

Jul-72	263.0	13150	55175	7608	47567	47567	0	100%	1	0	1	0
Aug-72	291.0	14550	62117	7608	54508	50000	4508	100%	1	0	1	0
Sep-72	345.0	17250	67250	7608	59642	50000	9642	100%	1	0	1	0
Oct-72	237.0	11850	61850	7608	54242	50000	4242	100%	1	0	1	0
Nov-72	142.0	7100	57100	7608	49492	49492	0	100%	1	0	1	0
Dec-72	436.0	21800	71292	7608	63683	50000	13683	100%	1	0	1	0
Jan-73	306.0	15300	65300	7608	57692	50000	7692	100%	1	0	1	0
Feb-73	346.0	17300	67300	7608	59692	50000	9692	100%	1	0	1	0
Mar-73	315.0	15750	65750	7608	58142	50000	8142	100%	1	0	1	0
Apr-73	87.0	4350	54350	7608	46742	46742	0	100%	1	0	1	0
May-73	90.0	4500	51242	7608	43633	43633	0	100%	1	0	1	0
Jun-73	33.0	1650	45283	7608	37675	37675	0	100%	1	0	1	0
Jul-73	14.0	700	38375	7608	30767	30767	0	100%	1	0	1	0
Aug-73	1.0	50	30817	7608	23208	23208	0	100%	1	0	1	0
Sep-73	3.0	150	23358	7608	15750	15750	0	100%	1	0	1	0
Oct-73	24.0	1200	16950	7608	9342	9342	0	100%	1	0	1	0
Nov-73	0.0	0	9342	7608	1733	1733	0	100%	1	0	1	0
Dec-73	13.0	650	2383	7608	-5225	0	0	31%	0	1	0	1
Feb-78	241.0	12050	12050	7608	4442	4442	0	100%	1	0	1	0
Mar-78	706.0	35300	39742	7608	32133	32133	0	100%	1	0	1	0
Apr-78	187.0	9350	41483	7608	33875	33875	0	100%	1	0	1	0
May-78	91.0	4550	38425	7608	30817	30817	0	100%	1	0	1	0
Jun-78	74.0	3700	34517	7608	26908	26908	0	100%	1	0	1	0
Jul-78	59.0	2950	29858	7608	22250	22250	0	100%	1	0	1	0
Aug-78	70.0	3500	25750	7608	18142	18142	0	100%	1	0	1	0
Sep-78	10.0	500	18642	7608	11033	11033	0	100%	1	0	1	0
Oct-78	4.0	200	11233	7608	3625	3625	0	100%	1	0	1	0
Nov-78	66.0	3300	6925	7608	-683	0	0	91%	0	1	1	0
Dec-78	231.0	11550	11550	7608	3942	3942	0	100%	1	0	1	0
Jan-79	215.0	10750	14692	7608	7083	7083	0	100%	1	0	1	0
Feb-79	458.0	22900	29983	7608	22375	22375	0	100%	1	0	1	0
Mar-79	534.0	26700	49075	7608	41467	41467	0	100%	1	0	1	0
Apr-79	99.0	4950	46417	7608	38808	38808	0	100%	1	0	1	0
May-79	214.0	10700	49508	7608	41900	41900	0	100%	1	0	1	0
Jun-79	251.0	12550	54450	7608	46842	46842	0	100%	1	0	1	0
Jul-79	141.0	7050	53892	7608	46283	46283	0	100%	1	0	1	0
Aug-79	170.0	8500	54783	7608	47175	47175	0	100%	1	0	1	0
Sep-79	50.0	2500	49675	7608	42067	42067	0	100%	1	0	1	0

Oct-79	143.0	7150	49217	7608	41608	41608	0	100%	1	0	1	0
Nov-79	286.0	14300	55908	7608	48300	48300	0	100%	1	0	1	0
Dec-79	404.0	20200	68500	7608	60892	50000	10892	100%	1	0	1	0
Jan-80	376.0	18800	68800	7608	61192	50000	11192	100%	1	0	1	0
Feb-80	120.0	6000	56000	7608	48392	48392	0	100%	1	0	1	0
Mar-80	474.0	23700	72092	7608	64483	50000	14483	100%	1	0	1	0
Apr-80	245.0	12250	62250	7608	54642	50000	4642	100%	1	0	1	0
May-80	234.0	11700	61700	7608	54092	50000	4092	100%	1	0	1	0
Jun-80	203.0	10150	60150	7608	52542	50000	2542	100%	1	0	1	0
Jul-80	272.0	13600	63600	7608	55992	50000	5992	100%	1	0	1	0
Aug-80	305.0	15250	65250	7608	57642	50000	7642	100%	1	0	1	0
Sep-80	183.0	9150	59150	7608	51542	50000	1542	100%	1	0	1	0
Oct-80	295.0	14750	64750	7608	57142	50000	7142	100%	1	0	1	0
Nov-80	218.0	10900	60900	7608	53292	50000	3292	100%	1	0	1	0
Dec-80	397.0	19850	69850	7608	62242	50000	12242	100%	1	0	1	0
Mar-81	77.0	3850	53850	7608	46242	46242	0	100%	1	0	1	0
Apr-81	324.0	16200	62442	7608	54833	50000	4833	100%	1	0	1	0
May-81	275.0	13750	63750	7608	56142	50000	6142	100%	1	0	1	0
Jun-81	183.0	9150	59150	7608	51542	50000	1542	100%	1	0	1	0
Jul-81	68.0	3400	53400	7608	45792	45792	0	100%	1	0	1	0
Aug-81	32.0	1600	47392	7608	39783	39783	0	100%	1	0	1	0
Sep-81	59.0	2950	42733	7608	35125	35125	0	100%	1	0	1	0
Oct-81	17.0	850	35975	7608	28367	28367	0	100%	1	0	1	0
Nov-81	160.0	8000	36367	7608	28758	28758	0	100%	1	0	1	0
Dec-81	417.0	20850	49608	7608	42000	42000	0	100%	1	0	1	0
Jan-82	26.0	1300	43300	7608	35692	35692	0	100%	1	0	1	0
Feb-82	146.0	7300	42992	7608	35383	35383	0	100%	1	0	1	0
Mar-82	131.0	6550	41933	7608	34325	34325	0	100%	1	0	1	0
Apr-82	224.0	11200	45525	7608	37917	37917	0	100%	1	0	1	0
May-82	118.0	5900	43817	7608	36208	36208	0	100%	1	0	1	0
Jun-82	83.0	4150	40358	7608	32750	32750	0	100%	1	0	1	0
Jul-82	401.0	20050	52800	7608	45192	45192	0	100%	1	0	1	0
Aug-82	274.0	13700	58892	7608	51283	50000	1283	100%	1	0	1	0
Sep-82	132.0	6600	56600	7608	48992	48992	0	100%	1	0	1	0
Oct-82	220.0	11000	59992	7608	52383	50000	2383	100%	1	0	1	0
Nov-82	253.0	12650	62650	7608	55042	50000	5042	100%	1	0	1	0
Dec-82	197.0	9850	59850	7608	52242	50000	2242	100%	1	0	1	0
Jan-83	47.0	2350	52350	7608	44742	44742	0	100%	1	0	1	0

Feb-83	77.0	3850	48592	7608	40983	40983	0	100%	1	0	1	0
Mar-83	55.0	2750	43733	7608	36125	36125	0	100%	1	0	1	0
Apr-83	63.0	3150	39275	7608	31667	31667	0	100%	1	0	1	0
May-83	601.0	30050	61717	7608	54108	50000	4108	100%	1	0	1	0
Jun-83	319.0	15950	65950	7608	58342	50000	8342	100%	1	0	1	0
Jul-83	200.0	10000	60000	7608	52392	50000	2392	100%	1	0	1	0
Aug-83	92.0	4600	54600	7608	46992	46992	0	100%	1	0	1	0
Sep-83	0.0	0	46992	7608	39383	39383	0	100%	1	0	1	0
Oct-83	70.0	3500	42883	7608	35275	35275	0	100%	1	0	1	0
Nov-83	6.0	300	35575	7608	27967	27967	0	100%	1	0	1	0
Dec-83	33.0	1650	29617	7608	22008	22008	0	100%	1	0	1	0
Jan-84	72.0	3600	25608	7608	18000	18000	0	100%	1	0	1	0
Feb-84	49.0	2450	20450	7608	12842	12842	0	100%	1	0	1	0
Mar-84	71.0	3550	16392	7608	8783	8783	0	100%	1	0	1	0
Apr-84	98.0	4900	13683	7608	6075	6075	0	100%	1	0	1	0
May-84	106.0	5300	11375	7608	3767	3767	0	100%	1	0	1	0
Jun-84	104.0	5200	8967	7608	1358	1358	0	100%	1	0	1	0
Jul-84	88.0	4400	5758	7608	-1850	0	0	76%	0	1	1	0
Aug-84	37.0	1850	1850	7608	-5758	0	0	24%	0	2	0	1
Sep-84	0.0	0	0	7608	-7608	0	0	0%	0	3	0	2
Oct-84	103.0	5150	5150	7608	-2458	0	0	68%	0	4	1	0
Nov-84	17.0	850	850	7608	-6758	0	0	11%	0	5	0	1
Dec-84	105.0	5250	5250	7608	-2358	0	0	69%	0	6	1	0
Jan-85	11.0	550	550	7608	-7058	0	0	7%	0	7	0	1
Feb-85	35.0	1750	1750	7608	-5858	0	0	23%	0	8	0	2
Mar-85	80.0	4000	4000	7608	-3608	0	0	53%	0	9	0	3
Apr-85	66.0	3300	3300	7608	-4308	0	0	43%	0	10	0	4
May-85	44.0	2200	2200	7608	-5408	0	0	29%	0	11	0	5
Jun-85	62.0	3100	3100	7608	-4508	0	0	41%	0	12	0	6
Jul-85	57.0	2850	2850	7608	-4758	0	0	37%	0	13	0	7
Aug-85	65.0	3250	3250	7608	-4358	0	0	43%	0	14	0	8
Oct-85	60.0	3000	3000	7608	-4608	0	0	39%	0	15	0	9
Nov-85	54.0	2700	2700	7608	-4908	0	0	35%	0	16	0	10
Dec-85	147.0	7350	7350	7608	-258	0	0	97%	0	17	1	0
Jan-86	216.0	10800	10800	7608	3192	3192	0	100%	1	0	1	0
Feb-86	78.0	3900	7092	7608	-517	0	0	93%	0	1	1	0
Mar-86	31.0	1550	1550	7608	-6058	0	0	20%	0	2	0	1
Apr-86	112.0	5600	5600	7608	-2008	0	0	74%	0	3	1	0

May-86	25.0	1250	1250	7608	-6358	0	0	16%	0	4	0	1
Jun-86	73.0	3650	3650	7608	-3958	0	0	48%	0	5	0	2
Jul-86	125.0	6250	6250	7608	-1358	0	0	82%	0	6	1	0
Aug-86	80.0	4000	4000	7608	-3608	0	0	53%	0	7	0	1
Sep-86	141.0	7050	7050	7608	-558	0	0	93%	0	8	1	0
Oct-86	246.0	12300	12300	7608	4692	4692	0	100%	1	0	1	0
Nov-86	301.0	15050	19742	7608	12133	12133	0	100%	1	0	1	0
Dec-86	415.0	20750	32883	7608	25275	25275	0	100%	1	0	1	0
Jan-87	263.0	13150	38425	7608	30817	30817	0	100%	1	0	1	0
Feb-87	356.0	17800	48617	7608	41008	41008	0	100%	1	0	1	0
Mar-87	401.0	20050	61058	7608	53450	50000	3450	100%	1	0	1	0
Apr-87	411.0	20550	70550	7608	62942	50000	12942	100%	1	0	1	0
May-87	388.0	19400	69400	7608	61792	50000	11792	100%	1	0	1	0
Jun-87	257.0	12850	62850	7608	55242	50000	5242	100%	1	0	1	0
Jul-87	436.0	21800	71800	7608	64192	50000	14192	100%	1	0	1	0
Aug-87	344.0	17200	67200	7608	59592	50000	9592	100%	1	0	1	0
Sep-87	181.0	9050	59050	7608	51442	50000	1442	100%	1	0	1	0
Oct-87	152.0	7600	57600	7608	49992	49992	0	100%	1	0	1	0
Nov-87	153.0	7650	57642	7608	50033	50000	33	100%	1	0	1	0
Dec-87	193.0	9650	59650	7608	52042	50000	2042	100%	1	0	1	0
Jan-88	400.0	20000	70000	7608	62392	50000	12392	100%	1	0	1	0
Feb-88	338.0	16900	66900	7608	59292	50000	9292	100%	1	0	1	0
Mar-88	421.0	21050	71050	7608	63442	50000	13442	100%	1	0	1	0
Apr-88	106.0	5300	55300	7608	47692	47692	0	100%	1	0	1	0
May-88	219.0	10950	58642	7608	51033	50000	1033	100%	1	0	1	0
Jun-88	122.0	6100	56100	7608	48492	48492	0	100%	1	0	1	0
Jul-88	15.0	750	49242	7608	41633	41633	0	100%	1	0	1	0
Aug-88	34.0	1700	43333	7608	35725	35725	0	100%	1	0	1	0
Sep-88	8.0	400	36125	7608	28517	28517	0	100%	1	0	1	0
Oct-88	19.0	950	29467	7608	21858	21858	0	100%	1	0	1	0
Nov-88	3.0	150	22008	7608	14400	14400	0	100%	1	0	1	0
Mar-91	183.0	9150	23550	7608	15942	15942	0	100%	1	0	1	0
Apr-91	79.0	3950	19892	7608	12283	12283	0	100%	1	0	1	0
May-91	205.0	10250	22533	7608	14925	14925	0	100%	1	0	1	0
Jun-91	270.0	13500	28425	7608	20817	20817	0	100%	1	0	1	0
Jul-91	120.0	6000	26817	7608	19208	19208	0	100%	1	0	1	0
Aug-91	344.0	17200	36408	7608	28800	28800	0	100%	1	0	1	0
Sep-91	418.0	20900	49700	7608	42092	42092	0	100%	1	0	1	0

Oct-91	243.0	12150	54242	7608	46633	46633	0	100%	1	0	1	0
Nov-91	379.0	18950	65583	7608	57975	50000	7975	100%	1	0	1	0
Dec-91	315.0	15750	65750	7608	58142	50000	8142	100%	1	0	1	0
Jan-92	230.0	11500	61500	7608	53892	50000	3892	100%	1	0	1	0
Feb-92	333.0	16650	66650	7608	59042	50000	9042	100%	1	0	1	0
Mar-92	330.0	16500	66500	7608	58892	50000	8892	100%	1	0	1	0
Apr-92	418.0	20900	70900	7608	63292	50000	13292	100%	1	0	1	0
May-92	200.0	10000	60000	7608	52392	50000	2392	100%	1	0	1	0
Sep-99	32.0	1600	51600	7608	43992	43992	0	100%	1	0	1	0
Oct-99	50.0	2500	46492	7608	38883	38883	0	100%	1	0	1	0
Nov-99	63.0	3150	42033	7608	34425	34425	0	100%	1	0	1	0
Dec-99	74.0	3700	38125	7608	30517	30517	0	100%	1	0	1	0
Jan-00	180.0	9000	39517	7608	31908	31908	0	100%	1	0	1	0
Feb-00	41.0	2050	33958	7608	26350	26350	0	100%	1	0	1	0
Mar-00	152.0	7600	33950	7608	26342	26342	0	100%	1	0	1	0
Apr-00	105.0	5250	31592	7608	23983	23983	0	100%	1	0	1	0
May-00	149.0	7450	31433	7608	23825	23825	0	100%	1	0	1	0
Jun-00	94.0	4700	28525	7608	20917	20917	0	100%	1	0	1	0
Jul-00	187.0	9350	30267	7608	22658	22658	0	100%	1	0	1	0
Aug-00	114.0	5700	28358	7608	20750	20750	0	100%	1	0	1	0
Sep-00	85.0	4250	25000	7608	17392	17392	0	100%	1	0	1	0
Oct-00	149.0	7450	24842	7608	17233	17233	0	100%	1	0	1	0
Nov-00	195.0	9750	26983	7608	19375	19375	0	100%	1	0	1	0
Dec-00	109.0	5450	24825	7608	17217	17217	0	100%	1	0	1	0
Jan-01	167.0	8350	25567	7608	17958	17958	0	100%	1	0	1	0
Feb-01	166.0	8300	26258	7608	18650	18650	0	100%	1	0	1	0
Mar-01	259.0	12950	31600	7608	23992	23992	0	100%	1	0	1	0
Apr-01	208.0	10400	34392	7608	26784	26784	0	100%	1	0	1	0
May-01	386.0	19300	46084	7608	38475	38475	0	100%	1	0	1	0
Jun-01	183.0	9150	47625	7608	40017	40017	0	100%	1	0	1	0
Jul-01	381.0	19050	59067	7608	51459	50000	1459	100%	1	0	1	0
Aug-01	253.0	12650	62650	7608	55042	50000	5042	100%	1	0	1	0
Sep-01	143.0	7150	57150	7608	49542	49542	0	100%	1	0	1	0
Oct-01	77.0	3850	53392	7608	45783	45783	0	100%	1	0	1	0
Nov-01	269.0	13450	59233	7608	51625	50000	1625	100%	1	0	1	0
Dec-01	381.0	19050	69050	7608	61442	50000	11442	100%	1	0	1	0
Jan-02	705.0	35250	85250	7608	77642	50000	27642	100%	1	0	1	0
Feb-02	491.0	24550	74550	7608	66942	50000	16942	100%	1	0	1	0

Mar-02	542.0	27100	77100	7608	69492	50000	19492	100%	1	0	1	0
Apr-02	279.0	13950	63950	7608	56342	50000	6342	100%	1	0	1	0
May-02	189.0	9450	59450	7608	51842	50000	1842	100%	1	0	1	0
Jun-02	420.0	21000	71000	7608	63392	50000	13392	100%	1	0	1	0
Jul-02	163.0	8150	58150	7608	50542	50000	542	100%	1	0	1	0
Aug-02	458.0	22900	72900	7608	65292	50000	15292	100%	1	0	1	0
Sep-02	260.0	13000	63000	7608	55392	50000	5392	100%	1	0	1	0
Oct-02	353.0	17650	67650	7608	60042	50000	10042	100%	1	0	1	0
Nov-02	343.0	17150	67150	7608	59542	50000	9542	100%	1	0	1	0
Dec-02	365.0	18250	68250	7608	60642	50000	10642	100%	1	0	1	0
Jan-03	720.0	36000	86000	7608	78392	50000	28392	100%	1	0	1	0
Feb-03	353.0	17650	67650	7608	60042	50000	10042	100%	1	0	1	0
Mar-03	549.0	27450	77450	7608	69842	50000	19842	100%	1	0	1	0
Apr-03	125.0	6250	56250	7608	48642	48642	0	100%	1	0	1	0
May-03	125.0	6250	54892	7608	47283	47283	0	100%	1	0	1	0
Jun-03	184.0	9200	56483	7608	48875	48875	0	100%	1	0	1	0
Jul-03	153.0	7650	56525	7608	48917	48917	0	100%	1	0	1	0
Jan-04	150.3	7515	56432	7608	48823	48823	0	100%	1	0	1	0
Feb-04	107.3	5365	54188	7608	46580	46580	0	100%	1	0	1	0
Mar-04	289.0	14450	61030	7608	53422	50000	3422	100%	1	0	1	0
Apr-04	130.0	6500	56500	7608	48892	48892	0	100%	1	0	1	0
May-04	75.2	3760	52652	7608	45043	45043	0	100%	1	0	1	0
Jun-04	399.8	19990	65033	7608	57425	50000	7425	100%	1	0	1	0
Jul-04	155.62	7781	57781	7608	50173	50000	173	100%	1	0	1	0
Aug-04	195.9	9795	59795	7608	52187	50000	2187	100%	1	0	1	0
Sep-04	192.3	9615	59615	7608	52007	50000	2007	100%	1	0	1	0
Oct-04	152.6	7630	57630	7608	50022	50000	22	100%	1	0	1	0
Nov-04	0.0	0	50000	7608	42392	42392	0	100%	1	0	1	0
Dec-04	0.0	0	42392	7608	34783	34783	0	100%	1	0	1	0
Jan-05	310.6	15530	50313	7608	42705	42705	0	100%	1	0	1	0
Feb-05	264.54	13227	55932	7608	48324	48324	0	100%	1	0	1	0
Mar-05	293.6	14680	63004	7608	55395	50000	5395	100%	1	0	1	0
Apr-05	380.6	19030	69030	7608	61422	50000	11422	100%	1	0	1	0
May-05	224.5	11225	61225	7608	53617	50000	3617	100%	1	0	1	0
Jun-05	384.9	19245	69245	7608	61637	50000	11637	100%	1	0	1	0
Jul-05	243.4	12170	62170	7608	54562	50000	4562	100%	1	0	1	0

Aug-05	287.1	14355	64355	7608	56747	50000	6747	100%	1	0	1	0
Sep-05	0.0	0	50000	7608	42392	42392	0	100%	1	0	1	0
Oct-05	0.0	0	42392	7608	34783	34783	0	100%	1	0	1	0
Nov-05	0.0	0	34783	7608	27175	27175	0	100%	1	0	1	0
Dec-05	0.0	0	27175	7608	19567	19567	0	100%	1	0	1	0
Jan-06	32.9	1645	21212	7608	13603	13603	0	100%	1	0	1	0
Feb-06	24.8	1240	14843	7608	7235	7235	0	100%	1	0	1	0
Mar-06	31.3	1565	8800	7608	1192	1192	0	100%	1	0	1	0
Apr-06	240.6	12030	13222	7608	5613	5613	0	100%	1	0	1	0
May-06	132.1	6605	12218	7608	4610	4610	0	100%	1	0	1	0
Jun-06	74.4	3720	8330	7608	722	722	0	100%	1	0	1	0
Jul-06	168.9	8445	9167	7608	1558	1558	0	100%	1	0	1	0
Aug-06	159.9	7997	9555	7608	1947	1947	0	100%	1	0	1	0
Sep-06	162.6	8130	10077	7608	2468	2468	0	100%	1	0	1	0
Oct-06	511.0	25550	28018	7608	20410	20410	0	100%	1	0	1	0
Nov-06	54.4	2720	23130	7608	15522	15522	0	100%	1	0	1	0
Dec-06	139.4	6970	22492	7608	14883	14883	0	100%	1	0	1	0
Jan-11	20.4	1020	15903	7608	8295	8295	0	100%	1	0	1	0
Feb-11	9.7	485	8780	7608	1172	1172	0	100%	1	0	1	0
Mar-11	0.0	0	1172	7608	-6437	0	0	15%	0	1	0	1
Apr-11	114.0	5700	5700	7608	-1908	0	0	75%	0	2	1	0
May-11	299.4	14970	14970	7608	7362	7362	0	100%	1	0	1	0
Jun-11	246.1	12305	19667	7608	12058	12058	0	100%	1	0	1	0
Jul-11	381.4	19070	31128	7608	23520	23520	0	100%	1	0	1	0
Aug-11	109.9	5495	29015	7608	21407	21407	0	100%	1	0	1	0
Sep-11	343.0	17150	38557	7608	30948	30948	0	100%	1	0	1	0
Oct-11	93.2	4660	35608	7608	28000	28000	0	100%	1	0	1	0
Nov-11	44.4	2220	30220	7608	22612	22612	0	100%	1	0	1	0
Dec-11	48.0	2400	25012	7608	17403	17403	0	100%	1	0	1	0
Jan-12	208.4	10420	27823	7608	20215	20215	0	100%	1	0	1	0
Feb-12	21.0	1050	21265	7608	13657	13657	0	100%	1	0	1	0
Mar-12	112.5	5625	19282	7608	11673	11673	0	100%	1	0	1	0
Apr-12	187.6	9380	21053	7608	13445	13445	0	100%	1	0	1	0
May-12	132.4	6620	20065	7608	12457	12457	0	100%	1	0	1	0
Jun-12	159.5	7975	20432	7608	12823	12823	0	100%	1	0	1	0
Jul-12	221.4	11070	23893	7608	16285	16285	0	100%	1	0	1	0
Aug-12	255.4	12770	29055	7608	21447	21447	0	100%	1	0	1	0
Sep-12	248.8	12440	33887	7608	26278	26278	0	100%	1	0	1	0

Oct-12	64.0	3200	29478	7608	21870	21870	0	100%	1	0	1	0
Nov-12	172.6	8630	30500	7608	22892	22892	0	100%	1	0	1	0
Dec-12	178.2	8910	31802	7608	24194	24194	0	100%	1	0	1	0
Jan-13	175.4	8770	32964	7608	25355	25355	0	100%	1	0	1	0
Feb-13	88.6	4430	29785	7608	22177	22177	0	100%	1	0	1	0
Mar-13	98.0	4900	27077	7608	19469	19469	0	100%	1	0	1	0
Apr-13	269.0	13450	32919	7608	25310	25310	0	100%	1	0	1	0
May-13	127.4	6370	31680	7608	24072	24072	0	100%	1	0	1	0
Jun-13	23.6	1180	25252	7608	17644	17644	0	100%	1	0	1	0
Jul-13	63.6	3180	20824	7608	13215	13215	0	100%	1	0	1	0
Aug-13	52.8	2640	15855	7608	8247	8247	0	100%	1	0	1	0
Sep-13	231.8	11590	19837	7608	12229	12229	0	100%	1	0	1	0
Oct-13	149.6	7480	19709	7608	12100	12100	0	100%	1	0	1	0
Nov-13	46.0	2300	14400	7608	6792	6792	0	100%	1	0	1	0
Dec-13	74.0	3700	10492	7608	2884	2884	0	100%	1	0	1	0
Jan-14	251.1	12555	15439	7608	7830	7830	0	100%	1	0	1	0
Feb-14	73.8	3690	11520	7608	3912	3912	0	100%	1	0	1	0
Mar-14	317.4	15870	19782	7608	12174	12174	0	100%	1	0	1	0
Apr-14	441.2	22060	34234	7608	26625	26625	0	100%	1	0	1	0
May-14	215.8	10790	37415	7608	29807	29807	0	100%	1	0	1	0

Note: Runoff coefficient (C) of 1 was used because the calculation of roof catchment suggested by White (2014) and adopted in this analysis already accounts for the guttering condition and assigns a guttering coefficient range of 0 - 0.75, with 0.75 representing good condition.

Table A10-3. RWH potential of surveyed communal buildings in relation to meeting current and future village drinking water demands.

Building Location			Catchment characteristics										Projected supporting population at 5L/pers/day		
Village	Building Type	Owner	Roof area (m^2)	Building ID	Percentage of roof covered by gutters	Collecting Roof Area (m^2)	Gutter Condition	Gutter Efficiency	Effective Roof Area (m^2)	Improved Roof Area (m)	Rain Tank Capacity (L)	Population	RWH capacity under current catchment conditions (L/p/d)	RWH capacity under current and improved catchment conditions	RWH capacity with roof improvements and increased storage 20,000 L
Aonobuaka	*Maneaba*	Church	199.2	An1	50%	99.6	Adequate	0.55	55	149	5000	2010 (328)	0.65	1.5	2
												2030 (396)	0.55	1.25	1.7
Aonobuaka	Church	KPC	70.55	An2	50%	35.28	Replace	0.15	5	53	5000	2010 (328)	0.1	0.65	0.88
												2030 (396)	0.08	0.52	0.74
Aonobuaka Total									60	202	10,000	2010 (328)	0.83	2.2	3
												2030 (396)	0.69	1.8	2.5
Ewena	Church	KPC church	219.35	Ew1	50%	109.68	Good	0.75	82	165	10,000	2010 (166)	2.1	3.6	4.5
												2030 (141)	2.4	4.2	5.2
Ewena	*Maneaba*	Church	220.8	Ew2	50%	110.4	Good	0.75	83	166	10,000	2010 (166)	2.1	3.6	4.5
												2030 (141)	2.4	4.2	5.2
Ewena	Church	Catholic church	154.84	Ew3	50%	77.42	Good	0.75	58	116	5000	2010 (166)	1.35	2.4	3.3
												2030 (141)	1.6	2.8	3.8
Ewena Total									223	446	25,000	2010 (166)	5.7	10	12.6
												2030 (141)	6.7	11.8	14.8
Ribono	Church	Catholic church	376.6	Ri1	50%	188.3	Good	0.75	141	282	10,000	2010 (341)	1.55	2.8	3.4
												2030 (414)	1.3	2.3	2.8
Taniau	Church	Catholic priest	126	Ta1	<25%	25.2	Adequate	0.55	14	95	5000	2010 (310)	0.23	1.1	1.5
												2030 (392)	0.18	0.88	1.2
Taniau	*Maneaba*	Catholic church	140	Ta2	None	0	None	0	0	105	5000	2010 (310)	0	1.2	1.65
												2030 (392)	0	0.95	1.3
Taniau	Church	KPC church	65.32	Ta3	None	0	None	0	0	49	5000	2010 (310)	0	0.6	0.86
												2030 (392)	0	0.5	0.61
Taniau Total									155	531	25,000	2010 (310)	2.2	6.2	7.7
												2030 (392)	1.75	4.9	6.1

Tebunginako	*Maneaba*	*Maneaba*	508.26	Te1	50%	254.13	Good	0.75	191	381	10,000	2010 (424)	1.6	2.9	3.5
												2030 (402)	1.7	3	3.7
Tebunginako	Church	Old church	248.52	Te2	50%	124.26	Good	0.75	93	186	0	2010 (424)	0	0	1.8
												2030 (402)	0	0	1.9
Tebunginako Total									284	568	10,000	2010 (424)	2.3	4.2	5.4
												2030 (402)	2.4	4.4	5.6
Tuarabu	Church	LDS	161.5	Tu1	100%	161.5	Good	0.75	121	121	5000	2010 (560)	0.75	0.75	1
												2030 (645)	0.65	0.65	0.88
Tuarabu	Government	Airport terminal	58.5	Tu2	None	0	None	0	0	44	0	2010 (560)	0	0	0.42
												2030 (645)	0	0	0.36
Tuarabu	*Maneaba*	Catholic church	403	Tu3	50%	201.5	Adequate	0.55	111	302	1000	2010 (560)	0.77	1.8	2.2
												2030 (645)	0.67	1.55	1.9
Tuarabu Total									232	467	6000	2010 (560)	1.35	2.5	3.6
												2030 (645)	1.15	2.2	3.2

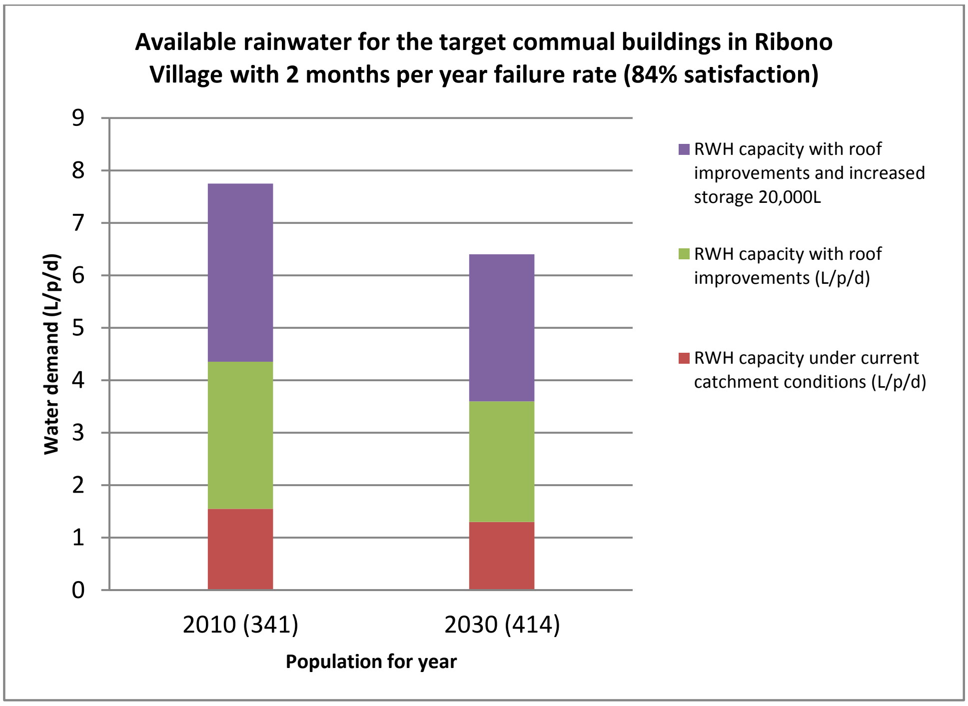


Figure A10-1. Analysis of the target communal buildings in Ribono Village.

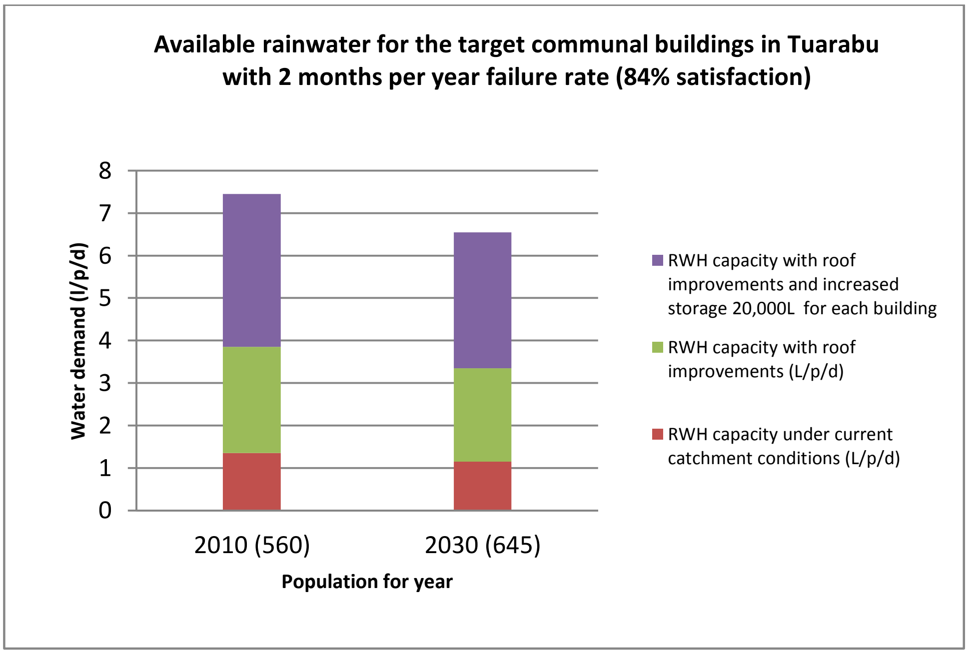


Figure A10-2. Analysis of the target communal buildings in Tuarabu Village.

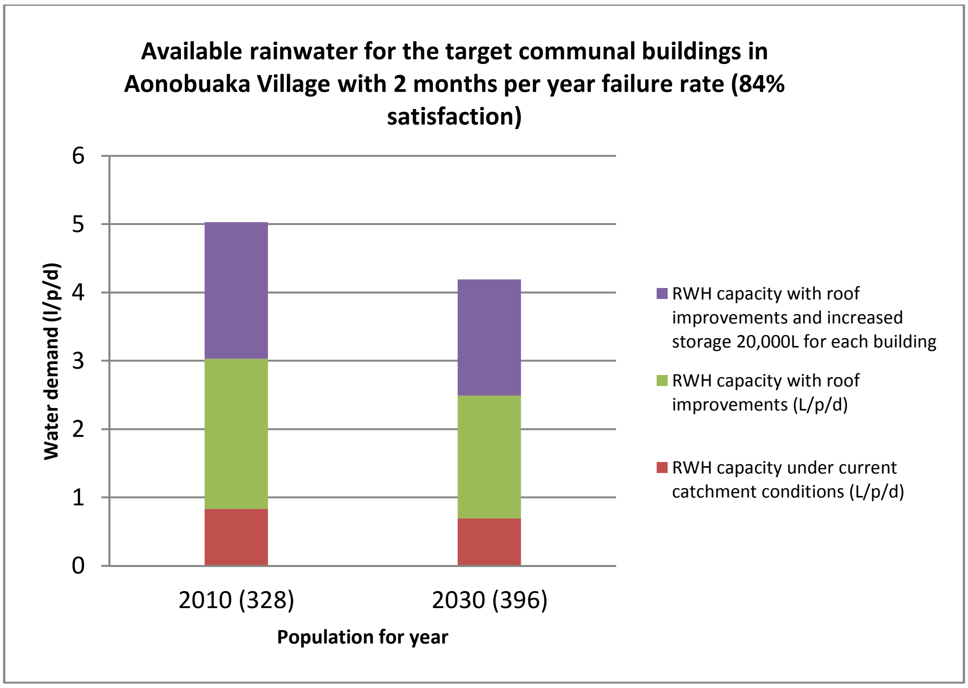


Figure A10-3. Analysis of the target communal buildings in Aonobuaka Village.

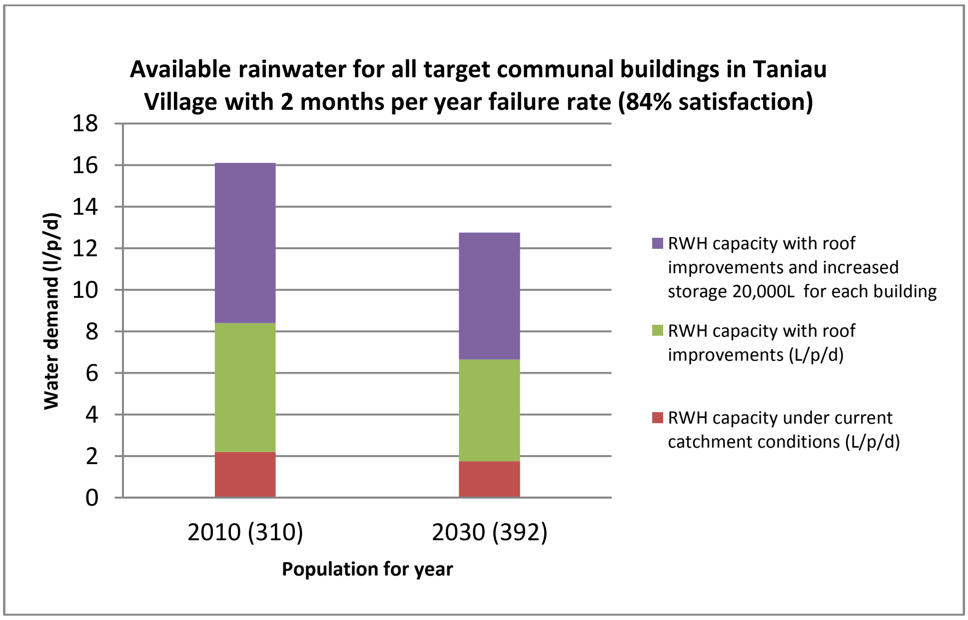


Figure A10-4. Analysis of the target communal buildings in Taniau Village.

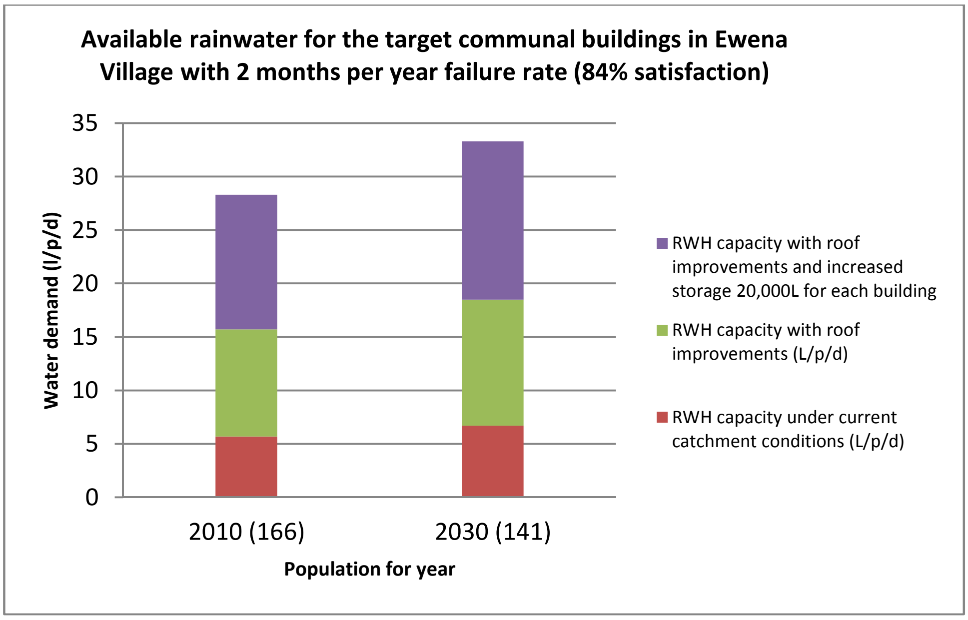


Figure A10-5. Analysis of the target communal buildings in Ewena Village.

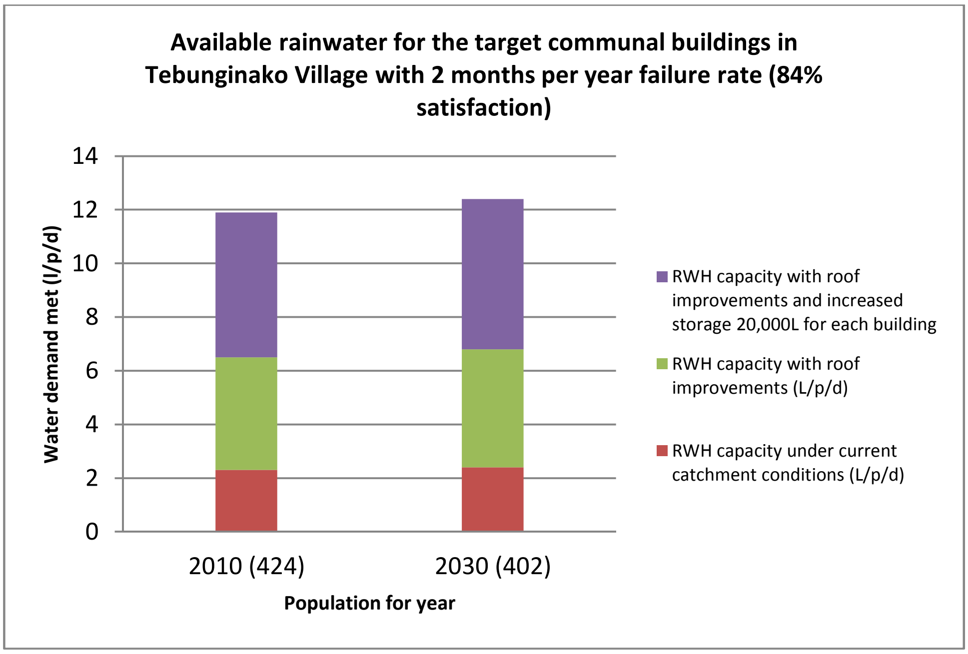


Figure A10-6. Analysis of the target communal buildings in Tebunginako Village.

Table A10-4. Analysis of varying roof catchment area (improved condition) with increasing storage volume (L) based on a fixed demand of 100 people with 2 months per year failure rate (or 84% satisfaction).

Roof Catchment (m^2)	5000 L	10,000 L	15,000 L	20,000 L	25,000 L	30,000 L
50	2	2.3	2.5	2.7	2.8	2.9
100	3.6	4	4.4	4.7	4.9	5
150	5	5.6	6	6.4	6.8	7
200	6.5	7.2	7.8	8.2	8.5	8.7
250	8	8.5	9.2	9.8	10.3	10.5
300	9.2	10.3	11	11.5	11.8	12
350	10.8	11.7	12.5	13	13.5	14
400	12	13	14	14.5	15	15.4
450	13	14	15	16	16.5	17
500	14.5	16	16.9	17.6	18	18.5

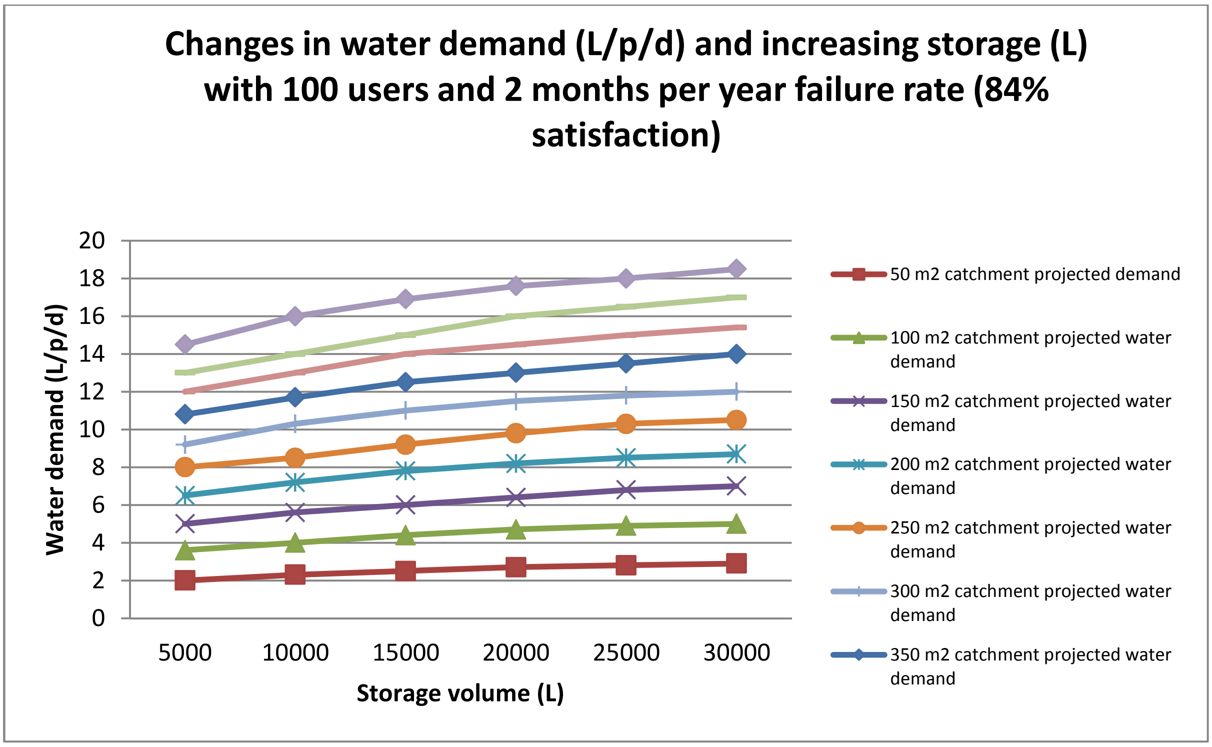


Figure A10-7. Analysis of changing water demand on varying roof catchment area based on a fixed number of users and 84% satisfaction.

Annex 11

Village Meeting Notes from Abaiang

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

Table A11-1. Village meeting notes from Tuarabu and Taniau.

Village	Date	Number of present	Issues raised	WRA team's response
Tuarabu	19/03/2013	• 22 men • 3 women	• St Paul head-master requested if project can provide a solar panel as the school well is no longer used due to stolen solar panel – this resulted in a heated argument between the teacher and the village councillor as the latter believed that the meeting was about village needs, whilst the Ministry of Education should be approached for School needs. • Will the project provide roofing for rainwater harvesting on household basis.	• It was highlighted that it is the community is responsible for the protection and management of water supply facilities. • Project will provide a wide-range of RWH facilities and assistance is likely to be focussed on communal buildings.
Taniau	21/03/2013	• 18 men • 9 women	• The villages enquired about the survey findings. • The separation distance between drinking water sources enquired. • Communities require well rings and toilet pans, as most of the families are still defecating in the bush and beach. • What should communities do to ensure that drinking water is safe for drinking?	• Summary of well assessment, water quality, RWH assessment and EM-survey findings were presented. • 25 m was reminded as the recommended separation distance. • Village was reminded that the project will provide some well infrastructural assistance and sanitation facilities in phase II. • The continued boiling of all drinking water is the practical solution to improve water safety.

- Note that the meeting at Ribono Village did not eventuate due to pre-arranged communal functions on both 8th and 9th February, whilst members of Ewena, Tebunginako and Aonobuaka villages did not come to the agreed venues and at the scheduled times set by the village councillors, possibly due to engagement with other communal activities.
- The meeting was primarily designed as an information exchange forum where preliminary WRA findings were presented back to the villagers, whilst the community members had a chance to raise prevalent water resources and sanitation issues.
- Even though some discussions were conducted, the general need was made known to those in attendance on the community-driven management and governance mechanisms. More effort will be needed to ensure the community's awareness and support of this approach for the sustainability of water resources and sanitation infrastructural systems.

Annex 12

Selected Survey Photos from Abaiang and Bonriki

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 Abaiang at the time of the assessment (8-22 March 2013).

The first two photos show the EM34 calibration and salinity measurements being conducted in Bonriki several days prior to the Abaiang survey – basically the calibration formula or relationship between the groundwater thickness (from salinity measurements) and EM34 values attained from the Bonriki exercise were later used to convert the Abaiang EM34 readings to a freshwater lens thickness estimate (Annex 8) assuming similar geological and climatic conditions).

Figure A12-1. Salinity monitoring at the Bonriki Water Reserve through pumping.

Figure A12-2. Preparing for EM34 calibration adjacent to a selected bore in the Bonriki Water Reserve where salinity measurements have been recorded through pipes installed at various aquifer depths.

Figure A12-3: EM34 field measurements on Ribono islet, with coral reef rocks partly exposed along the survey transect.

Figure A12-4. Ribono Catholic Church, a potential rainwater harvesting centre, with considerable infrastructural improvements needed.

Figure A12-5. Two polyethylene tanks connected to the Ribono Catholic Church roof catchment, which has around 50 % guttering coverage.

Figure A12-6. The Ribono Primary School well, which was reported to have a damaged submersible pump and stolen solar panels. Elevated 2,000 L polyethylene storage tank, in the background, in a good condition.

Figure A12-7. EM34 geophysical survey in Tebunginako near a* bwabwai *pit.

Figure A12-8. Household well using concrete blocks as casing material, with no apron.

Figure A12-9. Household well using concrete rings and concrete lid and a poly-pipe connected to a pump – the well can be improved by installing concrete aprons.

Figure A12-10. Brief consultation meeting with Taiwan Primary School teachers in the school staff room, near Tebunginako Village.

Figure A12-11. Brief consultation meeting with Junior Secondary School teachers and committee in the school **maneaba** ***near Aonobuaka Village.***

Figure A12-12. Solar pump system serving the entire St Joseph College school community, including the classrooms, hostels and staff quarters. There are reports that the well capacity is insufficient for the current demand and experiences elevated salinity during dry periods.

Figure A12-13. A maneaba *at St Joseph College – representing a potential RWH centre.*

Figure A12-14. Casual labourers assisting in the groundwater well assessment.

Figure A12-15. Island Water Technician, Matanterawa Tebaai, assisting in the RWH assessment of a building in Tuarabu Village.

Figure A12-16. Household well owner and casual labourer standing atop a completely covered well, only accessed by **Tamana** ***pumps.***

Figure A12-17. Household well in Taniau showing coral rock casing, coral gravel parapet, and the use of the **Tamana** *pump, with the distribution line resting on a plastic container.*

Figure A12-18. Village consultation meeting at Tuarabu Village, which was dominated by men.

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