Bonriki Inundation Vulnerability Assessment

Groundwater Field Investigations
Bonriki Water Reserve, South Tarawa, Kiribati

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Acknowledgements

The Bonriki Inundation Vulnerability Assessment project is part of the Australian government's Pacific–Australia Climate Change Science and Adaptation Planning Program, within the International Climate Change Adaptation Initiative. The project was developed by the Geoscience Division of the Secretariat of the Pacific Community in partnership with the Australian government and the Government of Kiribati GoK.

Key Government of Kiribati stakeholders that contributed to the implementation of the project were:

- Ministry of Public Works and Utilities (MPWU), in particular the Water Engineering Unit within the MPWU;
- The Public Utilities Board (PUB), in particular the Water and Sanitation Division and the Customer Relations Division within the PUB;
- The Office of the President, in particular the Disaster Management Office;
- The Ministry of Environment, Lands and Agricultural Development Lands Division;
- The Ministry of Fisheries and Marine Resources Development Minerals Division; and
- members of the Kiribati National Expert Group on climate change and disaster risk management.

Bonriki Village community members also played a key role in implementing the project. Community members participated in the school water science and mapping programme, assisted with construction of new piezometers and data collection for the groundwater component, and shared their knowledge and experiences with regards to historical inundation events and coastal processes.

Key technical advisors involved with project implementation included:

- Flinders University, Adelaide, Australia;
- University of Western Australia, Perth, Australia;
- University of Auckland, Auckland, New Zealand;
- United Nations Educational, Scientific and Cultural Organization, Institute for Water Education, Delft, the Netherlands; and
- Tony Falkland (Atoll Groundwater Specialist - Island Hydrology Services and Ian White (Atoll Groundwater Policy and Community Consultation).

Abbreviations

GoK	Government of Kiribati
MFMRD	Ministry of Lands Fisheries and Mineral Resources Department
MPWU	Ministry of Public Works and Utilities
KAP	Kiribati Adaptation Program
PACCSAP	Pacific–Australia Climate Change Science and Adaptation Planning Program
PUB	Public Utilities Board
SPC	Secretariat of the Pacific Community
UFM	ultrasonic flow meter

1. Introduction

1.1. Background

The Bonriki Inundation Vulnerability Assessment (BIVA) project is part of the Australian government's Pacific–Australia Climate Change Science and Adaptation Planning Program (PACCSAP), within the International Climate Change Adaptation Initiative. The objectives of PACCSAP are to:

- improve scientific understanding of climate change in the Pacific;
- increase awareness of climate science, impacts and adaptation options; and
- improve adaptation planning to build resilience to climate change impacts.

The BIVA project was developed by the Geoscience Division (GSD) of the Secretariat of the Pacific Community (SPC) in partnership with the Australian government and the Government of Kiribati (GoK).

1.1.1. Project objective and outcomes

The BIVA project aims to improve our understanding of the vulnerability of the Bonriki freshwater reserve to coastal hazards and climate variability and change. Improving our knowledge of risks to this freshwater resource will enable better adaptation planning by the GoK.

More specifically, the project has sought to use this knowledge to support adaptation planning through the following outcomes:

- Improved understanding and ability to model the role of reef systems in the dissipation of ocean surface waves and the generation of longer-period motions that contribute to coastal hazards.
- Improved understanding of freshwater lens systems in atoll environments with respect to seawater overtopping and infiltration, as well as current and future abstraction demands, recharge scenarios and land-use activities.
- Enhanced data to inform a risk-based approach in the design, construction and protection of the Bonriki water reserve.
- Increased knowledge provided to the GoK and the community of the risks associated with the impact of coastal hazards on freshwater resources in response to climate change, variability and sea-level rise.

1.1.2. Context

The Republic of Kiribati is located in the Central Pacific and comprises 33 atolls in three principal island groups. The islands are scattered within an area of about 5 million square kilometres. The BIVA project focuses on the Kiribati National Water Reserve of Bonriki. Bonriki is located on Tarawa atoll within the Gilbert group of islands in Western Kiribati (Figure 1). South Tarawa is the main urban area in Kiribati, with the 2010 census recording 50,182 people of the more than 103,058 total population (KNSO and SPC 2012). Impacts to the Bonriki water resource from climate change, inundation, abstraction and other anthropogenic influences have potential for severe impacts on people's livelihood of South Tarawa. The Bonriki water reserve is used as the primary raw water supply for the Public Utilities Board (PUB) reticulated water system. PUB water is the source of potable water use by at least 67% of the more than 50,182 people of South Tarawa (KNSO and SPC 2012). Key infrastructure including the PUB Water Treatment Plant and Bonriki International Airport and residential houses are also located on Bonriki, above the freshwater lens, making it an important economic, social and cultural area for the Republic of Kiribati.

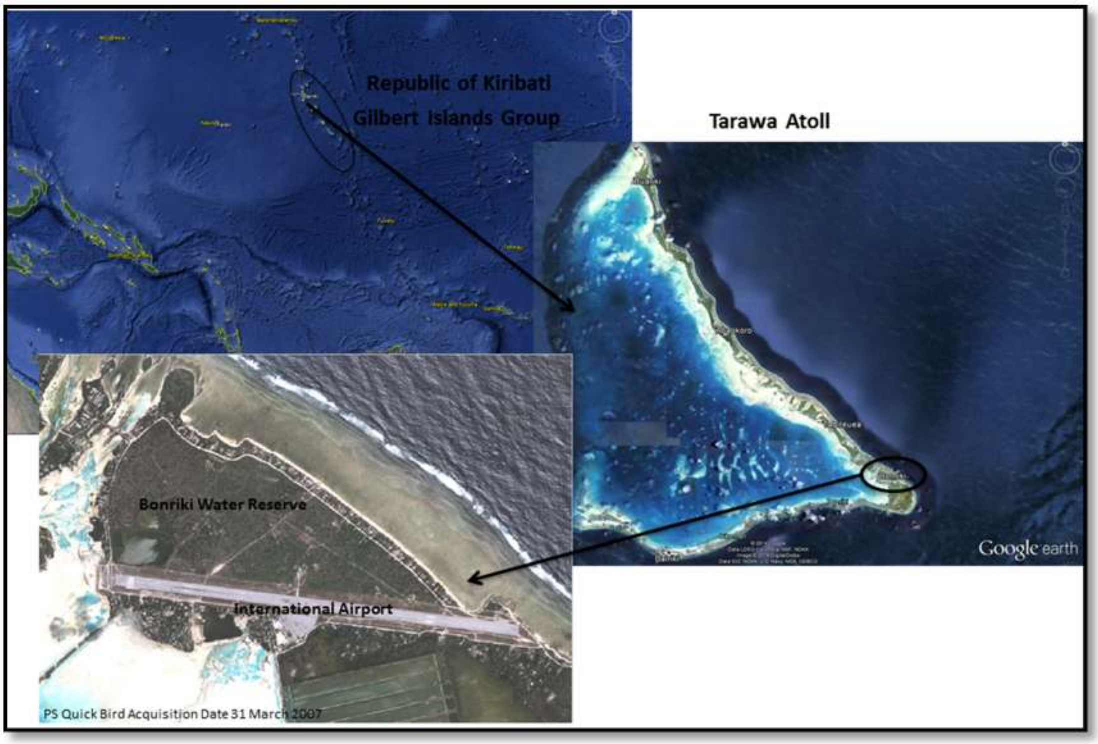

Figure 1. *Bonriki water reserve location.*

1.2. Purpose of this report

The purpose of this report is to provide a summary of the groundwater field investigation activities undertaken as part of the BIVA project and document key datasets and findings from these activities.

As illustrated in Figure 2, the project consisted of three interlinked components: 1) stakeholder engagement, 2) groundwater investigations and analysis, and 3) coastal investigations and analysis. The groundwater investigation component of the project has both been guided by numerical groundwater needs and supported with information provided by the projects' Technical Working Group and the GoK.

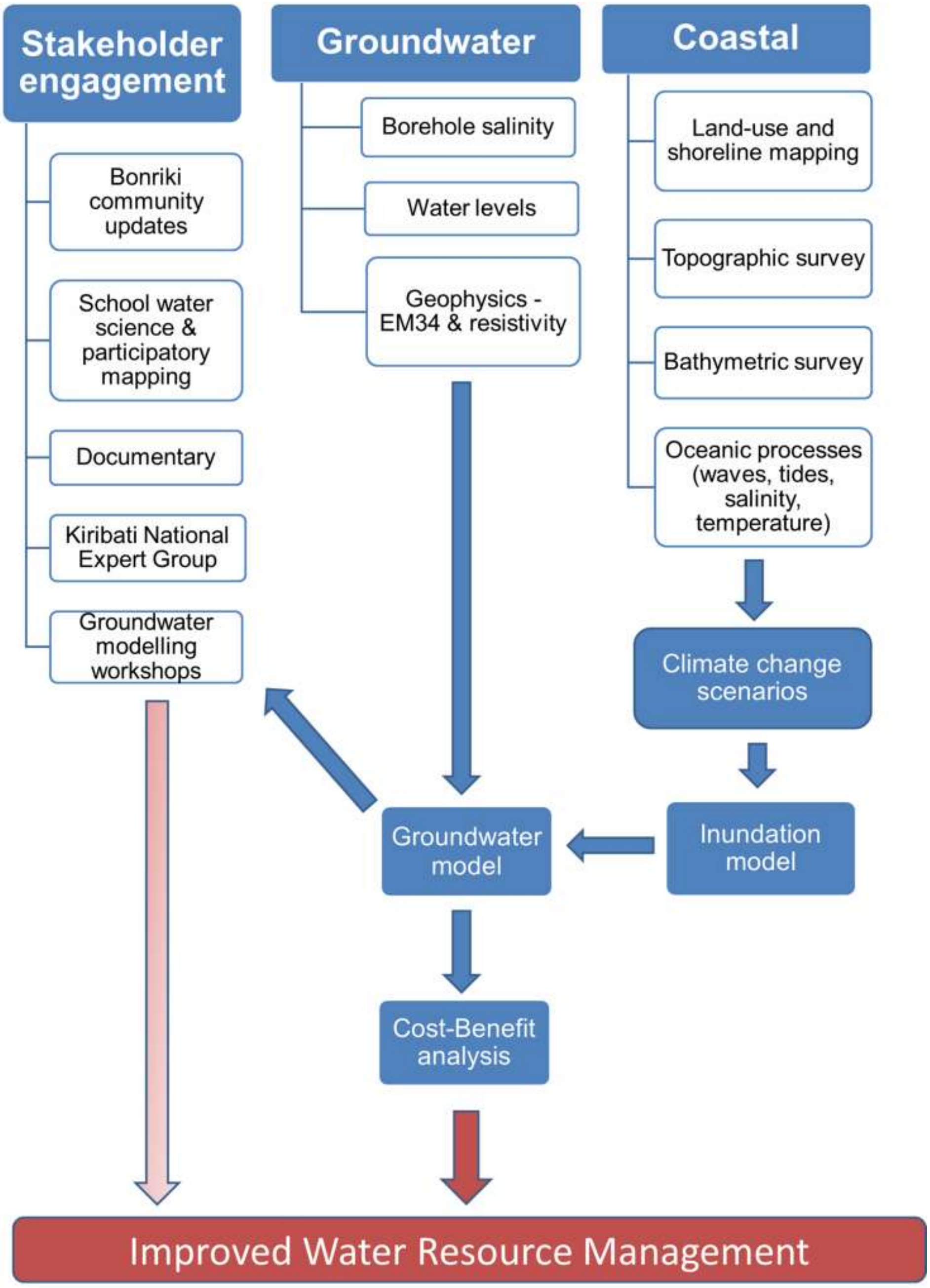

Figure 2: *Bonriki Inundation Vulnerability Assessment project components.*

1.3. Scope of this report

Numerical groundwater modelling requires data over time of the physical aspects of the groundwater system to help develop an understanding of the system. Detailed information is required on:

- topography,
- rainfall,
- recharge mechanisms,
- water level and water quality measurements,
- groundwater abstraction, and

- groundwater extent, occurrence, and characteristics.

This report provides details on activities and datasets that were undertaken and developed during the course of this investigation. The report is divided into two sections:

- a summary on the type of investigations and datasets collated, and
- an analysis of the datasets and information.

The collated datasets provide a valuable asset to the GoK for the management of groundwater in the Bonriki water reserve and future investigations.

2. Field Investigations

2.1. Location

The Republic of Kiribati comprises 33 atolls in three principal island groups, of which only 20 are inhabited. The islands are scattered within an area of about 5 million square kilometres in the mid-Pacific Ocean and comprise three island groups: the Gilbert Islands, Line Islands, and Phoenix Islands. The nearest neighbours are Nauru to the west, and Tuvalu and Tokelau to the south. The capital, Bairiki, is on Tarawa Atoll in the Gilbert group (Figure 3).

Figure 3: *Tarawa Atoll within the Gilbert Group, Kiribati. Bonriki is located in the southeastern corner of the atoll, immediately north of the airport. The satellite image of Tarawa is from Google Earth (accessed April 2012).*

The study area comprises the Bonriki freshwater reserve and the international airport. The freshwater reserve of Bonriki is the primary source of potable water and is the domestic supply for South Tarawa. The reserve has an estimated area of 0.7 km^2. It is reported that '67% of South Tarawa's households relied on water from the PUB water supply network as their primary drinking water supply source' (MPWU, PUB and MHMS 2012). The Bonriki water reserve is the main source of freshwater used by PUB for its raw water supply to South Tarawa. Bonriki airport, located on the land above the freshwater lens, and is the only international hub in the Gilbert Islands.

According to the 2010 census, South Tarawa's population (living in an area of 15.76 km^2) was 50,182 people, which is roughly half of Kiribati's total population of 103,058 people. South Tarawa's overall population density is 3,184 people/km^2. In 2010, Betio's population density was estimated to be as high as 10,230 people/km^2.

2.2. Rainfall

Daily rainfall data were collected in Betio with discontinuous records from 1947 to the present. This information is collected by and accessible from the Kiribati Meteorological Service (KMS) (Station No J61000).

The Bonriki water reserve is located approximately 25 km to the west of Betio's rainfall gauge. Manually recorded daily rainfall has been recorded since 1982 at the treatment plant in Bonriki that is operated by the PUB; however, the record has some gaps and more recently has become unreliable and is no longer used. In 2009, an automatic rainfall gauge was installed at the nearby Bonriki airport and is operated by the KMS with support from the Geoscience Division at the Secretariat of the Pacific Community (SPC).

2.2.1. Site location and characteristics

The KMS climate station for Tarawa is located at the KMS office in Betio (Figure 4). Climate parameters recorded at this station includes rainfall, humidity, wind, temperature, barometric pressure and evaporation.

Rainfall is also measured at the Bonriki airport using a TB3 automatic station (Figure 5) with continuous records available from March 2009. The Bonriki rainfall station is sited within the Bonriki airport control tower and fire station. It is calibrated annually and downloaded monthly by KMS staff. Data are held electronically at KMS in their climate database and at SPC's Geoscience Division.

When available, the data from the Bonriki site are used for the rainfall analysis. When this record is not available, a factored rainfall from Betio, based on a comparison of monthly rainfalls between the two sites, is relied on to fill the gaps for the Bonriki site.

Figure 4: *Location of Bonriki airport rainfall station from the Tarawa climate station in Betio, Tarawa (accessed from Google earth February 2015).*

Figure 5: *Calibrating the Bonriki airport TB3 rain gauge station.*

2.2.2. Data collection

A comparison between the Betio and Bonriki rainfall station datasets for the overlapping period indicates a difference between the amounts of rainfall recorded between the two rainfall stations. Over the six years of overlapping data, measured monthly rainfall totals in Betio are generally higher than those recorded in Bonriki. On average, it is calculated that Bonriki receives 13% less rainfall than Betio.

Rainfall in the tropics is less predictable than rainfall occurring in higher latitudes, and is generally more spontaneous and localised in nature. It is, therefore, important in this type of study to utilise site-specific rainfall data where possible.

A comparison of Betio and Boniriki rainfall on a monthly basis for the overlapping period is provided in Figure 6. The rainfall records are provided in Annex 1.

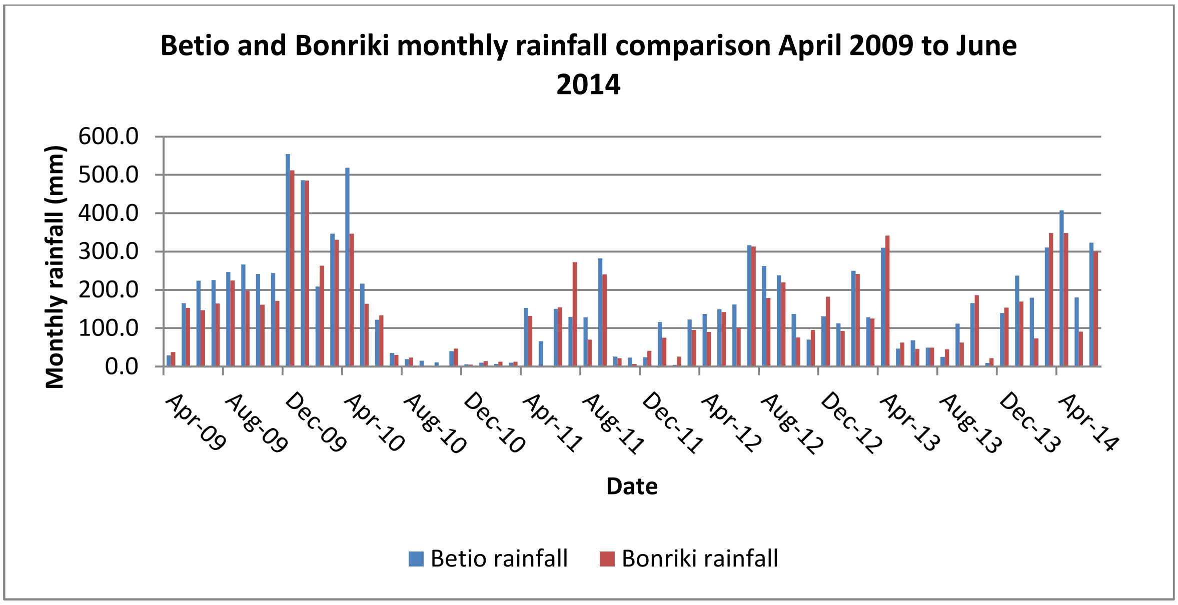

Figure 6: *Comparison of monthly rainfall between Betio and Bonriki rainfall stations since 2009.*

Monthly rainfall statistics for the period January 1947 to December 2013 are provided in Table 1. The maximum monthly rainfall for the period 1933–2014 for the combined dataset is 763 mm, which occurred in January 1949, with a minimum of 0 mm occurring three times: January 1947, October 1978 and September 2010, or once every 31.5 years. Mean and median data show that Bonriki has, on average, a ‘wetter’ December to April period (months with higher mean rainfalls) followed by a ‘drier’ May to November period (months with lower mean rainfall) (Figure 6).

Table 1: *Monthly rainfall statistics for the period January 1947 to Dec 2013 Bonriki (factored Betio and Bonriki data combined).*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean	239.2	176.0	185.1	175.6	139.3	132.5	145.8	127.8	110.1	102.8	107.2	188.4	**1,829.8**
Standard Deviation	192.2	132.3	147.9	130.7	99.6	88.5	107.3	114.2	94.1	112.8	107.4	141.5	**859.4**
CV[1]	0.80	0.75	0.80	0.74	0.71	0.67	0.74	0.89	0.86	1.10	1.00	0.75	**0.47**
Maximum	763.0	477.4	723.6	525.0	509.9	328.9	447.4	473.5	331.4	445.9	479.8	512.0	**3,840.86**
Minimum	0.0	0.9	0.4	0.3	2.5	0.5	0.4	3.0	0.0	0.0	0.7	5.5	**397.30**
No. years	67	67	67	67	67	67	67	67	67	67	67	67	**67**

Note: The coefficients of variability, CV, while not the highest in the Pacific are towards the high end, indicating variable rainfall in any one month.

[1] CV = coefficient of variation

An analysis of the Bonriki and factored Betio rainfall indicates that, on average, there has been a declining trend in annual rainfall since 1947, with this decreasing trend becoming more pronounced in the last 30 years, since 1984 (Figure 7). These results are contrary to the Pacific Climate Change Scientific Programme PCCSP climate projections for Tarawa, which suggest high confidence of increased rainfall and with an increase in intensity and frequency of days of extreme rainfall (Australian Bureau of Meteorology and CSIRO 2011, 2014). The projections suggest (with moderate confidence) that the number of droughts will decrease.

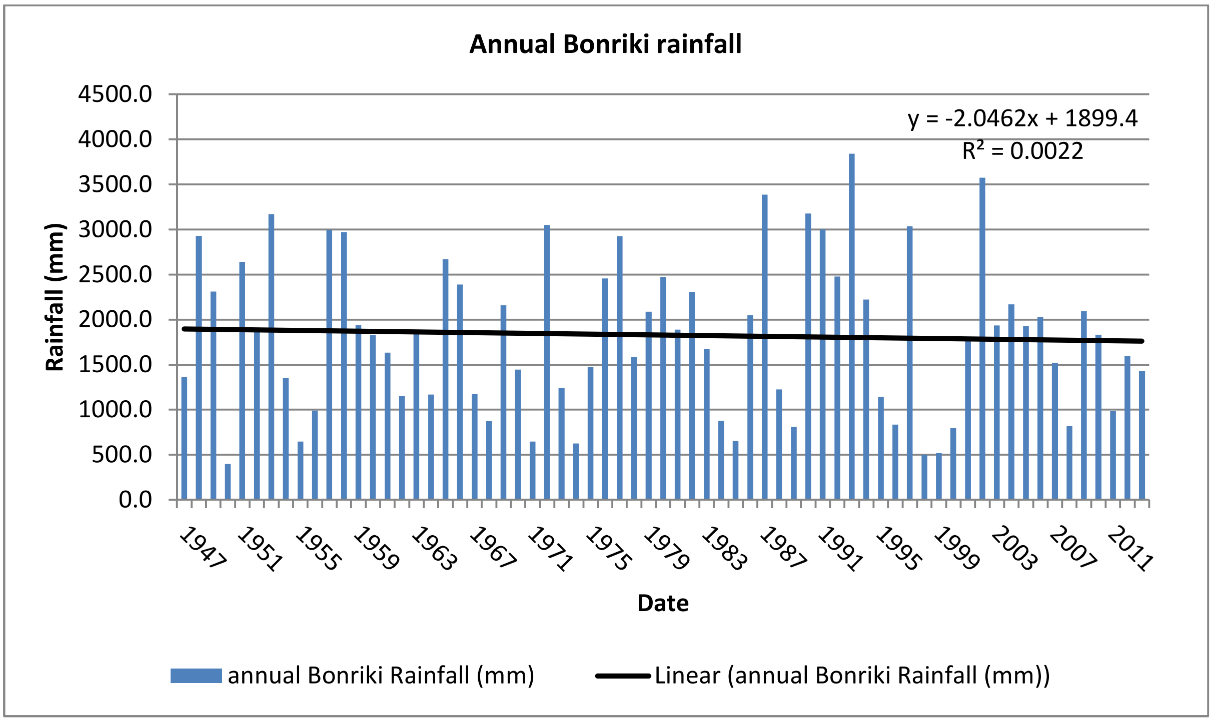

Figure 7: *Annual rainfall for the period 1984–2013 for Bonriki using the combined factored Betio rainfall and Bonriki rainfall data.*

A normalised annual cumulative departure from the mean annual rainfall from 1947 to 2013 is shown as Figure 8.

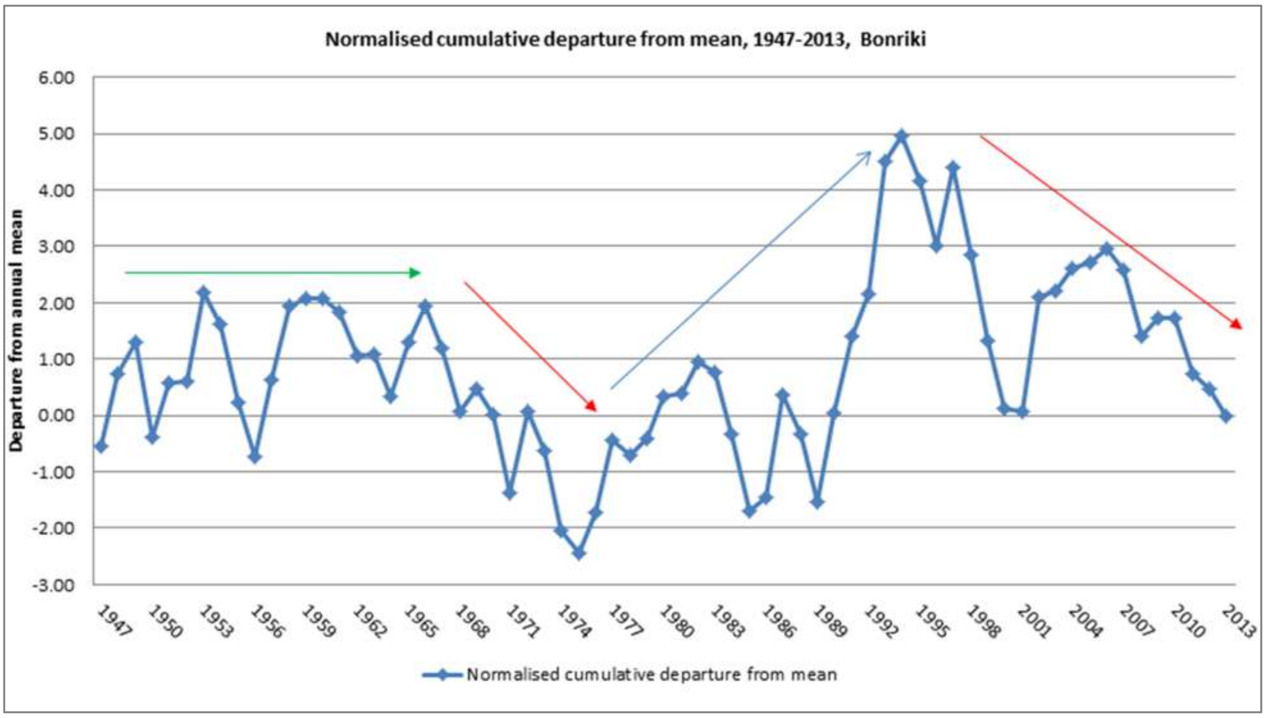

Figure 8: *Cumulative departure from the mean for annual normalised rainfall 1947–2013 for Bonriki using the combined factored Betio rainfall and Bonriki rainfall data.*

The normalised cumulative departure for annual rainfall or rainfall residual mass curve for the factored Betio rainfall and available Bonriki data indicates that from 1947 to 1966 there was generally stable annual rainfall, with three to four wet years followed by three to four drier years. From 1966 to 1975, there were nine years of drier-than-average climate, followed by generally wetter-than-average climate from 1976 to 1997 (21 years). The period from 1998 to 2013 (15 years) has been, on average, drier than the average over the 67 years of rainfall records.

2.3. Groundwater monitoring

Bonriki has, in general, some of the longest available groundwater monitoring records found within the Pacific. The available historical data are a tribute to earlier investigators, in particular Falkland 1992, with the support of the GoK. Groundwater monitoring records extend, albeit with gaps, from the 1980s to the present.

Current field investigations build on existing groundwater monitoring, which is scheduled to be undertaken quarterly by the GoK. Current investigations were able to extend the number of boreholes being monitored, which provided greater spatial distribution and more confidence in the available information, and indications of groundwater trends over this period.

In addition to groundwater monitoring, the project was able to provide the Ministry of Public Works and Utilities (MPWU) with additional sampling and measurement equipment, undertake basic borehole maintenance, and provide MPWU staff with additional training opportunities in monitoring techniques.

In total, 26 sites were monitored quarterly during these investigations, with over 700 measurements taken by SPC with the support of and in collaboration with MPWU staff between April 2013 and June 2014.

2.3.1. Monitoring borehole locations

There are 36 monitoring borehole locations that have been constructed in the Bonriki freshwater reserve. A number of these sites have been destroyed and others are limited to piezometers constructed into the top of the water table. Table 2 summarises the original and currently available monitoring network and construction dates and Figure 9 identifies the location of the monitoring boreholes. Location coordinates and elevation details are provided in Section 2.4.

Table 2: *Monitoring boreholes sites installed in the Bonriki water reserve from 1980 to 2014.*

Original monitoring borehole site Nos	Installation dates	Accessible boreholes in 2014	References
BN1, BN2, BN3(BH1), BN4, BN5, BN6, BN7, BN8, BN9, BN18(BH2); Total (10)	1980	BN1, BN2, BN4, BN6, BN7	Murphy (1981)
BN10; Total (1)	1983		Murphy (1984)
BN11, BN12, BN13, BN14, BN15, BN16, BN17; Total (7)	1985	BN11, BN13, BN15	Murphy (1986); Murphy (1987)
BN2B*, BN4B*, BN19, BN20, BN21, BN22, BN23, BN24; Total (8)	2000	BN2B*, BN19, BN20, BN21, BN22, BN23, BN24;	OEC, PPK, Erasito (2001)
BN25, BN26, BN27, BN28, BN29, BN30, BN31; Total (7)	2001	BN25, BN26, BN27, BN28, BN29, BN30, BN31	OEC, PPK, Erasito (2001)
BN32, BN33, BN34; Total (3)	2004	BN32, BN33, BN34	Falkland et al., (2004)
BN1B*, BN4C*, BN7B*, BN13B*, BN15B*, BN20B* BN23B*, BN35, BN36; Total (9)	2014	BN1B*, BN4C*, BN7B*, BN13B*, BN15B*, BN20B* BN23B*, BN35, BN36	

*monitoring boreholes are not new locations, drilled on existing sites.

Figure 9: *Monitoring borehole sites 1980–2014, Bonriki water reserve, Bonriki Tarawa.*

2.3.2. Monitoring borehole construction

Monitoring bores were constructed in Bonriki during four distinct investigation phases over the years 1980–1985, 2001, 2004 and 2014. The majority of monitoring bores have been constructed as multi depth sampling tubes. The monitoring bores consist of 8 mm sampling tubes installed at preselected depths. These sampling tubes allow the water to be pumped from discrete depths via the 8 mm sampling tubes, providing information on the salinity of the freshwater lens with depth. The monitoring bores in Bonriki, can have up to eight tubes installed, with separation depths between tubes generally at 3-m intervals, starting from 2–3 m below the water table and up to depths of 28 m. Water is abstracted from small glass filters positioned at discrete depths within gravel packs and separated by bentonite seals. Figure 10 is an example of monitoring bore construction used in Bonriki.

A 50-mm PVC screened tube is normally installed at the top of the freshwater lens to allow for water level measurements, sampling and installation of pressure loggers.

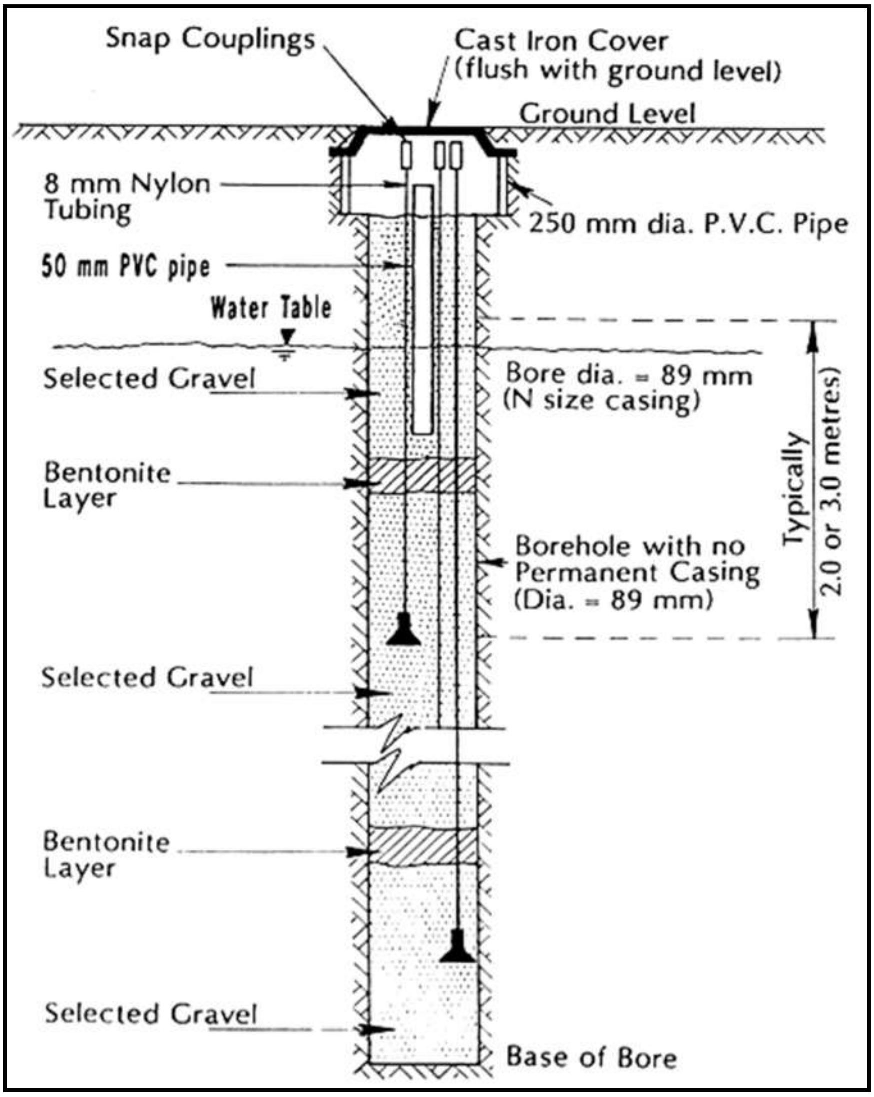

Figure 10: *Example of the multiple sampling tubes installed in Bonriki (Murphy 1986).*

Examples of the sampling tube setup with the monitoring boreholes, and the sampling technique used is provided in Figure 11, 12 and 13.

Figure 11: *Seven sampling tubes at selected depths with RYCO fittings, and 50-mm PVC piezometer to the water table within BN33 monitoring borehole box.*

Figure 12: *Sampling equipment used by MPWU staff members in the field, 12-V diaphragm pump (foreground), used to abstract water from 8-mm sampling tubes that can then be measured for salinities or other purposes.*

Figure 13: *Sampling of monitoring borehole and recording of measured parameters in the field, MPWU and SPC staff.*

Details on the monitoring borehole construction and an updated audit of status of the monitoring boreholes in November 2013 are provided in Annex 2.

Monitoring boreholes in the water reserve have been the subject of vandalism in the past. This includes the cutting of brass locks for their recyclable value, the destruction of the concrete protection box, their lids, the sampling tubes contained within, and the backfilling of the 50-mm piezometers with sand. This is considered, in part, to be a response to the ongoing conflict between government and residents on the accessibility of the land by traditional owners for alternate land-use activities, lack of awareness of the role of the monitoring boreholes, and in some cases curiosity and boredom.

Similarly, the climatic conditions within the tropics are particularly hard on equipment and infrastructure, which require additional attention to maintenance. During the course of this project additional field equipment was provided as indicated in Table 3.

Table 3: *Equipment provided to the MPWU, Water Engineering Unit March 2014.*

Equipment	Quantity	Serial number
Shurflo pump and fittings	1	
Flojet pump and fittings	1	
12-V battery	7	
Tools (steel brush, paint brush, paint scraper, cement trowel)		
Bailer	3	
TPS conductivity meter with accessories	1	V9439
Calibration standards (2.76 mS/cm)	5L	
Calibration standards (5 mS/cm)	1L	
Buckets	4	
Well borehole cover	1	
Replacement borehole key	1	

In addition, monitoring boreholes with steel lids were repainted to prolong the life of the borehole protection installed (Figure 14), and damaged cement monitoring borehole protection boxes were repaired where possible. An audit of the monitoring boreholes for recommended rehabilitation works is provided in Annex 3.

Figure 14: *The steel monitoring borehole lids have been repainted to extend its life.*

2.3.3. Data collection

Sampling from all available monitoring boreholes was carried out every three months over five separate occasions, from April 2013 to June 2014. The results from the sampling campaigns are provided in Annex 4.

Monitoring campaigns were aligned to coincide with MPWU's regular quarterly monitoring schedule for Bonriki, and MPWU staff were engaged in each monitoring campaign coordinated by SPC. This approach allowed for engaging in existing schedules when MPWU resources were already assigned, thereby reducing the impact on limited MPWU resources. It also had the advantage of providing additional SPC staff and resources to include monitoring boreholes that are normally not regularly sampled due to time and resourcing constraints.

Samples were taken by connecting a 12-V diaphragm type pump to the sampling tube and abstracting three sampling tube volumes prior to sampling into three separate sampling containers and measuring the salinity and temperature with a calibrated TPS W84 TDS and conductivity meter. Water level data in the 50-mm piezometers were also recorded along with the time and date of each visit, and general conditions or issues observed during the sampling.

All results were recorded in a dedicated field book and transferred to date specified Bonriki spreadsheets (e.g. Bonriki Monitoring August 2014.xls). Conductivity records from each sampling tube were reviewed and if there was general agreement between the values of the conductivity records the last conductivity sample taken was used to update the master sheet (Borehole Monitoring Data — BONRIKI [UPDATED Aug .2014] — Master Sheet. xls), alternatively an average of the three salinity readings was used.

Individual spreadsheets with the recorded monitoring data for each monitoring campaign, and the updated Master Sheet were provided to MPWU shortly after each monitoring campaign for its records.

At each monitoring site, the intention was to sample the freshwater lens at discrete and known depths to determine the salinity of the water at that specified depths, thereby allowing for a comparison of freshwater lens movement or change over time. At times, the sampling tubes became blocked and required backwashing, which involves pumping 1–2 L of a fresher water quality back down the sampling tube to help clear any blockage. In cases where blocked tubes were unable to be cleared by backwashing, a small diameter stainless steel wire was inserted into the sampling tube to clear blockages. This technique was also used to measure depths of sampling tubes.

In some cases, the sampling tubes were not constructed to sufficient depths to allow the thickness of the freshwater lens to be determined under all conditions. This is a limitation of the monitoring boreholes and reduces the effectiveness of the site to be able to observe changes in the freshwater lens due to climate and abstraction impacts over time. In a number of cases, monitoring boreholes sites have had their sampling tubes damaged or destroyed, which further limited access to information at important sites, thus making interpretation of the remaining data more difficult. It is recommended that additional or replacement monitoring boreholes should be constructed to sufficient depths to ensure that the entire profile of the groundwater from the fresh to the saline water can be sampled in all climatic conditions. The proposed monitoring sites that should be considered for redrilling are presented in Table 4.

Table 4: *Identification of monitoring borehole sites that should be considered for redrilling by order of priority.*

Monitoring borehole site replacement	Minimum depths for drilling	No. of sampling tubes	Comments
BN16	30 m	9 sampling tubes Sampling tubes at 3-m intervals below the water table 3, 6, 9, 12, 15, 18, 21, 24, 27, 30 m	This monitoring borehole site was destroyed due to sand mining activities; however, it is a critical borehole for the monitoring of the water reserve, and so it is recommended that the monitoring borehole be redrilled at either the original site or at the location of BN35
BN30	21 m	7 sampling tubes Sampling tubes at 3-m intervals below the water table 3, 6, 9, 12, 15, 18, 21 m	Replacement for destroyed borehole. Previously located between galleries 14 and 15.
BN19, BN20, BN25	BN19 – 30 m BN20- 30 m BN25 -27 m	10 sampling tubes for BN19 and BN20; and 9 sampling tubes for BN 25 Sampling tubes at 3-m intervals below the water table. 3, 6, 9, 12, 15, 18, 21, 24, 27, 30 m	Current boreholes are too shallow and do not extend into the freshwater lens sufficiently to be useful in monitoring, recommend redrilling and construction of new sampling tubes
BN26	24 m	8 sampling tubes Sampling tubes at 3-m intervals below the water table 3, 6, 9, 12, 15, 18, 21, 24 m	This borehole is in an important location, however there are limited sampling tubes to provide accurate information. Redrilling is recommended.
BN36	24 m	8 sampling tubes Sampling tubes at 3-m intervals below the water table 3, 6, 9, 12, 15, 18, 21, 24 m	This is a new site. Installed piezometer only in November 2013. Will provide information on the depth of the lens and impacts from boundaries and abstraction.
BN37	27 m	9 sampling tubes Sampling tubes at 3-m intervals below the water table 3, 6, 9, 12, 15, 18, 21, 24, 27 m	This is a new site recommended to be installed at a suitable location on a line between BN20 and BN4. Will provide information on the depth of the lens and peripheral edges of galleries.

Figure 15: *Location of recommended future monitoring boreholes sites or redrilling.*

2.4. Piezometer construction

The monitoring and management of freshwater lenses in atoll environments normally rely on measurements of salinity at pre-selected depths to observe variations in freshwater behaviour in response to recharge and abstraction.

Water level measurement, to observe changes within the freshwater lens as the variations in the water level due to recharge and abstraction, is more problematic in atoll environments being often masked by tidal impacts. However, accurate water level measurements used in combination with salinity information provides important information on the tidal impacts, hydrogeological characteristics, flow hydraulics, and efforts to collect accurate measurements to a surveyed measuring point, recording date and times will provide useful information. In Bonriki, water level measurements are undertaken in 50-mm piezometers with screens constructed within the first metre below the water table.

In some situations piezometers were not installed or had been vandalised or damaged over time. It was identified that additional information on the freshwater lens will be useful for both the BIVA project and future investigations at certain locations. In the absence of a drill rig, monitoring boreholes with sampling tubes could not be constructed, although piezometers could be constructed and provide valuable information at specific locations.

Under the BIVA project nine new piezometers and one duplicate piezometer due to vandalism, (ten piezometers in total), were constructed in the Bonriki water reserve.

2.4.1. Piezometer location

The locations of the new piezometers were determined based on spatial distribution, and included eight original sites in which piezometers were never installed, had been vandalised, or damaged over time; two new sites were chosen for installing piezometers under BIVA.

The location of these new piezometers and piezometer drill logs are provided in Annex 5.

2.4.2. Piezometer construction

The piezometers were constructed using an excavator, hired from the MacDow road building crew. An experienced excavator operator was used to construct pits of approximately 1 m^2 to 1 m below the water table, or until refusal, into which piezometers were installed under supervision of SPC staff.

Piezometers were constructed using 50-mm class 12 PVC. A sump of 0.1 m with a glued end cap secured the base of the piezometer, immediately above the sump was a 0.5-m machine-slotted screen with 1–2 mm saw cuts. Above the 0.5 m screen, was blank PVC pipe to the surface of the hole.

The pit, with the positioned piezometer, was backfilled with graded coral gravel sourced from MacDow under the Ecologically Sustainable Aggregates for Tarawa project. Approximately 1–2 m^2 of graded coral gravel was placed in each pit from the base of the pit to approximately 0.5 m above the top of the screen. Above the coral gravel the excavated sand was used to backfill the hole. Note that it became clear during the installation that the coral gravel used around the screen was likely to have been sourced from the lagoon and was unwashed prior to being used as a gravel pack. This resulted in increased salinity of the groundwater immediately surrounding the piezometer, which was observed over time to drop back to near normal background salinity observed prior to the piezometer construction. This will be discussed further in the report.

Construction details, drill logs, and construction images are provided in Annex 5.

Piezometers were bailed using a dedicated plastic bailer for a minimum of one hour or until the sample obtained was clear. Piezometers were completed with Enviroequip 180mm OD EEQFB180 monitoring borehole covers, which are finished flush with the ground level and accessed with a 10-mm Allen key.

Locations and elevations to top of pipe (TOP) measuring points were recorded using real time kinematic (RTK) survey equipment.

2.4.3. Data collection

Water level measurements and the total depth of the piezometer are taken to the TOP and recorded along with the time, date and field conditions, including recent rain and other observations. Water level measurements were taken with a calibrated Solinist TLC (temperature, water level, and conductivity) instrument. Conductivity readings were taken just above the base of the screen and likely indicate formation water.

Water samples for analysis of *Escherichia coli* (*E. coli*) were also taken on selected monitoring boreholes and for selected field campaigns. The sampling and analysis for this is explained in a separate section of this report. Similarly, *in situ* downhole loggers, which are capable of recording temperature, pressure and conductivity over time, were installed in 10 piezometers to provide useful information in regards to tide impacts as well as recharge responses. More detail is provided in Sections 3.1.3 and 3.2.

Elevation data for all boreholes referenced back to mean sea level allows flow directions under different climate and abstraction conditions to be determined. It is recommended that the collection of water level data for monitoring boreholes be continued with accurate readings, to provide valuable information for investigations, modelling, and the management of the groundwater system in the future.

2.5. Topographical survey

One of the limitations of making better use of collected water level information in atoll environments is the difficulty in obtaining accurate survey data. The BIVA project required detailed and comprehensive location and elevation information of the reef and the land surface for inundation modelling.

The elevation survey using RTK was undertaken by SPC as a capacity building exercise with the Ministry of Lands Fisheries and Mineral Resources Department (MFMRD). RTK provides accuracy to within a centimetre and is significantly faster than conventional survey techniques, particularly where a large number of survey points are required or where bench marks may not be relied on.

The resulting elevation information for boreholes improves the use of water level information obtained from monitoring borehole sites so that the information can better assist with the understanding and management of the Bonriki freshwater lens.

2.5.1. Survey methodology

The RTK survey requires a stable base station to be established which can receive continuous access to satellite signals to record the phase of the satellite while the mobile units or rovers compare their own phase measurements to that of the base station. In this way the 'rover' units can calculate their relative position to about 1 cm horizontally and 2 cm vertically.

The RTK survey was undertaken by both SPC and MFMRD staff over three separate occasions between 2013 and 2014 in order to complete all the survey work required. The base station was set up at the PUB water treatment plant at the Bonriki water reserve. Mobile receiving station 'rovers' were deployed and readings were taken using vehicles or on foot across the study area, including at the monitoring boreholes and at the abstraction galleries.

Data were post processed by SPC and elevation data for each point was provided to the datum. The resulting elevation data were used to construct a digital elevation model of the topography of the reef flat and the land surface within the study area (Begg et al. 2015).

The datum that the elevation data is referred to is Tide Gauge Zero (TGZ). TGZ was first established by the University of Hawaii. TGZ and the original reference point UT8 (circa 1992) are no longer available having been replaced by KIR1. KIR1 is considered fixed at 3.5334 m relative above the TGZ mark from the University of Hawaii tide gauge. This survey and other surveys, including the Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) tide gauge, reference back to the TGZ mark of the University of Hawaii tide gauge.

The elevation values obtained from the RTK survey are relative to the University of Hawaii TGZ reference. The annual mean sea level for 2013 taken from recorded readings measured at the SEAFRAME tide gauge sensor is 1.26 m above TGZ for 2013. In 2014 the annual sea level rise from the annual mean sea level in 2013 was 3.8 mm.

The measuring point to which the elevation data were recorded for monitoring boreholes is either the TOP for monitoring boreholes which have only a piezometer (Figure 16), or the lug used to lock the lid of the monitoring borehole box, referenced with a notch cut into the lug (Figure 17).

For galleries, the measuring point is to the top of the open well within the gallery pumping station. If access was unavailable then the RTK measuring point was to the concrete slab outside of the pumping station structure. Annex 6 summarises the RTK survey data collected by SPC and MFMRD staff during 2013–2014.

Figure 16: *Using an RTK rover unitr to measure the elevation to the Top of Pipe measuring point in piezometer BN35.*

Figure 17: *BN2B with the surveyed reference point identified by a notch in the locking lug of the monitoring box. (Damaged monitoring boxes were repaired as part of the project rehabilitation work).*

2.6. Geophysics

Geophysical survey techniques, including electromagnetic and resistivity, were undertaken during the BIVA project to assist with the identification of the size and extent of the freshwater lens beyond the known locations of the existing monitoring boreholes.

The information provided with the geophysics has been used to improve the conceptual understanding of the Bonriki groundwater system and for use in comparing the results from the interpolated borehole data.

2.6.1. Electromagnetics

Electromagnetics is a survey technique that relies on measuring the ground conductivity of the subsurface. Ground conductivity values obtained were used to interpret possible geological and hydrogeological models.

A Geonics EM34 electromagnetic survey system was used during the February 2014 field investigations. The EM34 uses two coils — a transmitter and a receiver — to measure ground conductivity.

The transmitter coil radiates an alternating electromagnetic field that induces electrical currents (termed eddy currents) in the earth below the coil. These eddy currents in turn generate a secondary magnetic field. The receiver coil detects and measures both the secondary and primary magnetic fields and calculates the apparent conductivity based on the ratio between the two fields.

The two coils are held by operators connected by a cable of one of three defined reference lengths, 10 m, 20 m or 40 m (Figure 18). The coils are placed in the vertical or horizontal dipole position depending on the investigation design of the survey, ground conditions, and targets.

The depth of exploration depends on the separation between the transmitter coil and the receiver coil, as well as on the coil orientation (coil axis/dipole horizontal or vertical). Geological factors such as moisture content, salinity of the pore water, temperature, and composition of colloids in the ground will influence the conductivity and the success of the survey.

This technique does not produce a unique result or solution. Measured values can be interpreted in a number of different ways, and the interpretation relies on an understanding of local ground conditions. A calibration technique used in atoll environments for groundwater exploration is the comparison of the measured apparent conductivity values against actual salinities measured in monitoring boreholes to develop a logarithmic profile of the freshwater lens' thickness.

Figure 18: *Ministry of Public Works and Utilities staff member undertaking EM34 surveys.*

2.6.1.1. Survey methodology

The EM34 survey was designed to investigate the lateral and vertical extents of the freshwater lens. Two near identical Geonics EM34 units, the SPC unit and the MPWU unit, were available at the time of the survey. The two units were purchased from Geonics within four years of each other. With the support of MPWU the two EM34 units were deployed at the Bonriki field site with the intention that greater survey coverage could be achieved if both units could be used. With this in mind, the two units were then used during the calibration exercise to ensure that they would provide similar readings of ground conductivities against the monitoring boreholes.

EM34 readings of ground conductivity were taken next to 20 existing monitoring boreholes for calibration purposes. The apparent ground conductivity readings were compared against the measured salinity at known depths and the depth to the water table for 19 monitoring boreholes collected during the field survey. Calibration readings were taken for each EM34 reference cable length 10 m, 20 m, 40 m, and using the 40 m reference cable at 10 m, 20 m, and 40m separations in both the north–south and east–west direction to give additional understanding, confidence and flexibility in survey techniques.

The results of the calibration exercise are provided in Annex 7 - EM34 survey results.

A review of the calibration results against the monitoring boreholes and using the two units indicate the following:

- In general, the readings between the two Geonics EM34 units — SPC and MPWU — were similar.
- The readings between the fixed distance reference cables and using the 40-m cable at variable distances were similar.
- The direction in which the coils were held, either east–west or north–south did not seem to make a significant difference to the readings.

Based on the results from the calibration exercise it was decided that in the interest of efficiency, to take readings at 10 m, 20 m, and 40 m spacings using the single 40-m reference cable with coil orientations in a general northeast–southwest direction, for each survey point and traverse.

An EM34 survey schedule was designed for along existing pathways in a northeast–southwest direction from the ocean to the lagoon side of the study area. In total, 12 survey lines with a 20-m spacing between measurement points and 200 m between survey lines were completed. The starting point for each traverse was recorded using a GPS, and survey data were annotated with comments and notes on field conditions. Readings of the 10-m, 20-m, and 40-m spacings using the 40-m reference cable were taken for each measurement point. The survey was carried out with the coils used in the horizontal dipole position.

Early during the survey, the SPC EM34 unit stopped operating. Damage to the receiver coil was suspected, and the unit was unable to be repaired on site. The survey was completed using EM34 equipment kindly loaned from MPWU.

2.6.1.2. Results

The results from the survey were compiled and reviewed, and each traverse with readings obtained from the 40-m reference cable were separated at three different distances and plotted against survey distance. The resulting profiles indicated quite different thicknesses of freshwater depending on the separation distance used.

Readings from the 20-m and 40-m spacings generally overestimated the freshwater lens thickness based on known borehole depths. The curve generated from plotting the calibration readings for each reference cable against known freshwater thicknesses is sensitive to variations in the readings recorded. Ground and field conditions at the time of the survey were in general, considered to be quite uniform with a depth to the water table between 0.5 m to 2.6 m, and an average depth of 1.5 m. It is recommended that additional care be taken during both calibration and surveys to ensure the readings have stabilised to minimise this apparent variability.

A hand-contoured map based on the interpreted thicknesses of the freshwater lens from EM34 readings in February 2014 was generated (Figure 19). There was a reliance on the use of the 10-m coil separation readings for interpretation which appeared to provide better alignment with available monitoring boreholes than the other coil separation distances.

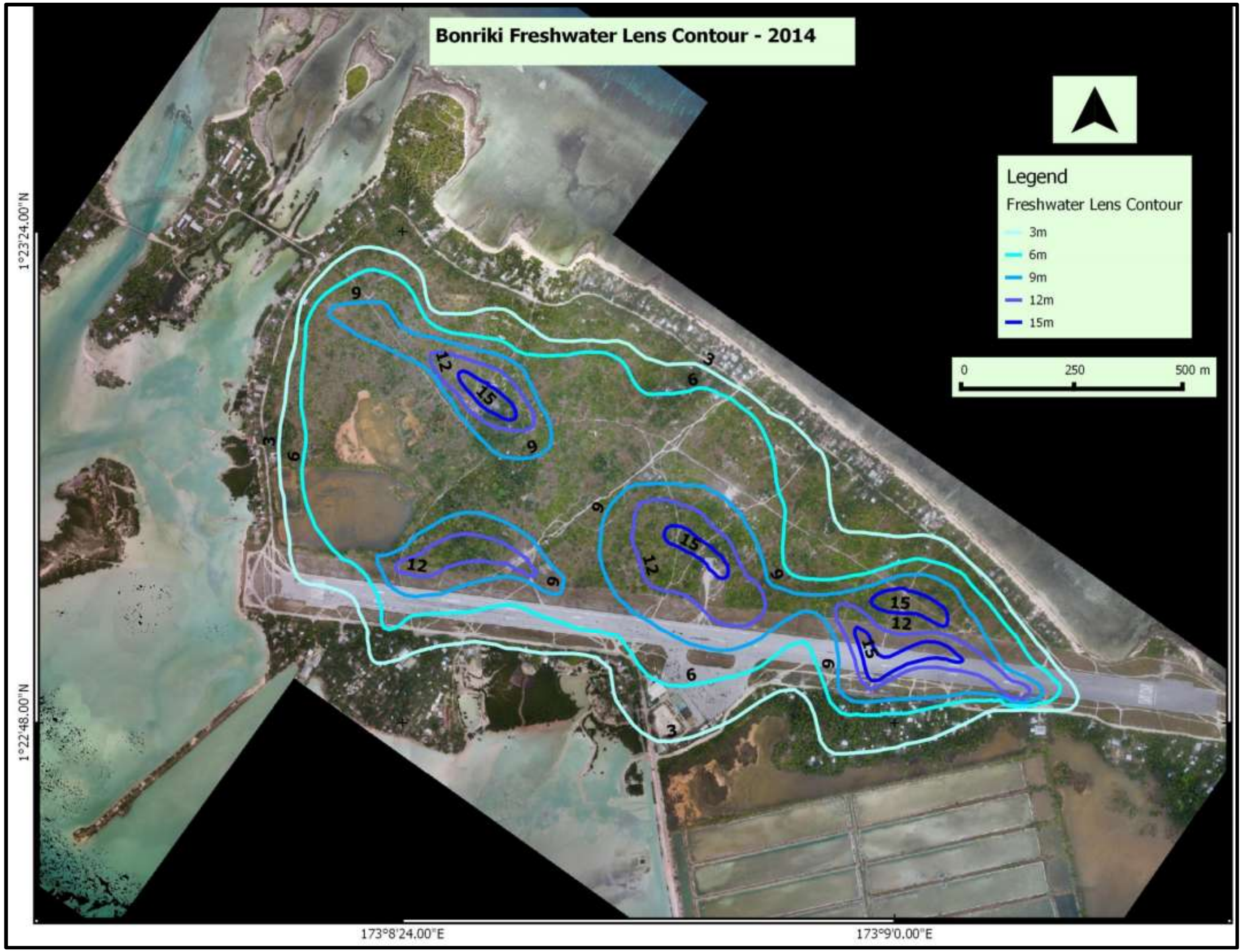

Figure 19: *Freshwater lens thickness, February 2014, based on EM34 surveys.*

2.6.2. Resistivity

Resistivity profiling using a SuperSting R1/IP with 56 electrodes from Advanced Geophysics Inc. was used for resistivity investigations at Bonriki in February 2014.

Electrical resistivity profiling involves measuring the apparent resistivity of soil and rock as a function of depth over a section from which an interpretation of the geology and hydrogeology of the subsurface can be made. The resistivity of soils is a function of porosity, permeability, ionic content or salinity of the pore fluids, and clay mineralisation. Resistivity is useful in determining freshwater lens thickness and shape.

Electrical current is injected into the ground through the use of stainless steel current electrodes, and then measured as a voltage in the potential electrode. Different spacing and sequencing of injection and measurement electrodes result in different arrays that are used for different investigations, depending on the depth and resolution of interest. At Bonriki, dipole–dipole and Wenner arrays were used for the surveys because they provided sufficient depth and resolution for the available time of the survey. Wenner arrays yielded the best data recovery at Bonriki and were relied on for the majority of the survey.

2.6.2.1. Survey methodology

The resistivity survey was designed to traverse across the Bonriki water reserve from the ocean side to the lagoon side, to generate a profile of the thickness of the freshwater lens and the shape of the lens.

A spacing of 4 m between electrodes was used. The 56 pegs allowed survey profiles of 220 m. Longer profiles using roll-along surveys, which involve leap frogging of the electrodes and cabling, were attempted, however, difficulties were encountered with this approach so single survey lines were used instead.

In order to maintain good contact resistance with the electrodes and the ground, the electrodes pegs were wetted with seawater to improve contact resistance. Dishwashing liquid was also trialled as a wetting agent with its increased viscosity to assist in improving contact resistance of the electrode peg with the ground. No noticeable difference, however, was observed between dishwashing liquid and seawater.

2.6.2.2. Results

In total, 16 resistivity surveys were undertaken, and the results from the surveys are provided in Annex 8. Resistivity surveys were able to identify the water table as a resistivity contrast between the saturated and unsaturated zone.

As with electromagnetic surveys, there is no one unique solution to the readings obtained for the resistivity surveys. That is the combination of geology and water salinity provides an apparent resistivity reading that can be used to infer subsurface conditions. Resistivity profiles provided information on the shape of the freshwater lens, and while it was not possible to delineate with confidence, due to non-unique solutions, the specific salinity of the freshwater lens at a specific depth, an estimate of freshwater thickness and its shape could be determined.

Resistivity surveys indicated a general thickening of the freshwater lens from the ocean to the lagoon side of the island and some features were interpreted as erosional features of the underlying limestone. The thickest parts of the freshwater lens were identified close to the 'freshwater ponds' and near the treatment plant, and appeared to be over 16 m thick. A plan of the estimated freshwater thickness for February 2014 based on resistivity surveys is provided in Figure 20.

It is clear that the two geophysical surveys generated different contours of freshwater thickness. The resistivity profiles provide a better indication of the shape of the freshwater lens across the water reserve and indicate that during the February 2014 survey, the eastern area had a relatively thin (6–8 m) freshwater lens, with the thickest part being the southwestern portion of the reserve near galleries 11, 12 and 13, and near the 'freshwater ponds', which is commensurate with other available information, including monitoring boreholes BN19, BN27 and BN21 and EM34 data.

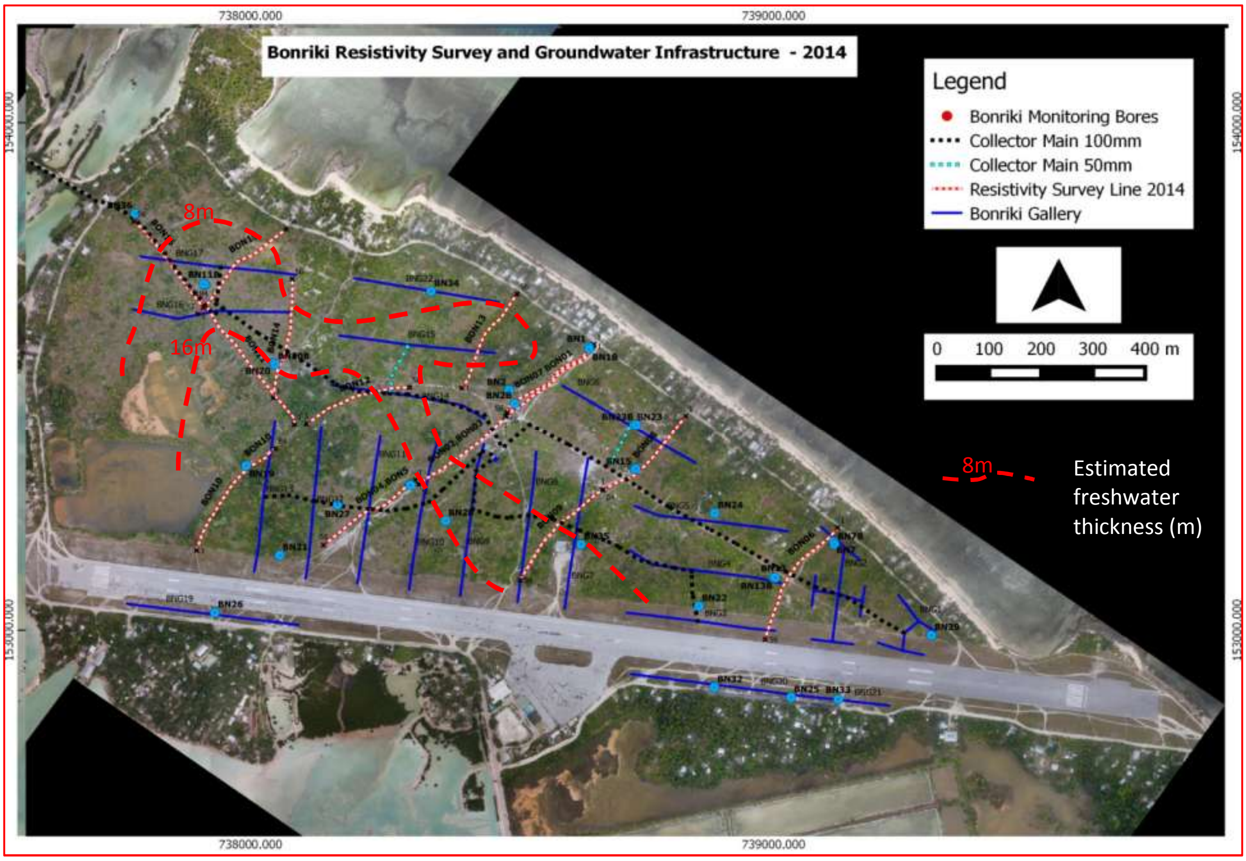

Figure 20: *Estimated freshwater thickness of the Bonriki freshwater lens (February 2014) from resistivity surveys.*

2.7. Infiltration galleries

2.7.1. Background

Infiltration galleries consist of horizontal pipes, gallery arms, of up to 150 m in length, constructed just below the groundwater table, and designed to allow groundwater to enter into these gallery arms, draining towards a vertical collection well, where it can be pumped. The advantage of this type of design is that it increases the yield of fresh groundwater that can be obtained compared with a single vertical well in hydrogeological conditions found on atolls, and reduces the risk of salinity intrusion, upconing, from pumping at too high a rate. Figure 21 is an example of the type of design for these infiltration galleries found on Bonriki.

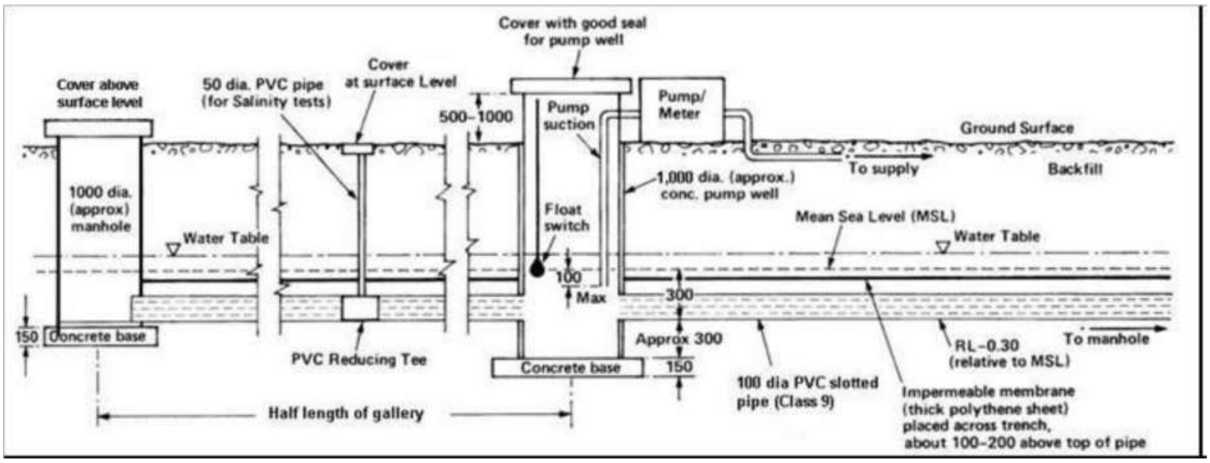

Figure 21: *Design of the infiltration gallery found on Bonriki. The pumping well is in the middle of two slotted PVC pipe gallery arms, with inspection wells at the midpoint and terminal ends of the arms (White et al. 2005).*

Abstraction from the groundwater system is a critical parameter to be determined for groundwater modelling. The location of the infiltration galleries in Bonriki is shown in Figure 22. All 22 of the infiltration gallery pump stations have a flow meter attached to them to allow abstraction to be recorded over time. In addition, there is a Bonriki master meter that records the total flow leaving the treatment plant in Bonriki, and which includes the flow from both the Bonriki water reserve and from the Buota water reserve. A separate meter also records the flow coming only from the Buota water reserve.

PUB operators for the Bonriki water reserve record the metered flow from the Buota water reserve meter and the Bonriki master meter on a daily basis, together with a daily salinity reading at the Bonriki master meter. The meter readings for each of the infiltration galleries in Bonriki and Buota are recorded on a monthly basis along with the salinity in these wells at the time of the meter reading.

At the commencement of the BIVA project, PUB identified a number of flow meters from individual galleries in Bonriki that required replacement. The project committed to the purchase of eight new flow meters of a type similar to what was installed, 50-mm Kent Elster H400s for galleries, and two new 100-mm flow meters for the collector lines feeding into the treatment plant.

Figure 22: *Gallery locations, Bonriki water reserve.*

2.7.2. Flow meter installation

The 10 flow meters and fittings were purchased under the project in order to assist PUB with ongoing accurate recording of abstraction. Meter specifications were developed in consultation with PUB staff, and included eight 50-mm Kent Elster H400 flow meters and two 100-mm Kent Elster H400 flow meters, similar to what was already in use in the water reserve. The materials were shipped directly to PUB to fit the new meters.

Flow meter installations by experienced PUB staff took place in mid-2013 using the existing or similar setup configurations with replacement gate valves, pressure valves, and PVC pipe and fittings as needed. The eight 50-mm flow valves were installed to replace ageing meters or meters suspected of incorrect reading, and one 100-mm flow meter that was used at one of the collector lines feeding into the treatment plant.

A typical setup of the replacement flow meters installed can be seen in Figure 23.

Figure 23: *Replacement flow meter installed in gallery 15.*

Recommended practice is to have a length of straight pipe, equivalent to 10 times the diameter of the pipe being used, run upstream, and a length of straight pipe, equivalent to 5 times the diameter of the pipe being used, run downstream of any flow meter installation in order to ensure compliance with recommended practice. The configuration above does not allow for this setup to be followed due to constraints in the pump station housing. The distorted flow could result in increased turbulence that in turn would result in faster flow causing the meter to read incorrectly (Figure 24).

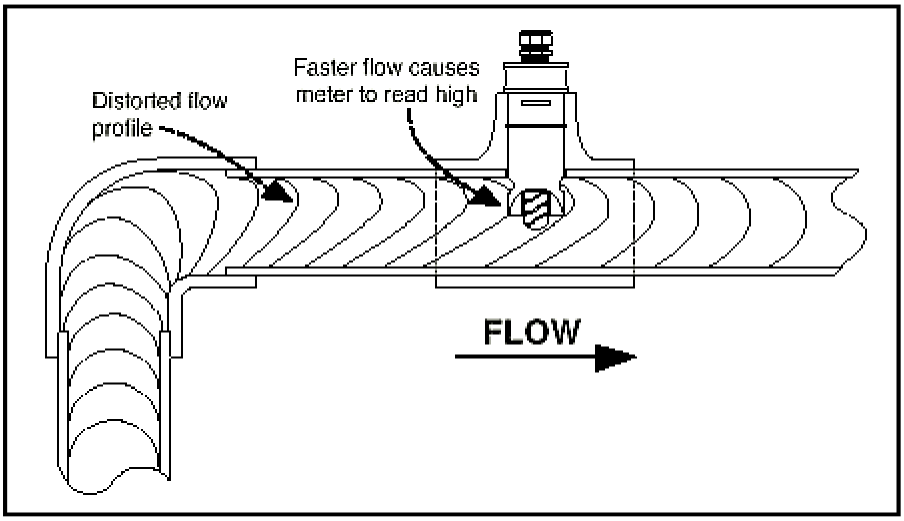

Figure 24: *Image of distorted flow due to elbow in pipe immediately upstream of flow meter, resulting in a higher reading (http://www.globalw.com/support/strtflow.html accessed 3/2/2014).*

The installed flow meters are capable of reading to the nearest litre, with the use of X0.1 m^3, x0.01 m^3 and x0.001 m^3 dials as shown in Figure 25. In practice, however, the meters are often read to the nearest KL with the use of barrel readings for recording in the field books by PUB staff.

It is recommended that flow meter installation is set up to conform to the recommended installation guidelines to ensure accurate readings and that the minimum amount of straight pipe upstream and downstream is used in the future.

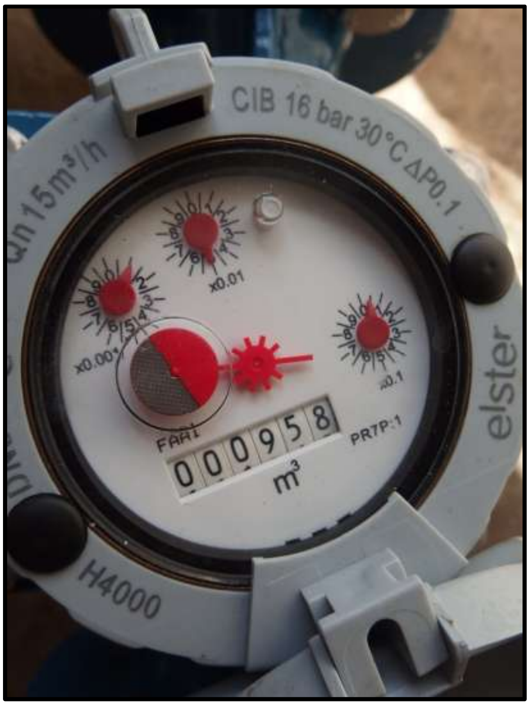

Figure 25: *A 50-mm Kent Elster H400 flow meter reading 958.051 m^3.*

2.7.3. Data collection

The daily recorded master meter flow records for both Buota and Bonriki and the monthly recorded individual gallery readings are recorded in a field book by PUB staff with records transcribed in Betio by PUB staff to the *water master sheet.xls* and individual monthly records (e.g. Bonriki Galleries water data Nov 2013.xls*).* However there is difficulty in compiling a complete record due to number of missing records.

The fixed Bonriki main meter, 'Bonriki Main Meter', at the treatment plant includes a combined flow of both the abstraction from Bonriki and the abstraction from Buota. There is also a fixed flow meter for Buota, 'Buota Main Meter', which allows the contribution from each of the well fields to be determined. Due to a broken pipeline from Buota to the Bonriki treatment plant no flow was received from Buota for the period June 2008–September 2012 inclusive. During this period the records indicate that the entire flow was sourced from the Bonriki well field.

Figure 26 indicates the abstraction and combined sustainable yield estimates over time for the combined flow from both Bonriki and Buota water reserves. Also identified are abstraction and sustainable yield estimates for the Bonriki water reserve only over time. It is interesting to note that recent abstraction is close to the estimated sustainable yield for both Bonriki and Buota.

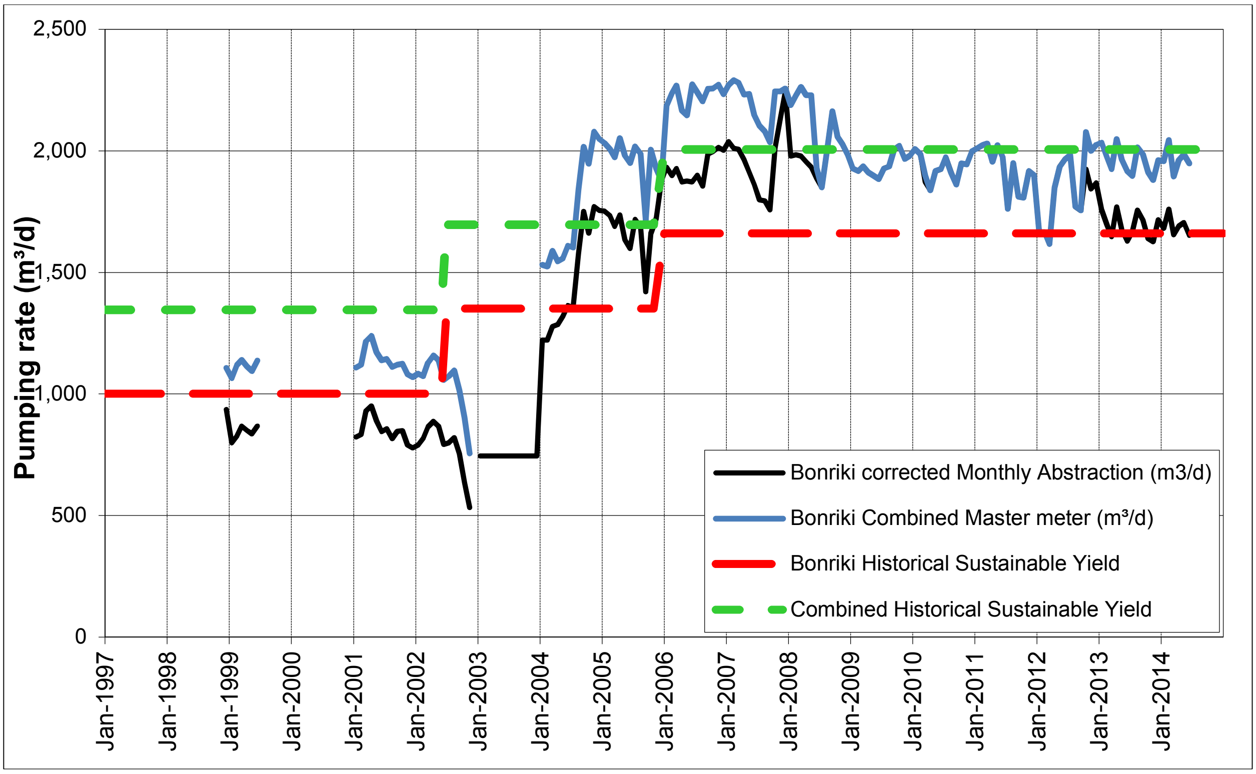

Figure 26: *Historical sustainable yields for both Bonriki, and Bonriki and Buota combined compared against the abstraction for Bonriki only and combined abstraction for both Bonriki and Buota.*

An analysis of the average monthly abstraction from the Bonriki water reserve suggests that there is increased abstraction during the last quarter of the calendar year, at a time when average rainfall leading into December is lower, suggesting some seasonality associated with the abstraction, and increased abstraction during drier periods (Figure 27).

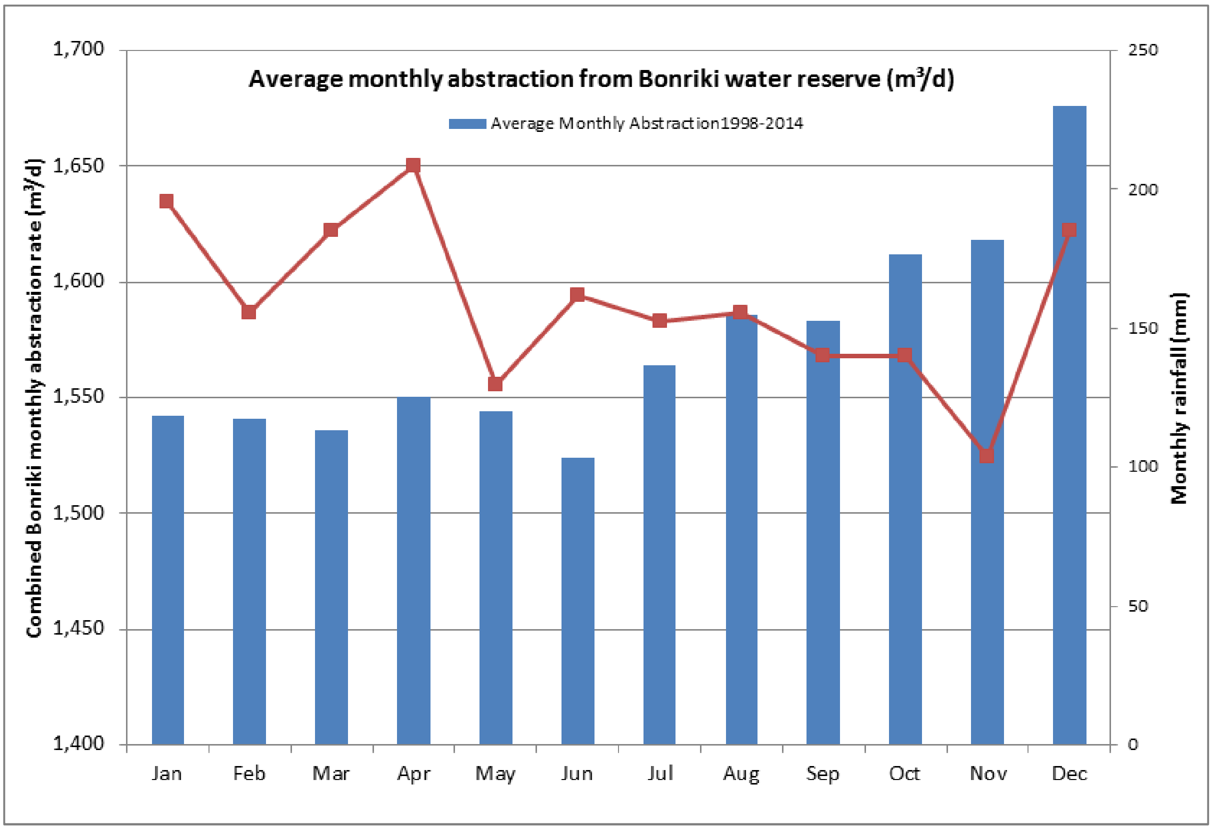

Figure 27: *Average monthly abstraction for the period 1999–2014 for the Bonriki water reserve and average rainfall.*

For a comparison with PUB records, an inspection of individual galleries was made and additional instantaneous flow rate measurements were taken in November 2013 and again in February 2014. The results from these are shown in Table 5.

At the time of the inspection in November 2013, 17 of the 22 infiltration galleries were operational. Three months later in February 2014, only 15 pumps were operational. A comparison between the instantaneous flow rates and the measured flow rate over the three-month period indicates reasonable alignment for at least seven of the galleries to the instantaneous flow rates, suggesting consistency in the flow meter readings and confidence that the pumps for which readings were available had (mostly) been operating continuously over that three-month period at the prescribed rates. During this period five galleries had been fitted with a new flow meter so it was not possible to get a longer-term comparison using the recorded metered volume; however, a comparison of instantaneous flow rates indicates reasonable alignment between the instantaneous flow rates. Based on observations and readings, it is recommended that new meters be installed for galleries 2, 7, 10, and 20, and for Bonriki Main Meter and Buota Main Meter.

In November 2014, Posch and Partners in collaboration with MPWU using ultrasonic flow meters (UFM) undertook leakage studies. During the course of their investigations they measured the flow leaving the Bonriki master meter. The study indicated a difference between the fixed Bonriki flow meter and the ultrasonic flow meter, with the Bonriki master meter identified as over reading the flow volume leaving the treatment plant at Bonriki by 16% (i.e. all readings from the master meter, according to this investigation, would need to be reduced by 16% (Schwaiger and Skerjanz 2014).

This information came to light after the project had completed its field work and was finalising the presentation to GOK. A reduction in abstraction of 16% will have an impact on model results. Given the potential importance of the reduced abstraction it was determined, in collaboration with PUB staff and Kiribati Adaptation Program III consultant, that additional tests on the Bonriki master meter at the treatment plant should be undertaken and include a measurement of flow at each of the gallery meters. This investigation was undertaken by trained PUB staff between 17 and 21 December 2014. The recommended approach to the flow meter testing and results from this investigation is provided in Annex 9.

Individual gallery meters, when compared with the UFM, give a wide range of results with some gallery flow meters indicating over-reading, and others under-reading. The range indicated is -186% to +41%, (+ is over reading, - is under reading), with the majority (70%) of fixed meters over-reading by an average of 25%.

The results from the additional investigation also indicate that the main meter at the treatment plant is indicated to be, on average, reading 17% higher than the UFM. Falkland (pers. comm. January 2015) acknowledges the age of the current flow meter at the Bonriki treatment plant and recommends its replacement, suggesting caution in assuming that this flow meter is indeed reading incorrectly. He offers the following reasons for why the UFM could be under-reading:

- Installed meters (tend to under-read over time but not over-read).
- The potential for air entrainment in the pipe where the UFM was installed.
- Incorrect spacing of the sensors (based on wrong pipe dimensions and other parameters).
- Incorrect input parameters, including the pipe’s outer diameter and wall thickness, the material of the pipe, water temperature, and sensor temps.

Falkland (pers. comm. January 2015) recommends additional meter testing to help resolve the issue of meter accuracy and to improve confidence in the available data. These recommendations are in Annex 9.

Falkland (pers. comm. January 2015) advises at this stage to not assume that the lower flow measurements from the UFM are necessarily more accurate than the main meter for the total Bonriki and Buota outflow until additional testing is carried out. In the mean time, he recommends treating the main meter flows as correct.

***Table 5:** Instantaneous flow rate measurements at Bonriki pumping stations.*

	November 2013						February 2014								
Gallery pump No.	**Date**	**Time**	**Operating**	**Flow meter KL**	**Flow rate L/sec**	**Conductivity EC µS/cm**	**Date**	**Time**	**Operating**	**Flow meter KL**	**Flow rate L/sec**	**Conductivity EC µS/cm**	**Flow Nov. 2013 to Feb. 2014 m^3/day**	**Estimated flow rate L/s**	**Comments**
1	19/11/2013	12:18	no				4/03/2014	11:00	No						no pump, not working since before June 2013, no electricity
2	19/11/2013	11:58	no				4/03/2014	11:10	No						no pump, no meter, since before September 2013 non-operational
3	19/11/2013	12:02	yes	109309	2.04		4/03/2014	11:15	Yes	124889	1.67	495	148.4	1.7	No access to well for WL measurement
4	19/11/2013	11:50	yes	705881.8	1.18	814	4/03/2014	11:50	Yes	1038	1.25	858			old flow meter Nov 2013, new BIVA flow meter Feb 2014
5	19/11/2013	11:43	yes	76461	1.35	1,260	4/03/2014	10:35	Yes	87570	1.25	1,325	105.8	1.2	
6	19/11/2013	11:37	no	21907		624	4/03/2014	10:40	No	21907		492	0.0	0.0	new pump is needed
7	19/11/2013	11:29	yes	26030	0.99	725	4/03/2014	10:50	Yes	31123		661	48.5	0.6	Flow meter is not working (Feb 2014)
8	19/11/2013	11:11	yes	64429	1.33	1,143	4/03/2014	10:30	Yes	76226	1.32	1,216	112.4	1.3	
9	19/11/2013	14:49	yes	651511.3	1.15	1,063	4/03/2014		Yes	726	0.91	930			old flow meter Nov 2013, new BIVA flow meter Feb 2014
10	19/11/2013	14:56	no	34602		817	4/03/2014		Yes	35415			7.7	0.1	meter and pump not working since before June 2013, pump repair required
11	20/11/2013	11:11	yes	128574	1.54	886	4/03/2014		Yes	142041	1.67	640	129.5	1.5	
12	19/11/2013	15:05	yes		0.83		4/03/2014		No						large concrete blocks preventing access est'd flow rate from meter
13	19/11/2013	15:10	yes	485978.4	0.64	736	4/03/2014		Yes	572	0.67	712			old flow meter Nov 2013, new BIVA flow meter Feb 2014
14	20/11/2013	11:00	yes	110852	1.37	876	4/03/2014	13:30	Yes	119787		816	85.9	1.0	Feb 14 comment – meter not working
15	19/11/2013	15:23	yes	958	1.19	975	4/03/2014		Yes	9821	1.43	996	84.4	1.0	new flow meter SPC BIVA installed circa Nov 2013
16	19/11/2013	15:43	yes	597371.6	0.99	838	4/03/2014		Yes	917	1	729			old flow meter Nov 2013, new BIVA flow meter Feb 2014
17	19/11/2013	15:52	yes	618116.8	0.54	888	4/03/2014		Yes	342	0.4	732			old flow meter Nov 2013, new BIVA flow meter Feb 2014
18							4/03/2014		No	8867				0.0	not visited in Nov 2013

	November 2013						February 2014								
Gallery pump No.	**Date**	**Time**	**Operating**	**Flow meter KL**	**Flow rate L/sec**	**Conductivity EC µS/cm**	**Date**	**Time**	**Operating**	**Flow meter KL**	**Flow rate L/sec**	**Conductivity EC µS/cm**	**Flow Nov. 2013 to Feb. 2014 m^3/day**	**Estimated flow rate L/s**	**Comments**
19	19/11/2013	15:32	yes	280371	0.72	1,114	4/03/2014		Yes	286987	0.71	1,173	63.0	0.7	meter stopped repaired on 20/11/2013 and operating again
20	19/11/2013	16:21	yes	216280		501	4/03/2014		No	219660		385	32.2	0.4	flow meter not working
21	19/11/2013	16:14	yes	321314	1.32	647	4/03/2014		Yes	332080	1.43	483	102.5	1.2	PUB old meter flow
22	19/11/2013	16:07	yes	329419	1.32	1,344	4/03/2014	13:20	No	341070	1.43	951	111.0	1.3	PUB old meter flow

2.8. Downhole loggers

Schlumberger CTD (conductivity, temperature and depth) 'diver' loggers are frequently used to record conductivity, temperature and pressure information in monitoring boreholes over an extended period without the need for manual measurements. The pressure data also records the barometric influence on the groundwater, which is compensated for with a separate logger that records barometric influence only (referred to as a 'baro diver'). The compensated 'diver' data is used to analyse changes in the water level due to tides, recharge and abstraction impacts. Ten diver loggers were installed to assist with field investigations.

2.8.1. Diver location

The divers were distributed across the study area in existing or constructed piezometers to provide sufficient spatial distribution in sites of interest in which existing information was available. The location of the divers is shown in Figure 28.

Figure 28: *Location of the 10 conductivity, temperature, and depth divers (divers installed November 2013 to March 2014, green colour, and divers installed November 2013 to June 2014 red colour). The barometric diver was located at monitoring borehole BN26.*

Data collection

CTD divers were installed in 10 selected wells within the water reserve, to investigate temperature, pressure and conductivity changes in the groundwater over a continuous period of 3.5 months, November 2013–March 2014, in order to determine the hydraulic connection between the unconsolidated sediments and oceanic influences, and as a guide to determining the tidal influence on the aquifer, and observe any recharge responses from rainfall occurring over the monitoring period. Loggers in four boreholes were retained until June 2014.

CTD divers were set to record data on conductivity, temperature and pressure every 30 minutes. Loggers were installed inside the 50-mm PVC piezometers, suspended on stainless steel wire at a depth that ensured they were situated within the screened portion of the piezometer, thereby providing some confidence that the formation water was being sampled.

A barometric logger was installed in monitoring borehole BN26 throughout the period to compensate for barometric influences. The barometric data logger failed from March to June 2015, and despite being returned to the supplier the data could not be retrieved. While not being able to remove the barometric pressure effects on the diver data limits the accuracy of the data, the data are still useful in being able to identify water level movements from other influences such as tides and recharge.

Diver data were collected every three months during scheduled field trips, during which time manual water level and salinity readings were taken. In most cases the logged data from the divers provided an accurate record, although in the case of BN20, the drift in the logger from November 2013 to March 2014 rendered the retrieved data unsuitable for analysis.

Five divers were installed in the newly constructed piezometers shortly after their completion. These piezometers were constructed with a ‘coral gravel’ pack around the screen of the piezometer, with 1–2m^3 of gravel pack placed in each piezometer pit. The materials used for this ‘coral gravel’ pack, believed to have been sourced from the lagoon, were unwashed. The salts contained within the sediments influenced the salinity of the water that was in contact with it. While this effect was unintentional, it did provide the project with an opportunity to study the dispersion of the introduced salt pulse over time, with diver loggers providing insight into this process. The plots from each of the diver loggers for the available period are provided in Annex 10.

2.9. Water quality

The Bonriki water reserve provides the majority of freshwater for South Tarawa. In recent years it has been the subject of increased encroachment from squatters in response to limited availability of space for housing, extractive industries such as sand and gravel mining and brick making, agricultural use such as small vegetable gardens, *babwai* pits, and small-scale pig farming. There is concern that these recent activities within the water reserve place additional threats to the water quality of the freshwater lens. The project provided an opportunity to undertake some basic bacteriological sampling and a field analysis to both provide some baseline information and determine if any impact to the water quality from current land-use activities can be identified.

2.9.1. Bacteriological sampling and analysis methodology

Bacteriological sampling was undertaken from existing monitoring boreholes using the available piezometers and sampling tubes. Sampling was carried out at the same time as the borehole monitoring during two field campaigns, November 2013 and February 2014, and followed standard sampling approaches using sterile sample bottles, with samples kept cool in a field esky prior to analysis within 24 hours of sample collection.

Sample preparation relied on pre-prepared disposable petri dishes and used membrane filtration methodology to determine the most probable number of colonies for total coliforms and *Escherichia coli* (*E. coli*). Annex 11 provides details on the methodology of the 'EC compact dry' analysis technique used and results from the sampling.

The location of the samplings undertaken during each campaign (November 2013 and February 2014) are identified in Figure 29 and Figure 30, respectively.

Figure 29: *Location of bacteriological sampling sites for November 2013.*

Figure 30: *Location of bacteriological sampling sites for February 2014.*

2.9.2. Results

In total, 60 samples were collected and analysed during the two field campaigns (November 2013 and February/March 2014). Sampling was restricted to the top 12 m of the freshwater lens, from discrete points. It was considered that this would be the most important zone for water quality because the water abstracted from infiltration galleries is generally from within the first 2 m of the saturated zone, and where one would expect contamination from surface infiltration to be first detected.

E. coli is found in the gut of warm-blooded animals, and is a useful indicator for potential contamination from pathogens. A practical guide on the suitability of water for potable purposes is provided by Wisner and Adams (2002).

Results from the sampling are provided in Annex 11, with a summary of the results from the two field campaigns in Table 6.

Table 6: *Summary of results from bacteriological sampling November 2013 and February 2014, Bonriki, Tarawa.*

Escherichia coli/100ml	Classification	Nov 2013 No. of samples	Feb 2014 No. of samples	Total No. of samples	% of samples
0	Guide compliant	15	27	42	70%
1–10	Tolerable	2	0	2	3%
10–100	Requires treatment	2	1	3	5%
>100	Unsuitable without proper treatment	6	7	13	22%
		25	35	60	100%

3. Analysis

3.1. Hydrogeology

3.1.1. Background

Over the years, there have been a number of investigations of the potential of the Bonriki freshwater lens, which have been referred to during the course of this project (AGDHC 1982; Falkland 1992; Falkland and Woodroffe 1997; Falkland and White 2001; Falkland et al. 2004; Murphy 1981, 1982, 1984, 1986, 1987). These sources provide background information on the hydrogeology of the Bonriki water reserve and include drilling and monitoring data and some previous geophysical investigations.

Current investigations build on this existing information and provide additional information to assist with the development of the conceptual and numerical groundwater models; they also, include additional water level and salinity information in addition to geophysical investigations to assist with conceptual modelling of the freshwater lens.

Geological cross sections were constructed (Bosserelle et al. 2015) based on existing drilling logs and are presented as Figure 31. Sections represent the Bonriki aquifer as a series of stacked Holocene sand and gravel sediments deposited over an erosional Pleistocene limestone surface.

The resulting freshwater lens contour maps from the monitoring records for 2013–2014, and EM34 and resistivity data, are used to develop a picture of the Bonriki freshwater lens for the period April 2013–June 2014 (Figure 32, Figure 33 and Figure 34).

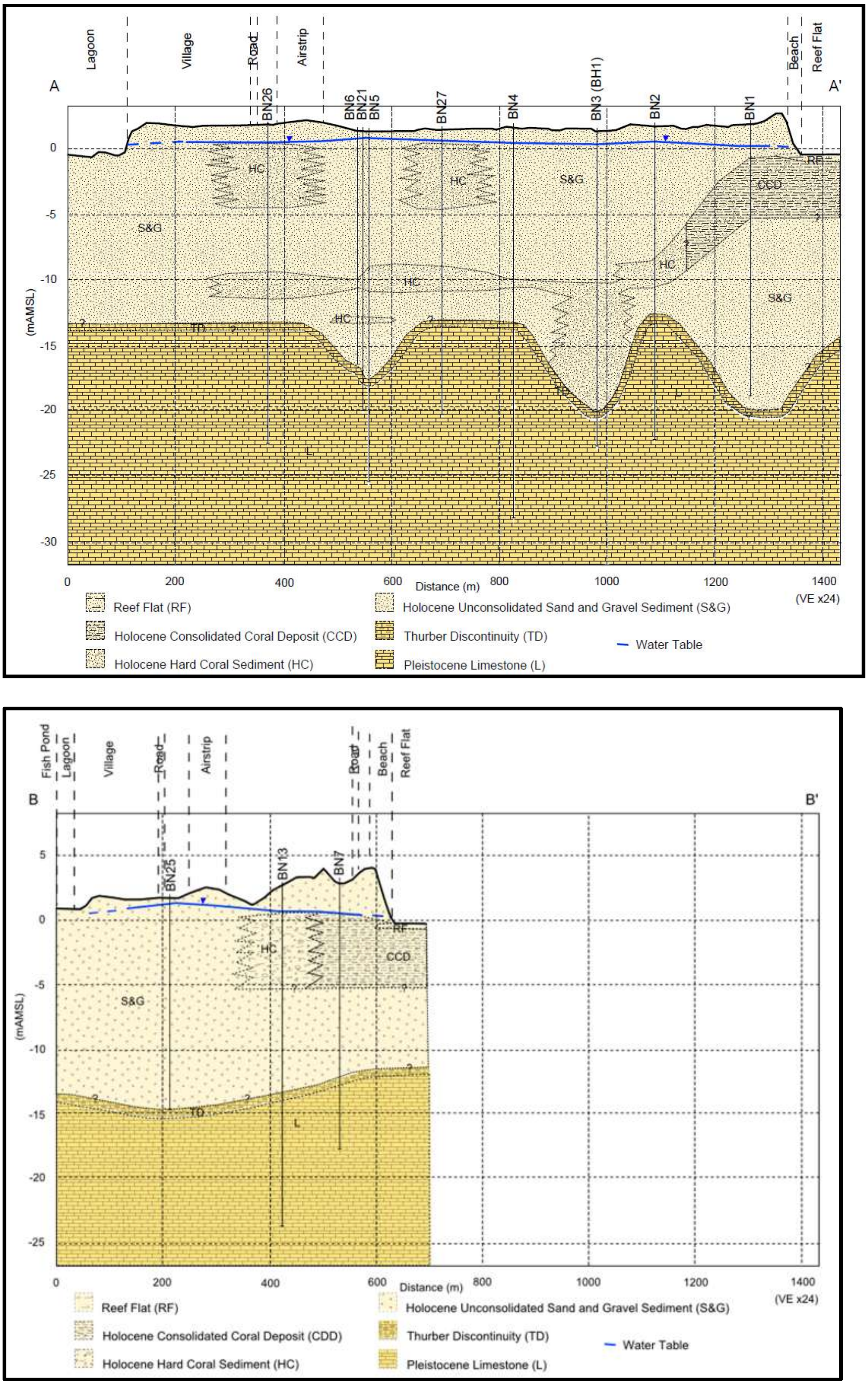

__Figure 31:__ Cross sections constructed from interpreted drilling logs (Bosserelle et al. 2014).

Figure 32: *Contour map of the freshwater lens thickness from monitoring boreholes averaged over 2013–2014, with cross section profiles A–A' and B–B'.*

Figure 33: *Contour map of freshwater lens thickness from EM34.*

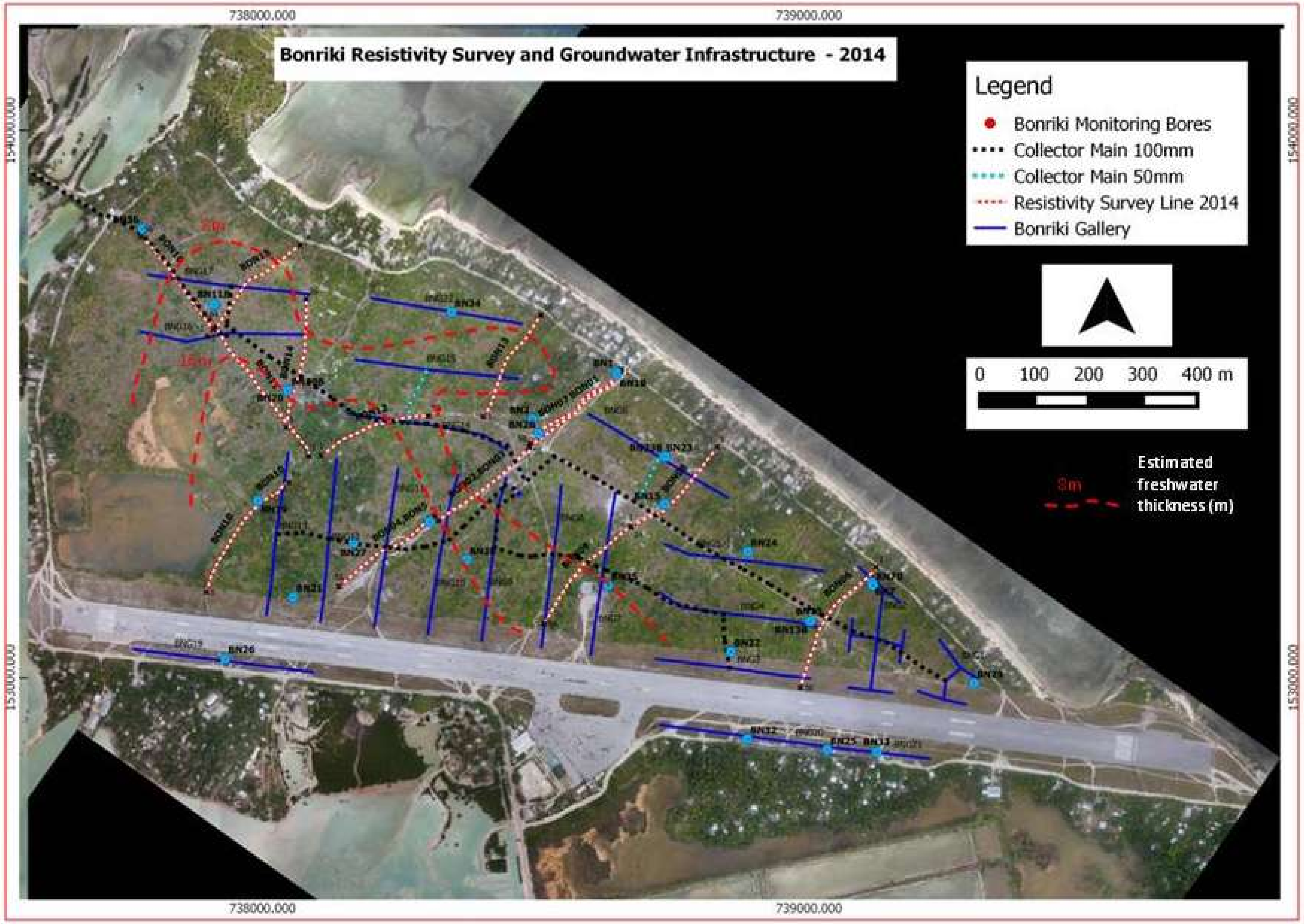

Figure 34: *Contour map of freshwater lens thickness from resistivity.*

The freshwater lens thickness profiles from the different approaches give some insight into the shape and extent of the freshwater lens. The monitoring boreholes and the resistivity profiles clearly indicate that the thickest part of the freshwater lens is towards monitoring boreholes BN19, BN20, BN21 and BN27. An additional freshwater lens of thickness near BN25, BN32 and BN13 has been identified by the EM34 survey and the water level monitoring boreholes.

Resistivity also gives an indication of the uneven surface of the underlying Pleistocene surface which is indicated in the cross sections. This uneven surface appears to be a subdued karstic surface and is more pronounced in the shallower portion of the aquifer. There is also an increasing depth to the Pleistocene limestone with increasing distance from the ocean.

The average water levels from the monitoring boreholes, which were taken during the 2013–2014 project period, were contoured using Surfer software to provide a water table elevation plan for 2013–2014 water levels relative to the 2013 mean sea level. The plan provides an indication of the groundwater mounding that can be observed, and the presence of two discrete lobes of groundwater. The groundwater flow paths have been added to indicate the general flow of groundwater that can be expected (Figure 35).

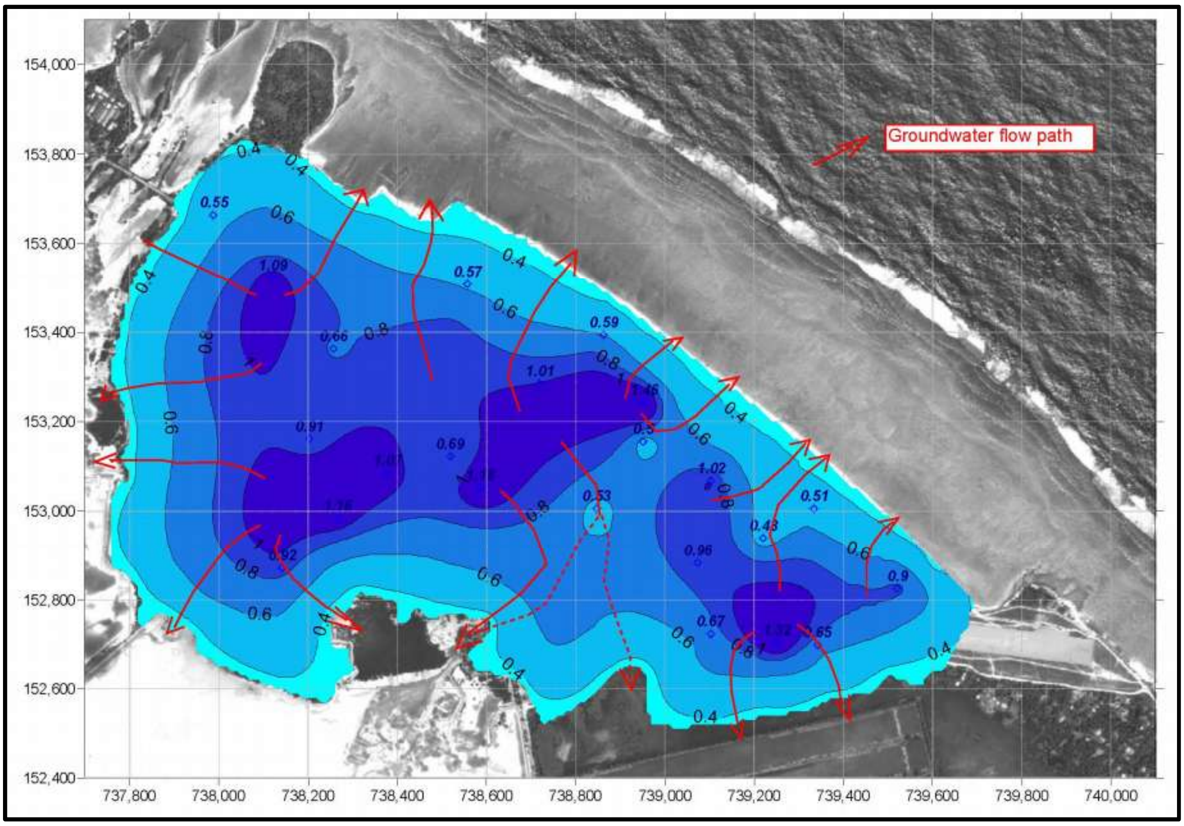

Figure 35: *Averaged water table elevations 2013–2014 relative to 2013 mean sea level, with annotated groundwater flow directions.*

3.1.2. Seasonal variation

During the 15 months of monitoring under the BIVA project (April 2013–June 2015), abstraction averaged 1689m^3/day, and rainfall over the period (average of 2300 mm) was slightly higher than the average over the last 30 years (2260 mm). Rainfall distribution was heavily weighted to the four months of March 2014 to June 2014 when 1088 mm, or 47%, of the total rainfall received fell during this period. That is, the monitoring observed mostly dry conditions during the first 11 months of the investigation followed by a significant and sustained recharge event for the remaining 4 months of investigation.

Quarterly monitoring of the boreholes over this period allowed for an interpolation of a salinity surface with depth, which when plotted over time, provides a picture of the expected trends in the freshwater lens and the behaviour of the groundwater at that location in response to climate and abstraction impacts.

Plots were generated for each monitoring borehole at interpolated electrical conductivity (EC) levels of 2,500 µS/cm, 10,000 µS/cm, and 25,000 µS/cm over the investigation period and in seven selected boreholes over a longer record period to provide reference to the current salinity surface with history. These plots are presented in Annex 12.

A general thinning of the freshwater lens was observed in all monitoring wells from April 2013 to February 2014, followed by a recharge event March 2014 to June 2014. It is possible to determine at each salinity surface for all boreholes both a rate of decline in the freshwater lens during the dry period, and a rate of thickening of the freshwater from March to June 2014 (Table 7).

Table 7: *Estimated rates in mm/day in which the freshwater lens can thin during a dry period and thicken during a recharge period.*

	2,500 µS/cm interpolated surface	10,000 µS/cm interpolated surface	25,000 µS/cm interpolated surface
Average rate of lens thinning during dry period mm/day	-6.0	-5.3	-1.3
Maximum rate of lens thinning during dry period mm/day	-27.7	-40.6	-7.9
Minimum rate of lens thinning during dry period mm/day	3.5	9.5	4.9
Standard deviation of lens thinning during dry period mm/day	9.1	12.0	3.2
Average rate of lens thickening during wet period mm/day	16.9	12.4	5.7
Maximum rate of lens thickening during wet period mm/day	88.0	116.7	12.5
Minimum rate of lens thickening during wet period mm/day	-1.8	-0.5	-1.0
Standard deviation of lens thickening during dry period mm/day	23.0	26.5	4.0

The results from this analysis suggest that over the climatic and abstraction conditions present during the study, the rate at which the freshwater lens thins was slower than the rate at which the lens was able to recover or thicken during a significant recharge event. It would also appear that the average rate of thinning and thickening decreases with depth; that is, less change in the position of the interpolated salinity surface is experienced at depth. However, the interpolated transition zone of 10,000 µS/cm appears to experience the greatest range of change and greatest variability as indicated by the maximum and minimum rates of thickening and thinning and the standard deviation, respectively.

This has implications for monitoring, and suggests that sampling tubes in the transition zone are important because they are most likely to experience the change in the salinity from climatic and abstraction impacts.

The data also demonstrate that the freshwater salinity surface, 2500 µS/cm, is more dynamic than deeper interpolated salinity surfaces. On average, the upper portion of the freshwater lens, <2500 µS/cm, demonstrates that the greatest overall thinning impact and during a recharge event will respond with, on average, greater thickening than deeper in the freshwater lens profile.

3.1.3. Tidal impact

As the tide rises and falls in the ocean and lagoon, it forces the aquifer water to also fluctuate, albeit with a smaller amplitude and 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's materials determines the efficiency with which the tidal pulse is transmitted from place to place.

Tidal lag is simply the time difference between, for example, 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%.

Tidal efficiencies and lags reflect the amount of tidal influence or 'hydraulic communication' of various portions of the aquifer with the ocean and lagoon. Higher efficiencies and shorter lags indicate a greater amount of influence or communication with the ocean, and are expected to be found at sites relatively close to the shoreline although this is not always the case. Similarly, tidal efficiencies increase consistently with depth, and tidal lags decrease consistently with depth (Hunt and Peterson 1980).

Several factors complicate the tidal picture:

- pockets of heterogeneous material that 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 lagoon sides, creating complicated interference effects, especially toward the centre of the island;

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

Table 8 is a summary of the tidal lags and efficiencies calculated for the Bonriki water reserve and incorporates the results from the diver loggers installed in nine wells under the BIVA project and calculations made by Falkland and White (2001). Note that the maximum and minimum tidal range is on the order of 2.2 m and 0.5 m with an average tidal range of 1.4 m.

Table 8: *A summary of logger data records and calculated tidal lags and efficiencies for Bonriki.*

Location	Distance from closest water body, ocean or lagoon (m)	Tidal lag (hours)	Tidal efficiency	Estimated depth of Holocene sands to Pleistocene limestone (mbgl)
BN1B	80	1.9	8%	-17.7
BN2B	270	2.3	6%	-11.7
BN4C	500	0.5	32%	-11.8
BN7B	90	1.5	7%	-11.1
BN21	380	0.9	17%	-15.1
BN26	260	1.1	14%	-11.6
BN36	110	1.3	14%	-11.9
BN32	450	0.7	9%	-10.7
BN29	90	2	6%	-9.0
PS1	130	2.5–3	4%	-10.0
PS7	350	2.5	4%	-12.8
PS16	275	2–2.25	7%	-11.6
PS18	365	2.75	5%	-10.9
Average	**258**	**1.7**	**10%**	**-12**

Tidal data have been plotted to give an indication of the distribution of the tidal lag and efficiency with distance to the closest tidally influenced water body (Figure 36). There is an expectation that for measurements at similar depth (i.e. to the top of the water table), the tidal lag would increase with distance from the tidally influenced ocean or lagoon, and that tidal efficiency would decrease farther away from the ocean or lagoon. This does not appear to hold true for Bonriki for all sites, however. BN4C indicates that despite a significant distance from the closest tidally influenced water body, there is good communication, high efficiency and low tidal lag. This suggests a geological anomaly, allowing the tidal pulse to be registered more quickly than expected.

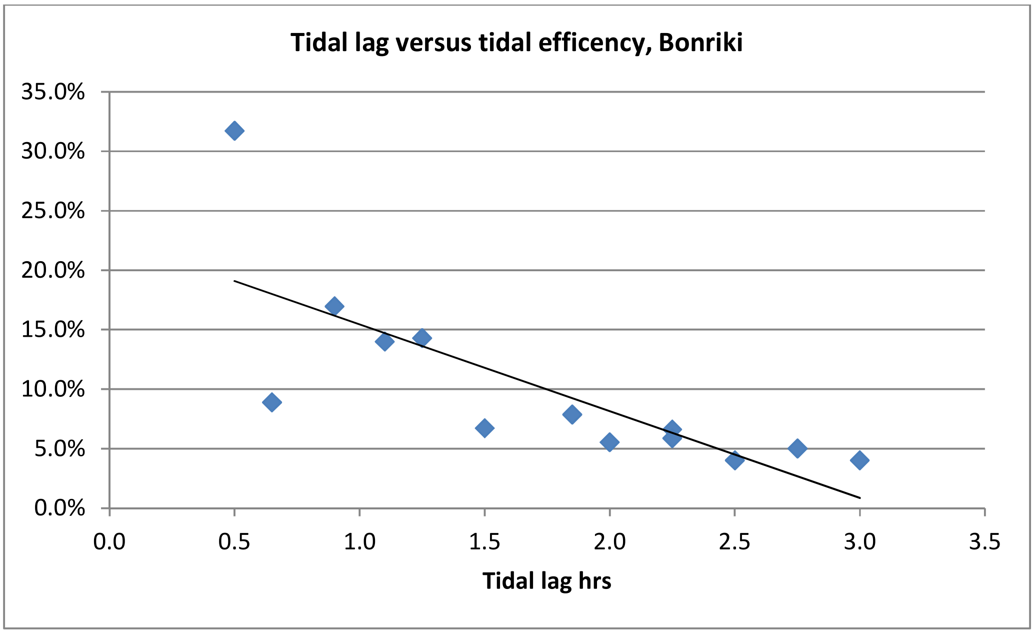

Figure 36: *The relationship between tidal lag and tidal efficiency for selected monitoring boreholes in Bonriki. Note that BN4C, with a high tidal efficiency of 32% is an anomalous reading.*

3.2. Recharge

The spatial and temporal variability of recharge is one factor that influences the thickness of freshwater lenses on atoll islands. Rainfall has a strong control on fresh groundwater occurrence (Falkland 1992) in Tarawa, which is affected by the El Niño–Southern Oscillation (ENSO) phenomenon. The Southern Oscillation Index and annual rainfall are strongly correlated for Tarawa. Droughts related to ENSO events have a direct impact on the recharge to the atoll's groundwater, with a decrease in the thickness of freshwater lenses and an increase in the salinity of groundwater (Alam and Falkland 1997; White et al. 2005).

3.2.1. Rainfall response

Diver loggers in selected piezometers and the results from the scheduled manual monitoring were used to investigate the response of the freshwater lens to rainfall events. It was possible to infer zones of higher and lower water level fluctuations in response to rainfall events, which are suggested to indicate spatial variation in recharge across the water reserve. This information, together with the analysis of the changes in freshwater thickness due to rainfall, was used to determine the spatial distribution of recharge in the groundwater numerical model of Bonriki. The plots of diver loggers for the selected piezometers are provided in Annex 10, and for salinity monitoring of monitoring boreholes in Annex 12.

Local runoff and ponding are important causal factors that influence the spatial variability in recharge, combined with differences in soil and aquifer properties, and the proximity to surface water bodies and the ocean. Water level responses to rainfall events were observed only at some specific locations, while other observation wells remained unchanged. Monitoring sites with diver loggers installed, adjoining the airstrip or close to the freshwater ponds, locations BN21, BN26, BN29, BN32 and BN20 (Figure 30), all show an instantaneous water level response to rainfall events. Monitoring boreholes BN1B, BN2B, BN4C, BN7B and BN36, located away from the airstrip and on the peripheral extents of the water reserve, do not demonstrate such a water level response to recharge.

Similarly, a review of the freshwater lens thickness from the monitoring boreholes has been used to assess the change in thickness of the freshwater lens over time in response to rainfall in order to provide an indication of recharge and discharge response time and amount relative to other locations. It was identified from an analysis of the freshwater lens thickness that some monitoring boreholes indicated a significant and measurable response to rainfall events, with an observable increased thickness in the freshwater lens or freshening of the freshwater lens, while other monitoring boreholes did not demonstrate an observable response or the response was delayed.

In some cases this thickening or freshening of the freshwater lens correlated with the water level response; that is, for boreholes farther from the ocean or the lagoon, which indicated a water level response, also demonstrated a rapid freshening of the freshwater lens at BN21 and BN19. Monitoring boreholes sited closer to the lagoon or the ocean, which also indicated a water level response to rainfall, did not demonstrate any significant thickening or freshening of the freshwater lens. This was interpreted to be indicative of higher discharge to the nearby ocean or lagoon from these areas (e.g. BN26, BN25, BN32 and BN33).

A plan of recharge response is provided in Figure 37, which shows the zoning of the recharge response and relative amounts of recharge compared with other locations in the water reserve. Recharge is a function of proximity to islet edges, topography, hardstand areas and drainage, geology, and vegetation cover. Note that the boundaries of each zone should not be considered as 'hard boundaries' but rather a gradation from one zone to the next, reflecting the gradational changes in the factors affecting recharge.

Figure 37: *Estimated response recharge or discharge across the Bonriki water reserve.*

3.2.2. Water level and salinity analysis of recharge

A comparison of the diver data collected from November 2013–March 2014 indicates that rapid water level responses were observed in monitoring boreholes BN21, BN26, BN29, BN32 and BN20, which are located close to the airstrip or the freshwater ponds. Boreholes BN1B, BN2B, BN4C, BN7B and BN36 do not demonstrate an observable response to rainfall events (see Annex 10).

The rapid water level response observed in BN21, BN26, BN29 and BN32 is associated with tarmac runoff on the sides of the runway, which causes increased infiltration in the surrounding area. The monitoring site located close to the lakes, BN20, also shows a quick response to rainfall events, with peaks in the water table elevation. The response to rainfall events for BN20, which is close to the freshwater ponds, is less marked in the location close to the ponds than in locations adjoining the runway. For example, on 17 March 2014, 111 mm of rainfall fell on Bonriki, leading to water level responses towards the runway between 0.7 m and 0.81 m, while in the vicinity of the ponds the increment of the water level was lower, at only 0.54 m (Table 9).

Table 9: *Water table fluctuations in locations that show response to significant rainfall events.*

Date of significant rainfall event	Rainfall (mm)	Water level increment (m)				
		BN21	BN26	BN32	BN29	BN20B
24/12/2013	48.0	0.30	0.30	0.33	0.09	
28/12/2013	34.3	0.23	0.32	0.24	0.08	
10/01/2014	44.0	0.30	0.37	0.31	0.12	
18/02/2014	32.0	0.18	0.30	0.20		
12/03/2014*	41.0	0.45	0.41		0.23	0.24
17/03/2014*	111.0	0.70	0.73		0.81	0.54

*Pressures readings are not compensated with barometric pressure.

The analysis of water level fluctuations from diver loggers indicated that monitoring sites close to the reef flat on the ocean side usually receive less recharge from rainfall than locations in the centre of the island towards the ponds and adjoining the airstrip. The response to rainfall events at BN1B, BN2B, BN4C, BN7B and BN 36 is not observable in the water level or in the EC readings at the watertable, indicating that recharge occurs at a lower rate or is a delayed response. It appears that these boreholes, except BN4C, share similarities in that they are located close to the ocean or edges of the islet, away from hardstand areas (e.g. the runway, and/or are in relatively elevated areas, and/or are in areas where reef flat rock is either exposed at the surface or close to the surface). Proximity to the coast, topography, and geology and to a lesser extent vegetation cover is identified as influencing the recharge distribution on Bonriki.

Water levels in all of the remaining monitoring boreholes that did not have divers installed in them were also reviewed. The time period between manual water level readings in monitoring boreholes is quarterly, and as observed in the diver loggers, recharge produces a rapid rise of the water level (Table 9). The frequency of the manual monitoring is insufficient to identify specific recharge events. Whilst some variation in the water level at quarterly monitoring can be observed in some boreholes it is not currently possible to isolate this water level response to recharge from other effects such as tidal impacts. While water level monitoring on a quarterly basis remains useful for other applications, it is insufficient to allow the investigation of recharge impacts. Recharge studies require the use of downhole water level loggers, such as divers, to help understand the dynamics of the groundwater system.

A correlation between water levels and salinity, as EC, against rainfall events was undertaken with diver loggers. In general, as can be expected, associated with an increasing water level after a rainfall event is a decrease in the EC in the piezometer, this is observed at monitoring locations BN20B, BN21, BN26 and BN32. However, at monitoring location BN29 rainfall events produce an initial increment in the EC of the piezometer followed by a gradual freshening of the shallow freshwater lens. It is suggested that at BN29 there is a source of salts, most likely airborne derived, that accumulate on the surface near the borehole. These salts infiltrate into the water table with rainfall, provoking a rapid and measurable rise in the EC in the piezometer, followed by a return to background salinity after the rain event has passed. It would appear to take up to four days for the salinity to return back to pre-rainfall salinity conditions following a significant rainfall event (Figure 38).

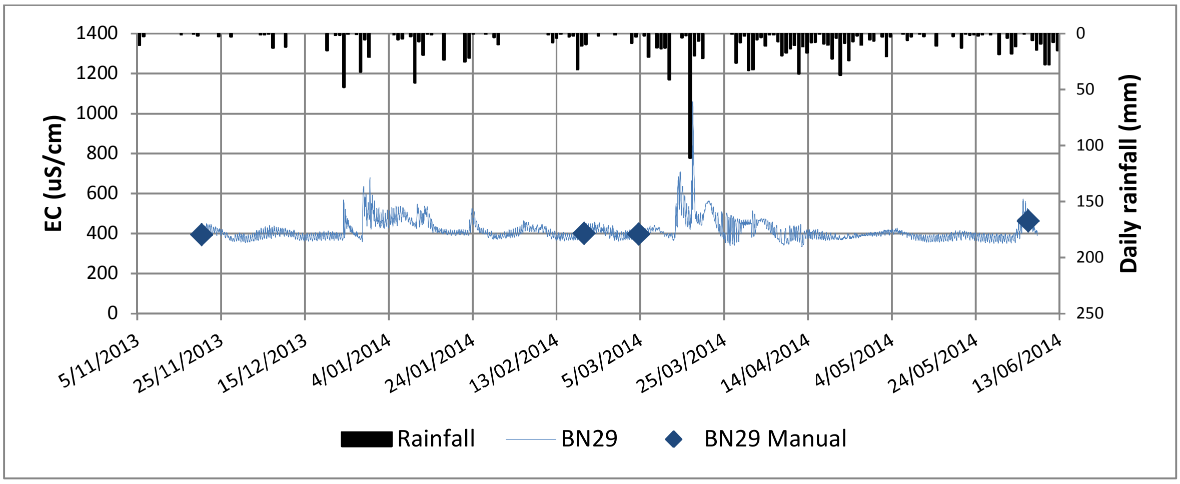

Figure 38: *Salinity response in monitoring borehole BN29 showing an increase in salinity immediately following a significant rainfall event.*

During the monitoring period, a high rainfall period occurred between 24 December 2013 and 23 January 2014, with 265.5 mm of rainfall, followed by a low rainfall period of 20 days between 24 January 2015 and 08 February 2014, with a total rainfall of only 15 mm. The EC of monitoring locations BN21, BN26 and BN32, which adjoin the runaway, show low EC values during the high rainfall period. However, the response of EC to the dry period varies considerably between the monitoring locations. For example, EC at BN21 is very sensitive to periods without rainfall, with a clear increment in EC of the water in the piezometer; whereas at BN26 and BN32, EC remains low for at least 15 days after the wet period has passed. These differences in the response of EC to dry periods could be related with the depth of the water table with respect of the ground surface and evapotranspiration process, and in conjunction with a tidal mixing response, where the rise and fall of the tides and the freshwater lens results in a mechanical mixing of the fresh groundwater with the underlying more saline groundwater. At BN21 the water table is shallower — on average 0.95 m below ground level (m BGL), while at BN26, the water table is deeper — on average 1.6 m BGL, which makes it less sensitive to evaporation or evapotranspiration processes.

The graphs in Annex 10 of BN21 indicate the manual salinity measurements taken on a quarterly basis with continuous readings observed. It is clear that while the manual readings at BN21 from November 2013 to February 2014 suggest a freshwater lens increase, this may not in fact be the long-term trend but rather a shorter response relative to a recharge event. Some care is required when interpreting the quarterly monitoring data in order to recognise the recharge response observed in some monitoring boreholes.

At monitoring location BN4C, located in the centre of Bonriki, water table variations do not show a clear response to rainfall events; however, the response can be observed, with major rainfall events of more than 30 mm, with a decrease of EC, which occurs approximately one day after the rainfall event has occurred. As mentioned in Section 3.1.3, water table variations at this location are highly influenced by the tides, showing good communication and possible heterogeneities within the Holocene sediments. However, the effect of the rainfall from recharge is observed through a decrease in EC values.

The remaining monitoring sites (BN1B, BN2B, BN7B and BN36), which are located close to the reef flat on the ocean side, do not show a response in the water table or to EC readings, indicating that recharge might be less or delayed compared with locations in the centre of the island towards the ponds adjoining the runway or that discharge is also higher in these areas making the freshwater lens appear to be more stable or less responsive to recharge.

3.2.3. Observations

The observations obtained from the available monitoring information highlight the importance of spatial variability of recharge from rainfall (see Figure 37). The observations were used to define zones with observable variable responses to recharge. These zones include:

- the safety zone adjoining the runway where the recharge is increased due to tarmac runoff;
- the ponds towards the west of the islet, which also present high recharge rates and rapid response;
- the inland region of Bonriki, which is a vegetated zone with low lying bushes, pandanus and coconut trees within which variability is observed in the recharge associated with the aforementioned vegetation cover, topography, location relative to the edges of the islet, and the surface and underlying geology. The eastern part of the reserve with its higher topography and exposure of reef rock in places is observed to be a moderate to low recharge zone with a slow or delayed response to recharge. The western part of the reserve is more likely to experience moderate to high recharge with a moderate response;
- the peripheral edges of the islet, which are considered to be a high discharge zone; that is, the recharge occurring in this zone becomes discharge and a water level response is less likely to occur, and only minor changes to freshwater lens thickness are observed.

3.3. Abstraction

3.3.1. Observations

The study by Posch and Partners in November 2014 (Schwaiger and Skerjanz 2014), and the follow-up investigations undertaken by PUB in December 2014 using the UFM, bring into question the recorded flow from the Bonriki Master Meter. The UFM testing undertaken suggests that the fixed flow meter at the Bonriki Master Meter is over-reading by 17%.

In addition, testing with the UFM of the fixed flow meters at the galleries was undertaken and the results suggest that there are inaccuracies in the fixed flow meter readings, which further suggest that a review of the fixed flow meters is needed. There is significant variability observed between the UFM and the fixed flow meters, and this maybe due, in part, to the setup of the fixed flow meters not conforming to the recommended distances of straight pipe before or after the flow meter, resulting in misreading.

The existing flow meters are of industry standard and suited to their application at Bonriki. While some are old and require replacement, many are quite new. Eight new meters were installed in galleries under this project. These fixed flow meters are considered to record accurately when leaving the factory and, provided that they are installed and maintained correctly, are expected to provide many years of accurate service. The instaneous flow readings taken from the fixed flow meters in November 2013 and again in February 2014 indicate close alignment, as does the comparison between the flow rates of November 2013 and February 2014 meter readings. The uncertainity raised by the UFM testing is of concern and, because it is important to understand accurately the abstraction that is occurring in order to assist with management, additional testing of fixed flow meters is warranted.

3.3.2. Recommendations

While it is recommended that the current fixed meter is due for replacement, before dismissing or altering the available fixed meter readings, additional testing using two UFM in series at different distances from the current fixed flow meter, with appropriate quality assurance on the testing and setup is recommended to ensure the accuracy of the UFM.

A review of the set up of the fixed flow meters in the galleries and at the main meter should be undertaken and where possible the setups shoud be altered to conform with recommended practice. Old meters and meters observed to be reading incorrectly should be relaced. Additional testing of the flows leaving the galleries using the UFM should be undertaken over a longer period to investigate the accuracy of the fixed flow meters.

A schedule of testing of the main meters and the galleries using the two UFM should be developed in consultation with PUB and with consideration to the recommendations provided by Falkland (pers. comm. 2015) as outlined in Annex 9.

Monthly monitoring of the flow readings at all galleries in conjunction with salinity and hours pumped should continue to be recorded. A dedicated monitoring book should be developed in collaboration with PUB staff, to record the readings and with carbon copies. One copy should be held on site, or where the historical books are archived, and one copy provided to PUB Betio for archiving into the database or spreadsheet.

3.4. Water quality

3.4.1. Observations

Freshwater lenses in atoll environments are susceptible to contamination due to the shallow depth to groundwater. The commonly observed contamination sources at Bonriki water reserve include human graves, agriculture (*babwai* pits and pigs), poorly sited and constructed sanitation systems, small industries such as sand mining and brick making, and the construction of dwellings with associated general household activities such as washing, gardening and waste disposal.

The *E. coli* sampling at monitoring boreholes indicated a greater extent of contamination from November 2013 compared with February 2014. While BN24, BN23, BN23B, BN4C, BN28, BN20B and BN20 indicated the presence of *E. coli* at depths greater than 2 m (in the nylon tubes) during the November 2013 sampling. Water quality improved for boreholes BN20B, BN20, BN4C and BN28 during re-sampling in February 2014.

Figure 39 outlines November 2013 bacteriological sampling results at monitoring boreholes, with *E. coli* counts per 100 ml of sample. Of the nine sampled locations, BN21, BN4C, BN23B, BN20 and BN2 were found to have *E. coli* levels greater than 100 counts/100 ml. While BN19, BN27 and BN28 had *E. coli* levels less than 100 counts/100 ml.

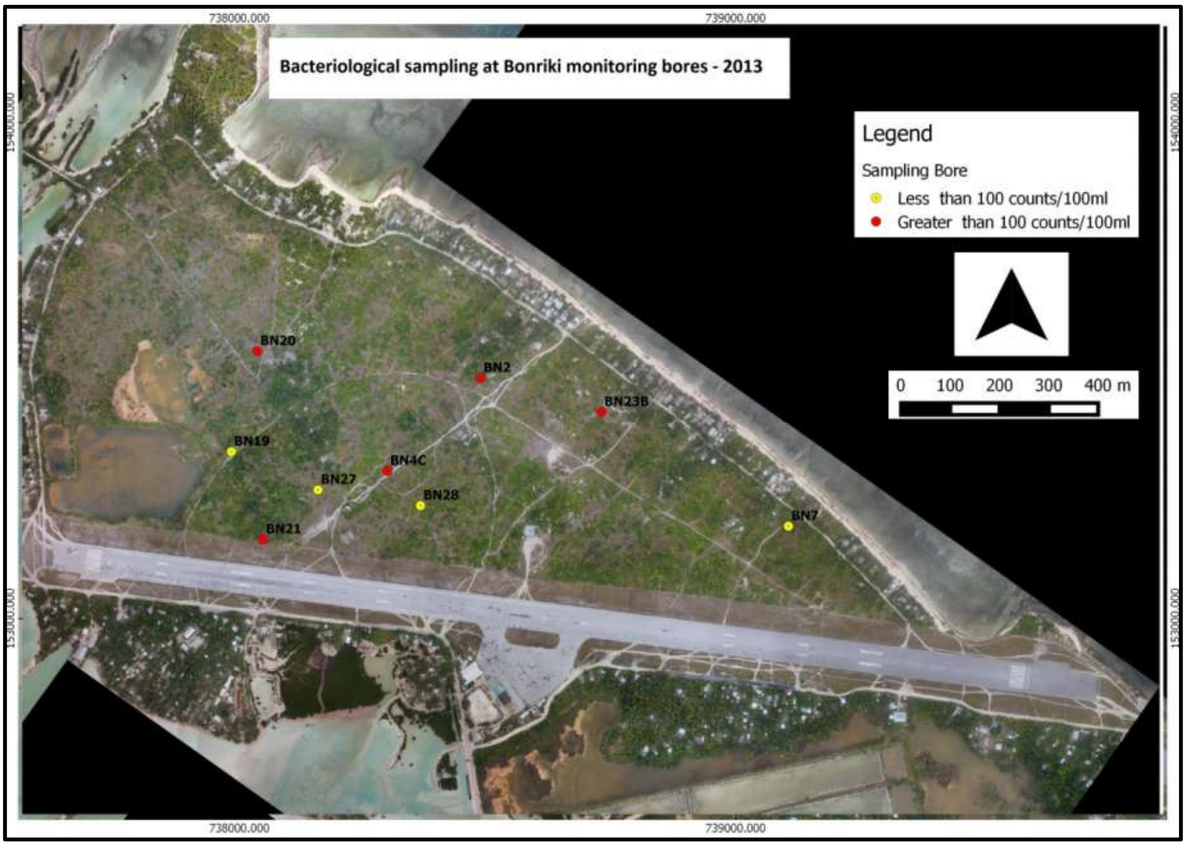

Figure 39: *Distribution of E. coli positive tests at Bonriki, November 2013.*

The distribution of *E. coli* positive tests may be attributed to nearby anthropogenic activities, including nearby settlement and possible inappropriate waste disposal or land-use activities although this is not conclusive.

Figure 40 identifies the February 2014 bacteriological sampling results for monitoring boreholes. Of the 20 sampled boreholes BN36, BN20, BN32, BN25, BN23 and BN24 were found to have *E. coli* levels greater than 100 counts/100 ml. While BN11B, BN34, BN1, BN2B, BN4C, BN27, BN21, BN26, BN28, BN35, BN15, BN7, BN7B, BN19, BN13B and BN29 had *E. coli* levels less than 100 counts/100 ml.

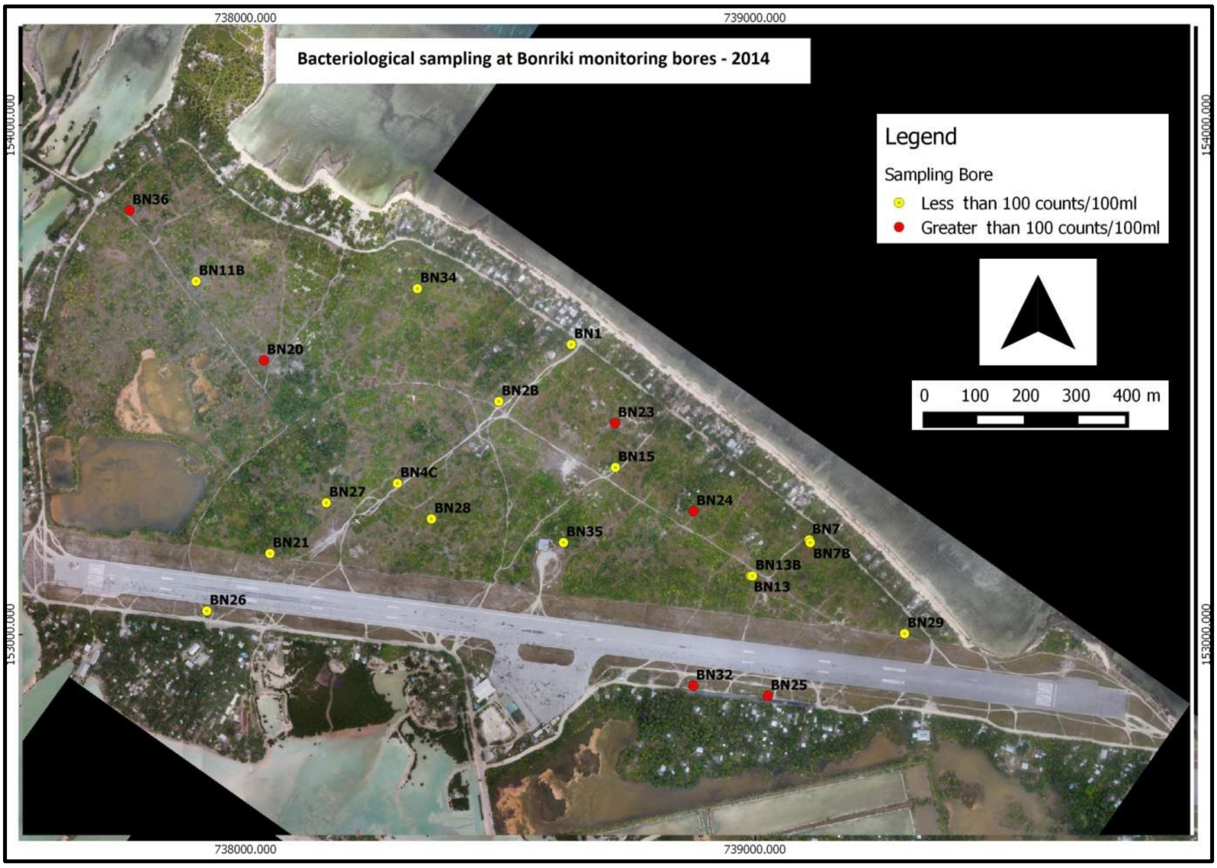

Figure 40: *Distribution of E. coli positive tests at Bonriki, February 2014.*

While not conclusive, the distribution of *E. coli* positive tests (i.e. those >100 counts/100 ml) from the sampling undertaken can be associated with nearby anthropogenic activities such as nearby settlements, and possible inappropriate waste disposal or land-use activities.

It is recommended that additional bacteriological testing be undertaken of the monitoring boreholes over time to better understand the impact of encroachment and into the future. Protection of the water source from contamination will reduce the costs associated with treatment and provide greater surety of supply.

4. Conclusions and Recommendations

The groundwater field investigations undertaken between April 2013 and July 2014 enabled the project to expand on the current knowledge and information available for the Bonriki water reserve. This information was useful specifically for the groundwater model and for extending the knowledge and capacity of GoK staff and the datasets that they utilise for their operation and management of the Bonriki freshwater lens.

In collaboration with GoK staff, the project was able to:

- extend the regular quarterly monitoring to all available monitoring boreholes,
- undertake basic maintenance,
- check on the accuracy of the readings,
- support GoK with additional equipment needs, and
- provide a quality verified updated database of readings over the project.

A borehole audit on the sampling tubes, piezometers, and general condition of monitoring boreholes was undertaken, with the remeasuring of sampling tubes where possible. A number of sampling tubes that were no longer operational or were at insufficient at depth were identified, with recommendations for redrilling and construction of new sampling tubes in some cases.

Nine piezometers were constructed to replace piezometers that had been destroyed, or at sites that had not previously existed. These piezometers provided valuable information on the water table from which groundwater flows and groundwater elevations could be determined and were completed to make them available for future sampling and monitoring. RTK surveys provided elevation data for monitoring sites to high accuracy, which permits the improved analysis of groundwater data. The survey provided GoK staff with a training opportunity to further refine their skills in this survey technique.

Diver loggers, installed within the piezometers at 10 sites for a minimum of three months, provided very valuable insight into the recharge processes and responses as well as tidal impacts that had previously been unmeasured. The period of measurement was fortunate in that it coincided with the end of an extended dry period followed by a protracted rainfall period, thereby providing the project with the opportunity to attempt zoning of the recharge and its responses within the Bonriki water reserve. This information was used for the development of the numerical model and will be useful in future management of the groundwater and for groundwater protection.

Sampling of selected monitoring boreholes for bacteriological analysis provides useful insight into the current distribution of contamination and its association with existing land-use activities. The sampling suggests that bacteriological contamination is occurring in those sites near to where there is established settlement and activities such as sand mining (e.g. BN23). While additional testing of sites would help to verify this, the results indicate that restricting settlement and associated activities within the Bonriki water reserve is justified.

Ten new fixed flow meters were installed with the support of the project to replace ageing meters and to assist GoK with determining the abstraction from individual galleries and the water reserve in total. Recent studies by Posch and Partners, November 2014, using a UFM have questioned the validity of the fixed meter readings that have been relied on from the main meter and galleries.

Future testing into the difference in readings between the fixed meters and the UFM is required to help resolve this important issue.

The following recommendations are provided from the groundwater field investigations:

- Redrilling and construction of new sampling tubes to sufficient depths for monitoring of the entire thickness of the freshwater lens BN16 (30 m), BN30 (21 m), BN19 (30 m), BN20 (30 m), BN25 (27 m), BN26 (24 m), BN36 (24 m) and BN37 (27 m).
- Recommendations in borehole audit Annex 3 are reviewed and implemented.
- Flow meter installation in galleries and at main meters is reviewed, and installations are modified to conform with the recommended installation guidelines for accurate metering. New flow meters are installed for galleries 2, 7, 10 and 20, and the Bonriki Main Meter, and the Buota Main Meter.
- Additional testing of fixed flow meters for galleries and main meters to verify the accuracy of the meters. A schedule of planned activities and a clear approach on what is required should be developed with PUB staff. This work should a priority in order to provide confidence in groundwater abstracted from the individual galleries and the main meters. Refer to Annex 9 for specific recommendations on additional testing of meters.
- Monthly monitoring of the flow readings at all galleries in conjunction with salinity and hours pumped should continue to be recorded. A dedicated monitoring book should be developed in collaboration with PUB staff to record the readings (with carbon copies). One copy should be held on site, or where the historical books are archived, and one copy should be provided to PUB Betio for archiving into the database or spreadsheet
- Additional bacteriological testing of the monitoring boreholes should be undertaken on a regular basis (annually). Enforcement of restricting settlement and other activities within the Bonriki water reserve is justified.

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6. Annexes

Annex 1. Monthly rainfall records Bonriki, Tarawa

Table A1.1: *Rainfall records for Bonriki. Data from Bonriki airport (yellow cells), and factored rainfall from observed Betio rainfall (blue cells).*

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1947	0.0	78.0	110.0	94.0	253.2	208.0	81.5	57.4	20.6	62.7	121.2	275.1	**1361.7**
1948	538.7	237.5	457.7	405.6	211.6	225.8	153.4	119.1	28.2	32.5	134.9	383.3	**2928.3**
1949	763.0	205.0	280.7	405.4	70.4	71.1	373.9	3.0	57.9	8.9	39.9	32.0	**2311.2**
1950	14.5	4.3	3.8	17.0	7.9	12.2	15.0	76.2	30.5	45.5	69.1	101.3	**397.3**
1951	228.6	56.9	60.2	227.6	192.5	292.4	259.8	473.5	296.4	88.9	53.8	411.5	**2642.1**
1952	473.2	211.6	196.6	109.2	135.4	157.2	39.6	63.0	48.8	25.4	67.3	340.9	**1868.2**
1953	333.5	454.9	246.1	525.0	337.6	143.0	116.1	179.6	256.0	123.7	43.2	410.7	**3169.4**
1954	396.5	288.5	196.9	97.8	35.6	0.5	80.8	93.2	99.7	5.8	36.6	20.1	**1352.0**
1955	62.0	22.1	78.5	64.3	39.4	97.5	51.6	73.4	128.3	9.1	4.1	15.5	**645.8**
1956	216.7	67.8	11.2	53.1	45.0	84.6	181.4	95.0	61.0	56.4	37.1	82.3	**991.6**
1957	131.8	118.9	215.9	186.9	230.9	260.4	289.6	140.5	222.8	324.1	479.8	394.5	**2996.1**
1958	148.1	432.1	723.6	292.1	164.6	165.4	351.8	174.2	88.9	13.2	213.4	205.7	**2973.1**
1959	396.5	391.2	221.5	142.0	227.3	100.3	78.5	64.0	34.5	24.1	165.9	91.4	**1937.2**
1960	453.4	241.8	186.9	166.4	165.9	134.9	101.6	63.8	27.7	24.9	5.8	254.5	**1827.6**
1961	245.4	244.3	157.7	167.1	208.5	142.2	135.9	157.0	41.7	42.7	69.3	21.1	**1632.9**
1962	69.9	40.1	112.8	142.5	91.7	54.9	162.8	129.0	123.7	41.1	42.4	139.7	**1150.6**
1963	155.8	43.9	107.4	69.0	34.8	57.8	207.0	146.9	126.3	343.6	310.5	258.2	**1861.2**
1964	368.6	332.8	169.6	35.1	3.2	51.5	25.6	41.4	25.4	1.4	56.9	56.8	**1168.1**
1965	120.5	477.4	254.4	118.9	95.8	136.5	319.2	213.0	210.0	354.8	159.7	208.4	**2668.6**
1966	727.2	324.9	249.8	186.8	83.4	65.3	273.3	57.8	112.5	76.7	133.2	98.3	**2389.4**
1967	221.7	60.9	83.6	152.6	9.3	75.3	91.7	74.8	72.0	49.5	56.1	227.8	**1175.3**
1968	216.9	118.0	13.8	0.3	3.2	12.6	33.9	25.8	158.9	64.2	66.3	159.9	**873.7**
1969	273.1	256.1	426.4	304.0	143.4	189.9	151.2	22.0	101.9	39.1	28.8	221.0	**2157.0**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1970	287.9	248.9	324.5	274.0	72.2	70.8	59.0	89.4	1.4	3.0	3.4	12.2	**1446.6**
1971	22.4	39.1	3.3	68.7	52.6	86.8	85.2	36.2	35.9	88.4	61.0	67.3	**646.8**
1972	154.8	46.9	238.9	73.6	371.6	328.9	296.6	446.9	318.2	257.7	136.1	380.5	**3050.8**
1973	624.9	240.9	104.6	130.3	54.8	36.8	0.4	11.4	1.5	17.5	3.0	15.0	**1241.0**
1974	1.8	38.1	0.4	10.7	98.6	59.3	147.4	44.1	54.4	52.8	32.2	85.2	**624.9**
1975	269.5	262.7	265.6	255.5	92.8	168.0	88.8	5.1	23.5	4.3	0.7	38.5	**1474.9**
1976	123.4	40.9	119.5	191.2	298.3	301.8	239.6	312.1	175.8	80.9	142.3	432.6	**2458.3**
1977	559.7	261.0	354.5	180.2	150.2	75.6	223.8	143.5	269.4	118.8	420.2	169.4	**2926.2**
1978	463.2	271.0	402.1	141.6	43.8	27.9	11.6	23.9	29.4	0.0	35.2	139.3	**1588.8**
1979	244.6	279.5	424.7	78.6	126.8	155.0	56.1	72.3	60.3	166.4	143.5	278.5	**2086.4**
1980	379.2	109.7	315.1	429.5	220.3	212.3	110.0	159.4	106.2	67.5	187.5	176.4	**2473.2**
1981	167.8	215.5	319.8	229.3	223.6	242.8	17.4	5.6	46.7	17.3	64.0	338.2	**1888.1**
1982	29.7	144.7	42.0	171.5	217.9	106.2	447.4	370.9	178.2	200.6	216.1	181.5	**2306.6**
1983	19.0	150.2	60.1	105.5	331.0	248.2	347.7	97.4	52.2	131.7	61.0	69.8	**1673.9**
1984	97.2	47.2	28.7	130.1	107.8	85.5	32.2	100.3	34.3	88.6	16.5	109.8	**878.1**
1985	28.0	39.1	70.2	19.7	74.9	61.8	58.9	31.6	45.8	35.2	42.8	147.0	**654.8**
1986	218.9	55.3	33.0	94.9	21.1	124.9	209.8	92.0	305.8	217.4	275.1	399.4	**2047.6**
1987	396.6	433.4	212.8	434.8	251.5	311.2	361.9	290.6	132.4	220.7	114.3	228.5	**3388.6**
1988	363.2	333.6	149.2	81.1	186.4	47.0	15.8	8.0	5.8	15.7	0.9	18.2	**1224.8**
1989	4.8	6.2	29.9	63.4	151.0	10.8	17.3	35.4	63.4	55.5	207.2	163.0	**807.8**
1990	567.2	164.9	420.1	412.4	126.8	152.8	150.9	239.3	297.1	16.8	271.8	358.8	**3179.0**
1991	443.4	142.9	100.3	87.7	157.3	307.9	200.0	388.9	274.4	223.3	401.2	273.4	**3000.8**
1992	179.5	265.0	293.3	473.0	257.5	89.8	103.2	93.6	71.9	62.0	113.2	476.6	**2478.8**
1993	342.8	271.8	544.4	413.4	509.9	303.5	239.8	239.4	181.2	381.4	88.3	324.8	**3840.9**
1994	237.2	121.7	111.3	142.3	76.9	137.6	117.4	231.1	276.2	250.7	198.1	322.4	**2222.9**
1995	307.1	202.0	165.2	125.5	46.0	52.4	20.5	145.8	11.1	39.1	5.9	22.7	**1143.2**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1996	29.2	81.7	57.8	59.5	162.8	61.0	89.9	15.9	57.3	158.4	25.3	36.9	**835.8**
1997	188.1	375.2	256.1	361.9	311.9	291.3	234.8	283.6	127.8	266.5	147.2	192.0	**3036.5**
1998	139.5	31.9	19.8	40.7	118.7	44.5	32.9	3.5	0.8	2.9	4.1	62.5	**501.9**
1999	3.4	6.2	84.9	96.4	121.9	56.9	44.4	33.5	37.7	18.9	4.7	8.4	**517.2**
2000	8.7	24.2	42.0	66.2	50.7	74.7	135.9	90.5	65.0	95.9	57.8	83.1	**794.6**
2001	87.6	86.8	175.9	247.4	124.5	70.7	209.3	193.9	74.3	22.8	105.7	373.1	**1772.1**
2002	438.9	357.6	267.1	193.2	86.2	278.8	133.0	417.9	331.4	432.8	341.8	296.8	**3575.6**
2003	444.7	238.3	238.9	207.1	102.5	111.5	145.6	74.9	103.1	67.6	119.7	80.4	**1934.3**
2004	138.3	162.2	150.8	348.3	199.2	255.8	178.5	203.4	155.8	109.2	25.9	240.4	**2167.8**
2005	266.2	208.9	358.9	201.7	101.0	69.2	186.8	163.2	124.7	81.3	44.6	122.2	**1928.9**
2006	18.6	43.8	62.6	131.4	52.1	195.4	126.4	193.9	125.2	445.9	185.5	449.2	**2030.0**
2007	375.5	400.3	288.2	43.2	124.7	77.9	86.0	38.7	15.3	20.5	35.8	11.9	**1518.0**
2008	11.9	0.9	17.1	36.4	141.1	165.1	104.3	48.2	10.6	41.9	107.7	132.2	**817.3**
2009	116.1	90.6	118.3	37.5	153.0	147.0	164.5	225.0	198.0	161.0	171.5	512.0	**2094.5**
2010	485.0	263.0	330.5	347.0	164.0	134.0	30.5	23.5	0.0	2.5	46.5	5.5	**1832.0**
2011	14.0	12.5	12.5	132.0	2.5	154.5	272.5	70.0	241.0	22.0	7.0	41.4	**981.9**
2012	75.5	26.0	95.0	90.5	142.5	101.0	313.5	178.5	219.5	76.5	95.0	182.0	**1595.5**
2013	93.0	241.5	125.5	341.5	62.5	46.0	49.5	45.5	62.5	186.0	22.0	154.0	**1429.5**

Note: Rainfall records are for Bonriki, and incorporate both observed rainfall at Bonriki and factored rainfall from observed Betio rainfall. Since March 2009 observed rainfall records from the Bonriki airport are used, which are highlighted in yellow. Prior to March 2009 Betio monthly recorded rainfall data is used, which is highlighted blue, and is factored to accommodate for the observed rainfall variance between Betio and Bonriki. On average, Bonriki receives 13% less rainfall than that observed in Betio over the course of a month.

Table A1.2: *Statistic for 67 year period, 1947-2013.*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean	239.2	176.0	185.1	175.6	139.3	132.5	145.8	127.8	110.1	102.8	107.2	188.4	**1,829.8**
Std dev	192.2	132.3	147.9	130.7	99.6	88.5	107.3	114.2	94.1	112.8	107.4	141.5	**859.4**
Cv	0.80	0.75	0.80	0.74	0.71	0.67	0.74	0.89	0.86	1.10	1.00	0.75	**0.47**
Max	763.0	477.4	723.6	525.0	509.9	328.9	447.4	473.5	331.4	445.9	479.8	512.0	**3,840.86**
Min	0.0	0.9	0.4	0.3	2.5	0.5	0.4	3.0	0.0	0.0	0.7	5.5	**397.30**
No. years	67	67	67	67	67	67	67	67	67	67	67	67	**67.00**

Table A1.3: *Statistic for 67 year period, 1947-2013.*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean	204.0	157.8	162.0	182.0	139.6	134.0	135.5	140.0	121.6	127.3	109.4	194.3	**1807.7**
Std dev	172.8	133.4	134.1	141.2	98.3	90.8	92.0	113.6	103.2	127.4	106.4	152.7	**961.3**
Cv	0.85	0.85	0.83	0.78	0.70	0.68	0.68	0.81	0.85	1.00	0.97	0.79	**0.53**
Max	567.2	433.4	544.4	473.0	509.9	311.2	361.9	417.9	331.4	445.9	401.2	512.0	**3840.9**
Min	3.4	6.2	19.8	19.7	21.1	10.8	11.6	3.5	0.8	0.0	0.7	8.4	**501.9**
No. years	30	30	30	30	30	30	30	30	30	30	30	30	**30.0**

Annex 2. Summary of monitoring boreholes, Bonriki

Abbreviations	
m	Metres
TOP	Measured from the top of the pipe
MBGL	Metres below ground level

Table A2.1: *Monitoring bores construction details and status in January 2014.*

Piezometer name	References	Monitoring purpose	Year drilled	Piezometer total depth (m) (TOP)	Borehole total depth (m) (MBGL)	Monitor depths (m) / Status in January 2014	Monitoring period
BN1	Murphy (1981)	Salinity	1980	None	21	No PVC pipe, tubes can be pumped (T1 (6.4m), T2* (9m), T3 (12.6m), T4 (14.5m), T5 (17.3m),T6 (19.2m))	Nov 1980–Nov 2013
BN1B	Leze & Sinclair (2014)	Water level	2013		2.6	Pipe	Nov-2013
BN2	Murphy (1981)	Salinity	1980	None	24	No PVC pipe, tubes can be pumped (T2 (9.1m), T3 (15.1m), T4 (18.8m), T5 (21.7m))	Nov 1980–Nov 2013
BN2B	OEC, PPK & Erasito (2001)	Salinity and water level	2000	2.26	12.5	PVC pipe, tubes can be pumped (T1 (6.4m), T2 (12.3m))	Jun 2005–Nov 2013
BN3 (original)	Murphy (1981)	Backfilled in 1983	1980		14	Destroyed	-
BN3 (was BH1)	Murphy (1981)	Salinity	1980		24.5	Destroyed	May 1984–Jul 1990
BN4	Murphy (1981)	Salinity	1980	None	30	No PVC pipe, tubes can be pumped (T1 (19.2m), T2 (23.9m), T3 (25.7m), T4 (28.3m))	Nov 1984 – vandalised; only 2 tubes could be pumped between 1989–2008, restored 2008–Nov 2013
BN4B	OEC, PPK & Erasito (2001)	Salinity and water level	2000		12.5	Destroyed	Feb 2001–Oct 2003
BN4C	Leze & Sinclair (2014)	Water level	2013		3.2	PVC pipe	Nov-2013
BN5	Murphy (1981)	Salinity	1980		27	Destroyed	Dec 1980–Jul 1989
BN6	Murphy (1981)	Backfilled in 1983	1980		18	Destroyed	-
BN7	Murphy (1981)	Salinity	1980	None	21	No PVC pipe, tubes can be pumped (T1 (5.8m), T2 (8.8m), T3 (11.9m), T4 (14.4m), T5 (17.6m),T6 (19.4m))	Dec 1980–Nov 2013
BN7B	Leze & Sinclair (2014)	Water level	2013		2.76	PVC pipe	Nov-2013

Piezometer name	References	Monitoring purpose	Year drilled	Piezometer total depth (m) (TOP)	Borehole total depth (m) (MBGL)	Monitor depths (m) / Status in January 2014	Monitoring period
BN8	Murphy (1981)	Backfilled in 1983	1980		13.5	Destroyed	-
BN9	Murphy (1981)	Salinity	1980		24	Destroyed	Dec 1980–Jun 1994
BN10	Murphy (1984)	Salinity	1983		22	Destroyed	Sept 1983–Jul 1990
BN11	Murphy (1986); Murphy (1987)	Salinity	1985	None	21	No PVC pipe, tubes can be pumped (T2 (14.6m), T3 (16.6m), T4 (19.6m))	Apr 1985–Nov 2013
BN11B	OEC, PPK & Erasito (2001)	Salinity and water level	2000	2.28	11.75	PVC pipe, tube can be pumped (T2 (11.5m))	Jun 2005–Nov 2013
BN12	Murphy (1986); Murphy (1987)	Salinity	1985		24	Destroyed	Apr 1985–Nov 1996
BN13	Murphy (1986); Murphy (1987)	Salinity	1985	None	27	No PVC pipe, tubes can be pumped (T1 (6.2m), T2 (9.2m), T3 (12.1m), T4 (15.05m), T5 (18.19m), T6 (21.03m), T7 (24.05m), T8 (27.2m))	Apr 1985–Nov 2013
BN13B	Leze & Sinclair (2014)	Water level	2013		2.8	PVC pipe	Nov-2013
BN14	Murphy (1986); Murphy (1987)	Salinity	1985		24	Destroyed	Apr 1985–Apr 1992
BN15	Murphy (1986); Murphy (1987)	Salinity	1985	None	24	No pipe, tubes can be pumped (T1* (12m), T2* (15m), T3*(18m), T4* (21m), T5* (23m))	Apr 1985–Nov 2013
BN15B	Leze & Sinclair (2014)	Water level	2013		3.25	PVC pipe	Nov-2013
BN16	Murphy (1986); Murphy (1987)	Salinity	1985		30	Destroyed	Apr 1985–Oct 2003
BN17	Murphy (1986); Murphy (1987)	Salinity	1985		27	Destroyed	Apr 1985–Dec 1987
BN18 (was BH2)	Murphy (1981)	Salinity	1980		25.2	Destroyed	Aug 1983–Nov 1988
BN19	OEC, PPK & Erasito (2001)	Salinity and water level	2000	2.05	15.2	PVC pipe, tubes can be pumped (T1* (6m), T2 (blocked), T3* (11m), T4* (14.4m)	Nov 2000–Nov 2013
BN20	OEC, PPK & Erasito (2001)	Salinity	2000	None	15.2	No PVC pipe, tubes can be pumped (T1* (6m), T2* (8m), T3 (11.6m), T4* (15.2m)	March 2001–Nov 2013
BN20B	Leze & Sinclair (2014)	Water level	2013		2.6	PVC pipe	Nov-2013
BN21	OEC, PPK & Erasito (2001)	Salinity and water level	2000	2.15	21.4	PVC pipe, tubes can be pumped (T1* (6m), T2* (9m), T3* (12m), T4* (15m), T5* (18m), T6* (21m))	Nov 2000–Nov 2013
BN22	OEC, PPK & Erasito (2001)	Salinity and water level	2000	2.2	21	PVC pipe, tubes can be pumped (T1 (6.5m), T2 (9.3m), T3 (10.9m), T4 (13.9m), T5 (15.6m), T6* (21m))	March 2001–Nov 2013
BN23	OEC, PPK & Erasito (2001)	Salinity and water level	2000	2.2	21	PVC pipe, tubes can be pumped (T1* (6m), T2 (9.6m), T3* (12m), T4 (12.8m), T5 (blocked),T6* (20m))	March 2001–Nov 2013

Piezometer name	References	Monitoring purpose	Year drilled	Piezometer total depth (m) (TOP)	Borehole total depth (m) (MBGL)	Monitor depths (m) / Status in January 2014	Monitoring period
BN23B	Leze & Sinclair (2014)	Water level	2013		3.58	PVC pipe	Nov-2013
BN24	OEC, PPK & Erasito (2001)	Salinity and water level	2000	2.76	22	Pipe, tubes can be pumped (T1 (6.2m), T2 (blocked), T3 (blocked), T4 (blocked), T5 (17.2m),T6 (20.2m))	March 2001–Nov 2013
BN25	OEC, PPK & Erasito (2001)	Salinity and water level	2001	1.77	16.7	PVC pipe, tubes can be pumped (T1* (6m), T2* (9m), T3* (11.5m), T4 (Blocked))	Nov 2001–Nov 2013
BN26	OEC, PPK & Erasito (2001)	Salinity and water level	2001	2.33	25	PVC pipe, tubes can be pumped (T1 (blocked), T2 (6.2m), T3* (12m), T4 (blocked), T5 (15.4m),T6 (blocked), T7 (24.2m))	March 2001–Nov 2013
BN27	OEC, PPK & Erasito (2001)	Salinity and water level	2001	1.99	22	PVC pipe, tubes can be pumped (T1* (6m), T2* (9m), T3* (12m), T4 (14.4m), T5* (17.5m), T6 (21m))	March 2001–Nov 2013
BN28	OEC, PPK & Erasito (2001)	Salinity and water level	2001	1.9	22	PVC pipe, tubes can be pumped (T1* (6m), T2 (blocked), T3* (12m), T4 (blocked), T5* (17m), T6* (20m))	March 2001–Nov 2013
BN29	OEC, PPK & Erasito (2001)	Salinity and water level	2001	1.68	22	PVC pipe, tubes can be pumped (T1* (6m), T2 (9.4m), T3* (12m), T4* (15m), T5 (18.4m), T6 (20.6m))	March 2001–Nov 2013
BN30	OEC, PPK & Erasito (2001)	Salinity and water level	2001		22	Destroyed	March 2001–Sept 2001
BN31	OEC, PPK & Erasito (2001)	Water level	2001		2.3	Destroyed	Oct 2001–Feb 2003
BN32	Falkland, White & Turner (2004)	Salinity and water level	2004	2.66	27.5	PVC pipe, tubes can be pumped (T1 (blocked), T2* (9m), T3* (12m), T4* (15m), T5* (18m), T6* (21m), T7 (23.7m), T8 (25.6m))	Oct 2004–Nov 2013
BN33	Falkland, White & Turner (2004)	Salinity and water level	2004	2.87	27.5	PVC pipe, tubes can be pumped (T1* (6m), T2* (9m), T3* (12m), T4* (15m), T5* (18m), T6* (21m), T7* (24m), T8* (27m))	Oct 2004–Nov 2013
BN34	Falkland, White & Turner (2004)	Salinity and water level	2004	2.715	25	PVC pipe, tube can be pumped (T1* (6m), T2* (9m), T3* (12m), T4 (13m), T5* (18m), T6 (20.4m), T7* (blocked))	Oct 2004–Nov 2013
BN35	Leze & Sinclair (2014)	Water level	2013		3.67	PVC pipe	Nov-2013
BN36	Leze & Sinclair (2014)	Water level	2013		4	PVC pipe	Nov-2013

Note: The depth of each pipe was re-measured in April and August 2013; when it was not possible to re-measure the depth this is denoted with (*) and the original value is retained.

Annex 3. Audit of monitoring boreholes, Bonriki

Table A3.1: *Status of monitoring boreholes in March (2014) and recommended rehabilitations works.*

Boreholes	Status (March 2014)	Recommendations for May 2014
BN1	• All tubes can be pumped (6) • No PVC piezometer present	
BN1B	• New piezometer constructed on 14/11/13, vandalised and filled with sand on 15/11/13 • Second construction on 18/11/13 • Total depth of the piezometer 2.57 m, WL (Water Level) = 1.66 m (20/02/14 08:35) (measured from top of piezometer) • Well cover installed	
BN2	• All tubes can be pumped (4) • No PVC piezometer present	
BN2B	• All tubes can be pumped (2) • PVC piezometer present • Total depth of the piezometer 2.26 m (measured from top of piezometer), WL = 1.64 m (20/02/14 10:17) (measured from top of piezometer)	
BN3 (original) and BN3 (BH1)	• Destroyed	
BN4	• All tubes can be pumped (4) • No PVC piezometer present • Re-label tubes 1, 2, 3 and 4, as the label is worn out	Re-label the tubes 1, 2, 3 and 4 to correspond to the correct depths
BN4B	• Destroyed	
BN4C	• New piezometer construction on 15/11/13 • Total depth of the piezometer 3.43 m (measured from top of piezometer), WL = 1.38 m (20/02/14 11:17) (measured from top of piezometer) • Well cover installed	
BN5	• Destroyed	
BN6	• Destroyed	

Boreholes	Status (March 2014)	Recommendations for May 2014
BN7	• All tubes can be pumped (6) • No PVC piezometer present • Repainting of steel lid complete	
BN7B	• New piezometer constructed on 15/11/13 • Total depth of the piezometer 2.88 m (measured from top of piezometer), WL = 2.565 m (20/02/14 13:55) (measured from top of piezometer) • Well cover installed	
BN8	• Destroyed	
BN9	• Destroyed	
BN10	• Destroyed	
BN11	• All tubes can be pumped (3) • No PVC piezometer present	
BN11B	• Tube 1 blocked (Tube 2, 11.5 m, can be pumped) • PVC piezometer present • Total depth of the piezometer 2.28 m (measured from top of piezometer), WL = 1.35 m (21/02/14 11:00) (measured from top of piezometer)	• The second borehole with a pipe is currently called BN11 (should be renamed to BN11B) • Re-label bore lids with correct names
BN 12	• Destroyed	
BN13	• All tubes can be pumped (8) • No PVC piezometer present	
BN13B	• New piezometer constructed on 15/11/13 • Total depth of the piezometer 3.19 m (measured from top of piezometer), WL = 2.25 m (20/02/14 15:01) (measured from top of piezometer) • Well cover installed	
BN14	• Destroyed	
BN15	• All tubes can be pumped (5) • No PVC piezometer present	
BN15B	• New piezometer constructed on 14/11/13 • Total depth of the piezometer 3.42 m (measured from top of piezometer), WL = 2.25 m (20/02/14 15:01) (measured from top of piezometer) • Well cover installed	

Boreholes	Status (March 2014)	Recommendations for May 2014
BN16	• Destroyed	Priority for construction of new monitoring bore location
Bn17	• Destroyed	
BN18 (was BH2)	• Destroyed	
BN19	• Tube 2 blocked (Tube 1, 6 m; Tube 3, 11 m; Tube 4, 14.4 m; can be pumped) • PVC piezometer present • Total depth of the piezometer 2.05 m (measured from top of piezometer), WL = 1.46 m (21/02/14 13:50) (measured from top of piezometer)	
BN20	• All tubes can be pumped (4) • No PVC piezometer present	
BN20B	• New piezometer constructed on 16/11/13] • Total depth of the piezometer 2.105 m (measured from top of piezometer), WL = 0.55 m (21/02/14 11:30) (measured from top of piezometer) • Well cover installed	
BN21	• All tubes can be pumped (6) • PVC piezometer present • Total depth of the piezometer 2.15 m (measured from top of piezometer), WL = 0.79 m (22/02/14 11:35) (measured from top of piezometer)	
BN22	• All tubes can be pumped (6) • PVC piezometer present • Total depth of the piezometer 2.2 m (measured from top of piezometer), WL = 0.73 m (19/02/14 9:09) (measured from top of piezometer) • Repainting of steel lid complete	
BN23	• Tube 5 blocked (Tube 1, 6 m; Tube 2, 9.6 m; Tube 3, 12 m; Tube 4, 12.8 m; Tube 6, 20 m; can be pumped) • PVC piezometer present but not deep enough and dry • Repainting of steel lid complete	
BN23B	• New piezometer constructed on 14/11/13 • Total depth of the piezometer 3.305 m (measured from top of piezometer), WL =	

Boreholes	Status (March 2014)	Recommendations for May 2014
	2.54 m (19/02/14 08:00) (measured from top of piezometer) • Well cover installed	
BN24	• Tubes 2, 3 and 4 blocked (Tube 1, 6.2 m, Tube 5, 17.2 m; Tube 6, 20.2 m; can be pumped) • PVC piezometer present • Total depth of the piezometer 2.76 m (measured from top of piezometer) (WL = 1.71 m (21/02/14 08:40)) (measured from top of piezometer)	
BN25	• All tubes pumping (4) • PVC piezometer present • Total depth of the piezometer 1.77 m (measured from top of piezometer), WL = 0.92 m (02/11/14 15:41) (measured from top of piezometer)	
BN26	• Tubes 1, 4 and 6 blocked (Tube 2, 6.2 m; Tube 3, 12.0 m; Tube 5, 15.4 m; Tube 7, 24.2 m; can be pumped) • PVC piezometer present • Total depth of the piezometer 2.33 m (measured from top of piezometer), WL = 1.455 m (22/02/14 11:03) (measured from top of piezometer)	
BN27	• All tubes can be pumped (6) • PVC piezometer present • Total depth of the piezometer 1.985 m (measured from top of piezometer), WL = 1.13 m (22/02/14 10:31) (measured from top of piezometer) • Repainting of steel lid complete	
BN28	• Tube 2 blocked (Tube 1, 6 m; Tube 3, 12 m; Tube 4, 15 m ; Tube 5, 17 m, Tube 6, 20 m; can be pumped) • PVC piezometer present • Total depth of the piezometer 1.90 m (measured from top of piezometer), WL = 0.86 m (22/02/14 08:00) (measured from top of piezometer)	
BN29	• All tubes can be pumped (6) • PVC piezometer present • Total depth of the piezometer 1.68 m (measured from top of piezometer), WL = 0.85 m (19/12/14 09:27) (measured from top of piezometer)	• Need a steel cover replacement 685x685 mm

Boreholes	Status (March 2014)	Recommendations for May 2014
	• Repainting of steel lid complete, however lid is badly corroded and requires replacement	
BN30	• Destroyed	
BN31	• Destroyed	
BN32	• Tube 1 blocked (Tube 2, 9 m; Tube 3, 12 m; Tube 4, 15 m Tube 5, 18.6 m; Tube 6, 21 m; Tube 7, 23.7 m; Tube 8, 25.6 m; can be pumped) • PVC piezometer present • Total depth of the piezometer 2.66 m (measured from top of piezometer), WL = 1.265 m (19/02/14 10:44) (measured from top of piezometer)	
BN33	• All tubes can be pumped (8) • PVC piezometer present • Total depth of the piezometer 2.87m (measured from top of piezometer), WL = 1.62m (18/02/14 8:30) (measured from top of piezometer)	
BN34	• Tube 7 blocked (Tube 1, 6 m; Tube 2, 9 m; Tube 3, 12 m; Tube 4, 13 m Tube 5, 18 m; Tube 6, 20.4 m; can be pumped) • PVC piezometer present • Total depth of the piezometer 2.715 m (measured from top of piezometer), WL = 1.45 m (21/02/14 15:00) (measured from top of piezometer) • Repainting of steel lid complete	
BN35	• New piezometer constructed on 16/11/13 (near rain station) • Total depth of the piezometer 3.42m (measured from top of piezometer), WL = 2.095 m (21/02/14 13:25) (measured from top of piezometer) • Well cover installed	
BN36	• New piezometer constructed on 16/11/13 • Total depth of the piezometer 2.89 m (measured from top of piezometer), WL = 1.705 m (21/02/14 09:39) (measured from top of piezometer) • Well cover installed	

Note: The RTK survey, with elevation and coordinates, is complete for all monitoring bores.

Annex 4. Summary of monitoring borehole sampling April 2013 – June 2014

This annex contains the results of the monitoring bore sampling at Bonriki water reserve, from April 2013 to June 2014.

The monitoring bore sampling was undertaken by Water and Sanitation Programme staff of the Geoscience Division of the Secretariat of the Pacific Community, and staff from the Ministry of Public Works and Utilities, throughout the duration of the project, on a quarterly basis commencing in April 2013.

Measurement procedure

Bores with the 8 mm sampling tubes were pumped using a 'Shurflo' diaphragm type pump, powered by a 12 volt car battery. The suction side of the pump was attached to 'John Guest' couplings/brass fitting at the top of each nylon monitoring tube, and each tube was purged for about 5 minutes, abstracting more than 5 litres to ensure sampling of formation water prior to collection. Measurements of conductivity and temperature were recorded with a portable WP 84 TPS meter (calibrated each morning prior to fieldwork), and stable EC readings were recorded in the data sheet. All sampling equipment, including pump, battery and chargers, and TPS salinity meter, was provided by the project and is retained by MPWU to allow for future monitoring.

Water level measurements in each piezometer were undertaken using a calibrated Solinst TLC (Temp/Level/Conductivity) meter.

Table 4.1, below, summarises the groundwater monitoring results.

Table A4.1: *Bonriki groundwater monitoring results April 2013–June 2014.*

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
RESULTS - MONITORING BORE SAMPLING APRIL 2013								
BN1	9-Apr-13	14:00	Amit and Tateti	Water table in nearby PVC pipe	1.4	Blocked	Blocked	Blocked
BN1	9-Apr-13		Amit and Tateti	Tube 1	6.4	962	6.7	7.3
BN1	9-Apr-13		Amit and Tateti	Tube 2	9.0	16560	6.7	7.3
BN1	9-Apr-13		Amit and Tateti	Tube 3	12.6	17230	6.7	7.3
BN1	9-Apr-13		Amit and Tateti	Tube 4	14.5	18430	6.7	7.3
BN1	9-Apr-13		Amit and Tateti	Tube 5	17.3	37020	6.7	7.3
BN1	9-Apr-13		Amit and Tateti	Tube 6	19.2	42300	6.7	7.3
BN2	10-Apr-13	08:09	Amit and Tateti	Water table in PVC pipe 2B, BN2B	1.7	709	6.6	6.6
BN2	10-Apr-13		Amit and Tateti	2B Tube 1, BN2B	6.4	2459	6.6	6.6
BN2	10-Apr-13		Amit and Tateti	Tube 2	9.1	3140	6.6	6.6
BN2	10-Apr-13		Amit and Tateti	2B Tube 2	12.3	5800	6.6	6.6
BN2	10-Apr-13		Amit and Tateti	Tube 3	15.1	16350	6.6	6.6
BN2	10-Apr-13		Amit and Tateti	Tube 4	18.8	35800	6.6	6.6
BN2	10-Apr-13	10:19	Amit and Tateti	Tube 5	21.7	47200	6.6	6.6
BN4	10-Apr-13	12:14	Amit and Tateti	Tube 2	19.2	35300	------	------
BN4	10-Apr-13		Amit and Tateti	Tube 3	23.9	45900	------	------
BN4	10-Apr-13		Amit and Tateti	Tube 4	25.7	48400	------	------
BN4	10-Apr-13	12:29	Amit and Tateti	Tube 5	28.3	49700	------	------
BN7	11-Apr-13	14:30	Amit and Tateti	Tube 1	5.8	1550	9.8	10.2
BN7	11-Apr-13		Amit and Tateti	Tube 2	8.8	1549	9.8	10.2
BN7	11-Apr-13		Amit and Tateti	Tube 3	11.9	4450	9.8	10.2
BN7	11-Apr-13		Amit and Tateti	Tube 4	14.4	20090	9.8	10.2
BN7	11-Apr-13		Amit and Tateti	Tube 5	17.6	33400	9.8	10.2
BN7	11-Apr-13	15:11	Amit and Tateti	Tube 6	19.4	40100	9.8	10.2
BN11	9-Apr-13	12:35	Amit and Tateti	Water table in PVC pipe, BN11B	1.4	503	11.1	11.3
BN11	9-Apr-13	13:11	Amit and Tateti	Tube 1, BN11B	4.5	No tube	No tube	No tube
BN11	9-Apr-13		Amit and Tateti	Tube 1	6.4	Blocked	Blocked	Blocked
BN11	9-Apr-13	12:58	Amit and Tateti	Tube 2, BN11B	11.5	2580	11.1	11.3
BN11	9-Apr-13		Amit and Tateti	Tube 2	14.6	2753	11.1	11.3

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN11	9-Apr-13		Amit and Tateti	Tube 3	16.6	16900	11.1	11.3
BN11	9-Apr-13	13:33	Amit and Tateti	Tube 4	19.6	39400	11.1	11.3
BN13	11-Apr-13	11:14	Amit and Tateti	Tube 1	6.2	5340	------	------
BN13	11-Apr-13		Amit and Tateti	Tube 2	9.2	6820	------	------
BN13	11-Apr-13		Amit and Tateti	Tube 3	12.1	7240	------	------
BN13	11-Apr-13		Amit and Tateti	Tube 4	15.1	8710	------	------
BN13	11-Apr-13		Amit and Tateti	Tube 5	18.2	34100	------	------
BN13	11-Apr-13		Amit and Tateti	Tube 6	21.0	41000	------	------
BN13	11-Apr-13		Amit and Tateti	Tube 7	24.1	45200	------	------
BN13	11-Apr-13	11:48	Amit and Tateti	Tube 8	27.2	46900	------	------
BN15	11-Apr-13	10:42	Amit and Tateti	Tube 1	12.0	6560	------	------
BN15	11-Apr-13		Amit and Tateti	Tube 2	15.0	9570	------	------
BN15	11-Apr-13		Amit and Tateti	Tube 3	18.0	30600	------	------
BN15	11-Apr-13		Amit and Tateti	Tube 4	21.0	39700	------	------
BN15	11-Apr-13	11:06	Amit and Tateti	Tube 5	23.0	43600	------	------
BN19	9-Apr-13		Amit and Tateti	Water table in PVC pipe	1.1	1178	------	------
BN19	9-Apr-13	13:40	Amit and Tateti	Tube 1	6.0	1187	------	------
BN19	9-Apr-13		Amit and Tateti	Tube 2	9.2	1226	------	------
BN19	9-Apr-13		Amit and Tateti	Tube 3	11.0	1225	------	------
BN19	9-Apr-13	13:58	Amit and Tateti	Tube 4	14.4	1227	------	------
BN20	9-Apr-13	15:19	Amit and Tateti	Tube 1	6.0	605	------	------
BN20	9-Apr-13	15:19	Amit and Tateti	Tube 2	8.0	602	------	------
BN20	9-Apr-13	15:19	Amit and Tateti	Tube 3	11.6	651	------	------
BN20	9-Apr-13	15:19	Amit and Tateti	Tube 4	15.2	652	------	------
BN21	10-Apr-13	15:50	Martin, Mwaketa, Burebure, Taina, Amini	Water table in PVC pipe	0.8	466	18.2	18.6
BN21	10-Apr-13		Martin, Mwaketa, Burebure, Taina, Amini	Tube 1	6.0	1472	18.2	18.6
BN21	10-Apr-13		Martin, Mwaketa, Burebure, Taina, Amini	Tube 2	9.0	1507	18.2	18.6
BN21	10-Apr-13		Martin, Mwaketa, Burebure, Taina, Amini	Tube 3	12.0	1659	18.2	18.6
BN21	10-Apr-13		Martin, Mwaketa, Burebure, Taina, Amini	Tube 4	15.0	1955	18.2	18.6
BN21	10-Apr-13		Martin, Mwaketa, Burebure, Taina, Amini	Tube 5	18.0	1683	18.2	18.6
BN21	10-Apr-13	15:05	Martin, Mwaketa, Burebure, Taina, Amini	Tube 6	21.0	12370	18.2	18.6
BN22	12-Apr-13	14:30	Martin, Tateti	Water table in PVC pipe	0.98	3390	------	------

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN22	12-Apr-13		Martin, Tateti	Tube 1	6.5	5710	------	------
BN22	12-Apr-13		Martin, Tateti	Tube 2	9.3	5780	------	------
BN22	12-Apr-13		Martin, Tateti	Tube 3	10.9	6080	------	------
BN22	12-Apr-13		Martin, Tateti	Tube 4	13.9	6660	------	------
BN22	12-Apr-13	15:11	Martin, Tateti	Tube 5	15.6	26800	------	------
BN22	12-Apr-13		Martin, Tateti	Tube 6	21.0	44100	------	------
BN23	11-Apr-13		Amit and Tateti	Water table in PVC pipe	2.01	616	10.3	10.5
BN23	11-Apr-13		Amit and Tateti	Tube 1	6.0	1312	10.3	10.5
BN23	11-Apr-13		Amit and Tateti	Tube 2	9.6	1773	10.3	10.5
BN23	11-Apr-13		Amit and Tateti	Tube 3	12.0	4310	10.3	10.5
BN23	11-Apr-13		Amit and Tateti	Tube 4	12.8	12700	10.3	10.5
BN23	11-Apr-13		Amit and Tateti	Tube 5	2.4	Blocked	Blocked	Blocked
BN23	11-Apr-13	15:11	Amit and Tateti	Tube 6	20.0	29100	10.3	10.5
BN24	11-Apr-13	09:30	Amit and Tateti	Water table in PVC pipe	1.8	616	3.0	4.3
BN24	11-Apr-13		Amit and Tateti	Tube 1	6.2	7300	3.0	4.3
BN24	11-Apr-13		Amit and Tateti	Tube 2	3.4	Blocked	Blocked	Blocked
BN24	11-Apr-13		Amit and Tateti	Tube 3	10.8	Blocked	Blocked	Blocked
BN24	11-Apr-13		Amit and Tateti	Tube 4	11.4	Blocked	Blocked	Blocked
BN24	11-Apr-13		Amit and Tateti	Tube 5	17.2	25700	3.0	4.3
BN24	11-Apr-13	10:14	Amit and Tateti	Tube 6	20.2	41000	3.0	4.3
BN25	12-Apr-13	11:30	Martin, Tateti	Water table in PVC pipe	0.7	423	------	------
BN25	12-Apr-13		Martin, Tateti	Tube 1	6.0	750	------	------
BN25	12-Apr-13		Martin, Tateti	Tube 2	9.0	810	------	------
BN25	12-Apr-13		Martin, Tateti	Tube 3	11.5	1193	------	------
BN25	12-Apr-13	11:59	Martin, Tateti	Tube 4	12.8	Blocked	Blocked	Blocked
BN26	10-Apr-13	17:00	Amit and Tateti	Water table in PVC pipe	1.5	379	4.1	5.2
BN26	10-Apr-13		Amit and Tateti	Tube 1	1.4	Blocked	Blocked	Blocked
BN26	10-Apr-13		Amit and Tateti	Tube 2	6.2	4280	4.1	5.2
BN26	10-Apr-13		Amit and Tateti	Tube 3	12.0	4130	4.1	5.2
BN26	10-Apr-13		Amit and Tateti	Tube 4	13.9	Blocked	Blocked	Blocked
BN26	10-Apr-13		Amit and Tateti	Tube 5	15.4	8360	4.1	5.2
BN26	10-Apr-13		Amit and Tateti	Tube 6	17.6	Blocked	Blocked	Blocked

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN26	10-Apr-13	17:59	Amit and Tateti	Tube 7	24.2	44700	4.1	5.2
BN27	10-Apr-13	14:05	Amit and Tateti	Water table in Pvc pipe	1.3	949	14.6	14.7
BN27	10-Apr-13		Amit and Tateti	Tube 1	6.0	1641	14.6	14.7
BN27	10-Apr-13		Amit and Tateti	Tube 2	9.0	1662	14.6	14.7
BN27	10-Apr-13		Amit and Tateti	Tube 3	12.0	1710	14.6	14.7
BN27	10-Apr-13		Amit and Tateti	Tube 4	14.4	2165	14.6	14.7
BN27	10-Apr-13		Amit and Tateti	Tube 5	17.5	8990	14.6	14.7
BN27	10-Apr-13	14:59	Amit and Tateti	Tube 6	21.0	38100	14.6	14.7
BN28	10-Apr-13	16:05	Amit, Tateti	Water table in PVC pipe	0.9	895	12.1	12.5
BN28	10-Apr-13		Amit, Tateti	Tube 1	6.0	1810	12.1	12.5
BN28	10-Apr-13		Amit, Tateti	Tube 2	3.0	Blocked	Blocked	Blocked
BN28	10-Apr-13		Amit, Tateti	Tube 3	12.0	1929	12.1	12.5
BN28	10-Apr-13		Amit, Tateti	Tube 4	15.0	Blocked	Blocked	Blocked
BN28	10-Apr-13		Amit, Tateti	Tube 5	17.0	24300	12.1	12.5
BN28	10-Apr-13	16:59	Amit, Tateti	Tube 6	19.7	40000	12.1	12.5
BN29	11-Apr-13		Amit and Tateti	Water table in PVC pipe	0.9	493	6.4	6.7
BN29	11-Apr-13	09:05	Amit and Tateti	Tube 1	6.0	2018	6.4	6.7
BN29	11-Apr-13		Amit and Tateti	Tube 2	9.4	6070	6.4	6.7
BN29	11-Apr-13		Amit and Tateti	Tube 3	12.0	9120	6.4	6.7
BN29	11-Apr-13		Amit and Tateti	Tube 4	15.0	32700	6.4	6.7
BN29	11-Apr-13		Amit and Tateti	Tube 5	18.4	39300	6.4	6.7
BN29	11-Apr-13	09:44	Amit and Tateti	Tube 6	20.6	42000	6.4	6.7
BN32	12-Apr-13	13:12	Amit and Tateti	Water table in PVC pipe	1.4	677	14.1	14.4
BN32	12-Apr-13		Amit and Tateti	Tube 1	1.3	Blocked	Blocked	Blocked
BN32	12-Apr-13		Amit and Tateti	Tube 2	9.0	944	14.1	14.4
BN32	12-Apr-13		Amit and Tateti	Tube 3	12.0	923	14.1	14.4
BN32	12-Apr-13		Amit and Tateti	Tube 4	15.0	3150	14.1	14.4
BN32	12-Apr-13		Amit and Tateti	Tube 5	18.0	19840	14.1	14.4
BN32	12-Apr-13		Amit and Tateti	Tube 6	21.0	42700	14.1	14.4
BN32	12-Apr-13		Amit and Tateti	Tube 7	23.7	46000	14.1	14.4
BN32	12-Apr-13	13:12	Amit and Tateti	Tube 8	25.6	47500	14.1	14.4
BN33	12-Apr-13		Amit & Tateti	Water table in PVC pipe	1.6	741	12.7	13.4

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN33	12-Apr-13		Amit & Tateti	Tube 1	6.0	809	12.7	13.4
BN33	12-Apr-13		Amit & Tateti	Tube 2	9.0	817	12.7	13.4
BN33	12-Apr-13		Amit & Tateti	Tube 3	12.0	811	12.7	13.4
BN33	12-Apr-13		Amit & Tateti	Tube 4	15.0	8490	12.7	13.4
BN33	12-Apr-13		Amit & Tateti	Tube 5	18.0	35500	12.7	13.4
BN33	12-Apr-13		Amit & Tateti	Tube 6	21.0	44100	12.7	13.4
BN33	12-Apr-13		Amit & Tateti	Tube 7	24.0	46000	12.7	13.4
BN33	12-Apr-13	10:57	Amit & Tateti	Tube 8	27.0	46700	12.7	13.4
BN34	9-Apr-13	15:48	Amit and Tateti	Water table in PVC pipe	1.5	1052	6.5	7.1
BN34	9-Apr-13		Amit and Tateti	Tube 1	6.0	1226	6.5	7.1
BN34	9-Apr-13		Amit and Tateti	Tube 2	9.0	8630	6.5	7.1
BN34	9-Apr-13		Amit and Tateti	Tube 3	12.0	5640	6.5	7.1
BN34	9-Apr-13		Amit and Tateti	Tube 4	13.0	18180	6.5	7.1
BN34	9-Apr-13		Amit and Tateti	Tube 5	18.0	39900	6.5	7.1
BN34	9-Apr-13		Amit and Tateti	Tube 6	20.4	40180	6.5	7.1
BN34	9-Apr-13	16:49	Amit and Tateti	Tube 7	13.6	Blocked	Blocked	Blocked
RESULTS – MONITORING BORE SAMPLING, JULY 2013								
BN1	31-Jul-13	07:40	Peter, Martin, Adrian, Vincent Amit and JC	Water table in nearby PVC pipe	1.4	Blocked	Blocked	Blocked
BN1	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.4	802	6.7	7.3
BN1	31-Jul-13	07:57	Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.0	18030	6.7	7.3
BN1	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.6	20930	6.7	7.3
BN1	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	14.5	19420	6.7	7.3
BN1	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	17.3	36500	6.7	7.3
BN1	31-Jul-13	08:17	Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	19.2	40800	6.7	7.3
BN2	31-Jul-13	08:44	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe 2B, BN2B	1.8	628	5.2	5.7
BN2	31-Jul-13	08:44	Peter, Martin, Adrian, Vincent Amit and JC	2B Tube 1, BN2B	6.4	3200	5.2	5.7
BN2	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.1	6780	5.2	5.7
BN2	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	2B Tube 2 , BN2B	12.3	4770	5.2	5.7
BN2	31-Jul-13	08:57	Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	15.1	19840	5.2	5.7
BN2	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	18.8	38000	5.2	5.7
BN2	31-Jul-13	09:10	Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	21.7	44500	5.2	5.7
BN4	1-Aug-13	08:05	Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	19.2	34500	------	------

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN4	1-Aug-13	08:17	Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	23.94	48100	------	------
BN4	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	25.74	46300	------	------
BN4	1-Aug-13	08:50	Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	28.32	48000	------	------
BN7	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Water table in nearby well	0.0	#N/A	7.8	8.0
BN7	1-Aug-13	15:00	Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	5.8	1713	7.8	8.0
BN7	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	8.8	2890	7.8	8.0
BN7	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	11.9	11210	7.8	8.0
BN7	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	14.4	23880	7.8	8.0
BN7	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	17.6	36200	7.8	8.0
BN7	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	19.4	39800	7.8	8.0
BN11	31-Jul-13	13:24	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe, BN11B	1.5	912	10.5	10.9
BN11	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1, BN11B	4.5	No tube	No tube	No tube
BN11	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.4	Blocked	Blocked	Blocked
BN11	31-Jul-13	13:44	Peter, Martin, Adrian, Vincent Amit and JC	Tube 2, BN11B	11.5	2670	10.5	10.9
BN11	31-Jul-13	13:50	Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	14.6	4670	10.5	10.9
BN11	31-Jul-13	13:56	Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	16.6	20080	10.5	10.9
BN11	31-Jul-13	14:00	Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	19.6	36200	10.5	10.9
BN13	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Depth to water table (estimate)	1.9	753	3.5	4.5
BN13	1-Aug-13	14:00	Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.2	5500	3.5	4.5
BN13	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.2	7230	3.5	4.5
BN13	1-Aug-13	13:02	Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.1	9300	3.5	4.5
BN13	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	15.1	18520	3.5	4.5
BN13	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	18.2	37000	3.5	4.5
BN13	1-Aug-13	13:24	Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	21.0	42800	3.5	4.5
BN13	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 7	24.1	46600	3.5	4.5
BN13	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 8	27.2	48100	3.5	4.5
BN15	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Depth to water table (estimate)	0.0	#N/A	12.4	13.2
BN15	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	12.0	705	12.4	13.2
BN15	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	15.0	15140	12.4	13.2
BN15	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	18.0	32300	12.4	13.2
BN15	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	21.0	40900	12.4	13.2
BN15	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	23.0	44700	12.4	13.2

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN19	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Depth to water table	1.3	1200	------	------
BN19	31-Jul-13	14:45	Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	1223	------	------
BN19	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.2	1253	------	------
BN19	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	11.0	1256	------	------
BN19	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	14.4	1295	------	------
BN20	31-Jul-13	14:12	Peter, Martin, Adrian, Vincent Amit and JC	Depth to water table (estimate)	0.0	#N/A	------	------
BN20	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	0	6.0	631	------	------
BN20	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	0	8.0	627	------	------
BN20	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	0	11.6	711	------	------
BN20	31-Jul-13	14:36	Peter, Martin, Adrian, Vincent Amit and JC	0	15.2	773	------	------
BN21	31-Jul-13	10:21	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.0	1588	15.7	15.8
BN21	31-Jul-13	10:27	Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	1795	15.7	15.8
BN21	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.0	1815	15.7	15.8
BN21	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	2008	15.7	15.8
BN21	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	15.0	2310	15.7	15.8
BN21	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	18.0	3150	15.7	15.8
BN21	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	21.0	24600	15.7	15.8
BN22	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	2.2	6570	------	------
BN22	1-Aug-13	16:00	Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.5	9450	------	------
BN22	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.3	9500	------	------
BN22	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	10.9	9850	------	------
BN22	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	13.9	13620	------	------
BN22	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	15.6	30300	------	------
BN22	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	21.0	45600	------	------
BN23	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	2.0	753	8.5	8.7
BN23	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	1573	8.5	8.7
BN23	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.6	2910	8.5	8.7
BN23	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	6420	8.5	8.7
BN23	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	12.8	17130	8.5	8.7
BN23	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	2.4	Blocked	Blocked	Blocked
BN23	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	20.0	30700	8.5	8.7
BN24	1-Aug-13	13:05	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.9	753	4.1	4.9

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN24	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.2	4190	4.1	4.9
BN24	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	3.4	Blocked	Blocked	Blocked
BN24	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	10.8	Blocked	Blocked	Blocked
BN24	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	11.4	Blocked	Blocked	Blocked
BN24	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	17.2	29200	4.1	4.9
BN24	1-Aug-13	14:00	Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	20.2	43800	4.1	4.9
BN25	2-Aug-13	08:40	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.1	508	10.8	11.0
BN25	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	1203	10.8	11.0
BN25	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.0	1240	10.8	11.0
BN25	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	11.5	2980	10.8	11.0
BN25	2-Aug-13	09:20	Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	12.8	Blocked	Blocked	Blocked
BN26	31-Jul-13	11:01	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.7	842	3.9	4.8
BN26	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	1.4	Blocked	Blocked	Blocked
BN26	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	6.2	4160	3.9	4.8
BN26	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	4880	3.9	4.8
BN26	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	13.9	Blocked	Blocked	Blocked
BN26	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	15.4	8900	3.9	4.8
BN26	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	17.6	Blocked	Blocked	Blocked
BN26	31-Jul-13	11:52	Peter, Martin, Adrian, Vincent Amit and JC	Tube 7	24.2	41800	3.9	4.8
BN27	31-Jul-13	09:33	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.3	822	11.2	11.3
BN27	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	1941	11.2	11.3
BN27	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.0	2190	11.2	11.3
BN27	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	2610	11.2	11.3
BN27	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	14.4	3480	11.2	11.3
BN27	31-Jul-13	10:13	Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	17.5	10370	11.2	11.3
BN27	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	21.0	37300	11.2	11.3
BN28	2-Aug-13	11:00	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.0	1187	12.1	12.5
BN28	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	1759	12.1	12.5
BN28	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	3.0	Blocked	Blocked	Blocked
BN28	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	1930	12.1	12.5
BN28	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	15.0	Blocked	Blocked	Blocked
BN28	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	17.0	23100	12.1	12.5

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN28	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	19.7	38200	12.1	12.5
BN29	1-Aug-13	11:06	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.0	414	4.5	5.3
BN29	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	3410	4.5	5.3
BN29	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.4	9850	4.5	5.3
BN29	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	23000	4.5	5.3
BN29	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	15.0	35300	4.5	5.3
BN29	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	18.4	40000	4.5	5.3
BN29	1-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	20.6	43200	4.5	5.3
BN32	2-Aug-13	07:50	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.5	631	13.2	13.7
BN32	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	1.3	Blocked	Blocked	Blocked
BN32	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.0	1094	13.2	13.7
BN32	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	1148	13.2	13.7
BN32	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	15.0	4420	13.2	13.7
BN32	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	18.0	22470	13.2	13.7
BN32	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	21.0	44200	13.2	13.7
BN32	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 7	23.7	46600	13.2	13.7
BN32	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 8	25.6	47300	13.2	13.7
BN33	2-Aug-13	13:12	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.7	836	12.5	13.3
BN33	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	849	12.5	13.3
BN33	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.0	850	12.5	13.3
BN33	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	862	12.5	13.3
BN33	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	15.0	10230	12.5	13.3
BN33	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	18.0	35800	12.5	13.3
BN33	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	21.0	44000	12.5	13.3
BN33	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 7	24.0	46200	12.5	13.3
BN33	2-Aug-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 8	27.0	46800	12.5	13.3
BN34	31-Jul-13	15:34	Peter, Martin, Adrian, Vincent Amit and JC	Water table in PVC pipe	1.6	1140	4.4	4.9
BN34	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 1	6.0	3250	4.4	4.9
BN34	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 2	9.0	11310	4.4	4.9
BN34	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 3	12.0	27000	4.4	4.9
BN34	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 4	13.0	30100	4.4	4.9
BN34	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 5	18.0	38400	4.4	4.9

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN34	31-Jul-13		Peter, Martin, Adrian, Vincent Amit and JC	Tube 6	20.4	41800	4.4	4.9
BN34	31-Jul-13	16:22	Peter, Martin, Adrian, Vincent Amit and JC	Tube 7	13.6	Blocked	Blocked	Blocked
RESULTS – MONITORING BORE SAMPLING, NOVEMBER 2013								
BN1	18-Nov-13	15:21	Amandine, Julie	Water table in BN1B piezometer	1.73	#N/A	6.6	7.3
BN1	18-Nov-13	15:21	Amandine, Julie	BN1 Tube 1	6.4	838	6.6	7.3
BN1	14-Nov-13	07:54	Amandine, Julie	BN1 Tube 2	9.0	20160	6.6	7.3
BN1	14-Nov-13		Amandine, Julie	BN1 Tube 3	12.6	21610	6.6	7.3
BN1	14-Nov-13		Amandine, Julie	BN1 Tube 4	14.5	19620	6.6	7.3
BN1	14-Nov-13		Amandine, Julie	BN1 Tube 5	17.3	38200	6.6	7.3
BN1	14-Nov-13	08:17	Amandine, Julie	BN1 Tube 6	19.2	41900	6.6	7.3
BN2	13-Nov-13	10:02	Amandine, Tateti, Peter, Phoebe	Water table in BN2B piezometer, BN2B	1.79	591	5.4	5.9
BN2	18-Nov-13	14:44	Amandine, Tateti, Peter, Phoebe	2B Tube 1, BN2B	6.4	3030	5.4	5.9
BN2	13-Nov-13	10:03	Amandine, Tateti, Peter, Phoebe	Tube 2	9.1	7120	5.4	5.9
BN2	18-Nov-13	14:52	Amandine, Tateti, Peter, Phoebe	2B Tube 2 , BN2B	12.3	4490	5.4	5.9
BN2	13-Nov-13		Amandine, Tateti, Peter, Phoebe	Tube 3	15.1	21760	5.4	5.9
BN2	13-Nov-13	10:12	Amandine, Tateti, Peter, Phoebe	Tube 4	18.8	39200	5.4	5.9
BN2	13-Nov-13	15:00	Amandine, Tateti, Peter, Phoebe	Tube 5	21.7	44800	5.4	5.9
BN4	18-Nov-13	16:23	Peter, Amandine, Julie	Water table in BN4C piezometer	1.27	#N/A	------	------
BN4	18-Nov-13	08:05	Peter, Amandine, Julie	Tube 1	19.2	34500	------	------
BN4	16-Nov-13	08:17	Peter, Amandine, Julie	Tube 2	23.9	43300	------	------
BN4	16-Nov-13		Peter, Amandine, Julie	Tube 3	25.7	44200	------	------
BN4	16-Nov-13	08:50	Peter, Amandine, Julie	Tube 4	28.3	45700	------	------
BN7	18-Nov-13	16:23	Amandine, Tateti	Water table in BN7B piezometer	2.54	#N/A	9.7	10.1
BN7	18-Nov-13	12:18	Amandine, Tateti	Tube 1	5.8	1640	9.7	10.1
BN7	18-Nov-13		Amandine, Tateti	Tube 2	8.8	1604	9.7	10.1
BN7	18-Nov-13		Amandine, Tateti	Tube 3	11.9	4560	9.7	10.1
BN7	18-Nov-13		Amandine, Tateti	Tube 4	14.4	23890	9.7	10.1
BN7	18-Nov-13		Amandine, Tateti	Tube 5	17.6	33800	9.7	10.1
BN7	18-Nov-13	12:41	Amandine, Tateti	Tube 6	19.4	41200	9.7	10.1
BN11	13-Nov-13	11:49	Peter, Amandine, Julie	Water table in BN11B piezometer, BN11B	1.44	714	8.9	10.0
BN11	13-Nov-13		Peter, Amandine, Julie	Tube 1, BN11B	4.5	No tube	No tube	No tube
BN11	13-Nov-13		Peter, Amandine, Julie	Tube 1	6.4	Blocked	Blocked	Blocked

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN11	13-Nov-13	13:44	Peter, Amandine, Julie	Tube 2, BN11B	11.5	3110	8.9	10.0
BN11	13-Nov-13		Peter, Amandine, Julie	Tube 2	14.6	5240	8.9	10.0
BN11	13-Nov-13		Peter, Amandine, Julie	Tube 3	16.6	24300	8.9	10.0
BN11	13-Nov-13		Peter, Amandine, Julie	Tube 4	19.6	39100	8.9	10.0
BN13	18-Nov-13	08:17	Amandine, Peter	Water table in BN13B piezometer	2.26	#N/A	------	------
BN13	18-Nov-13	08:17	Amandine, Peter	Tube 1	6.2	7910	------	------
BN13	18-Nov-13	08:43	Amandine, Peter	Tube 2	9.2	8990	------	------
BN13	18-Nov-13		Amandine, Peter	Tube 3	12.1	11280	------	------
BN13	18-Nov-13		Amandine, Peter	Tube 4	15.1	18780	------	------
BN13	18-Nov-13		Amandine, Peter	Tube 5	18.2	37300	------	------
BN13	18-Nov-13		Amandine, Peter	Tube 6	21.0	42800	------	------
BN13	18-Nov-13	09:32	Amandine, Peter	Tube 7	24.1	45800	------	------
BN13	18-Nov-13		Amandine, Peter	Tube 8	27.2	No data	No data	No data
BN15	18-Nov-13	10:23	Amandine, Peter	Water table in BN15B piezometer	2.485	#N/A	------	------
BN15	18-Nov-13	11:15	Amandine, Peter	Tube 1	12.0	8050	------	------
BN15	18-Nov-13		Amandine, Peter	Tube 2	15.0	12960	------	------
BN15	18-Nov-13		Amandine, Peter	Tube 3	18.0	33800	------	------
BN15	18-Nov-13		Amandine, Peter	Tube 4	21.0	41800	------	------
BN15	18-Nov-13		Amandine, Peter	Tube 5	23.0	44600	------	------
BN19	13-Nov-13		Peter, Amandine, Julie, Martin	Water table in BN19 piezometer	1.83	#N/A	------	------
BN19	13-Nov-13	12:58	Peter, Amandine, Julie, Martin	Tube 1	6.0	1317	------	------
BN19	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 2	9.2	Blocked	Blocked	Blocked
BN19	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 3	11.0	1373	------	------
BN19	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 4	14.4	1405	------	------
BN20	19-Nov-13	14:33	Amandine, Tateti	Water table in BN20B piezometer	0.73	#N/A	------	------
BN20	19-Nov-13	14:52	Amandine, Tateti	Tube 1	6.0	637	------	------
BN20	19-Nov-13		Amandine, Tateti	Tube 2	8.0	628	------	------
BN20	19-Nov-13		Amandine, Tateti	Tube 3	11.6	701	------	------
BN20	19-Nov-13	15:27	Amandine, Tateti	Tube 4	15.2	778	------	------
BN21	13-Nov-13	08:40	Martin, Tateti, Peter, Amandine, Julie	Water table in BN21 piezometer	1.07	1673	13.6	13.7
BN21	13-Nov-13	08:51	Martin, Tateti, Peter, Amandine, Julie	Tube 1	6.0	2113	13.6	13.7
BN21	13-Nov-13		Martin, Tateti, Peter, Amandine, Julie	Tube 2	9.0	2118	13.6	13.7

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN21	13-Nov-13		Martin, Tateti, Peter, Amandine, Julie	Tube 3	12.0	2245	13.6	13.7
BN21	13-Nov-13		Martin, Tateti, Peter, Amandine, Julie	Tube 4	15.0	2730	13.6	13.7
BN21	13-Nov-13		Martin, Tateti, Peter, Amandine, Julie	Tube 5	18.0	3710	13.6	13.7
BN21	13-Nov-13	09:11	Martin, Tateti, Peter, Amandine, Julie	Tube 6	21.0	30200	13.6	13.7
BN22	20-Nov-13	10:45	Amandine, Tateti	Water table in BN22 piezometer	1.065	4810	------	------
BN22	20-Nov-13		Amandine, Tateti	Tube 1	6.5	11460	------	------
BN22	20-Nov-13		Amandine, Tateti	Tube 2	9.3	11690	------	------
BN22	20-Nov-13		Amandine, Tateti	Tube 3	10.9	12160	------	------
BN22	20-Nov-13		Amandine, Tateti	Tube 4	13.9	13150	------	------
BN22	20-Nov-13		Amandine, Tateti	Tube 5	15.6	33400	------	------
BN22	20-Nov-13	11:07	Amandine, Tateti	Tube 6	21.0	44700	------	------
BN23	19-Nov-13		Amandine, Tateti	Water table in BN23 piezometer	0.00	#N/A		
BN23	19-Nov-13	11:28	Amandine, Tateti	Water table in BN23B piezometer	0.73	#N/A	8.5	8.6
BN23	19-Nov-13		Amandine, Tateti	Tube 1	6.0	1878	8.5	8.6
BN23	19-Nov-13		Amandine, Tateti	Tube 2	9.6	2790	8.5	8.6
BN23	19-Nov-13		Amandine, Tateti	Tube 3	12.0	6260	8.5	8.6
BN23	19-Nov-13		Amandine, Tateti	Tube 4	12.8	18500	8.5	8.6
BN23	19-Nov-13		Amandine, Tateti	Tube 5	2.4	Blocked	Blocked	Blocked
BN23	19-Nov-13	12:12	Amandine, Tateti	Tube 6	20.0	31300	8.5	8.6
BN24	19-Nov-13	09:48	Amandine, Tateti	Water table in BN24 piezometer	1.75	1104	3.9	4.6
BN24	19-Nov-13		Amandine, Tateti	Tube 1	6.2	4020	3.9	4.6
BN24	19-Nov-13		Amandine, Tateti	Tube 2	3.4	Blocked	Blocked	Blocked
BN24	19-Nov-13		Amandine, Tateti	Tube 3	10.8	Blocked	Blocked	Blocked
BN24	19-Nov-13		Amandine, Tateti	Tube 4	11.4	Blocked	Blocked	Blocked
BN24	19-Nov-13		Amandine, Tateti	Tube 5	17.2	30000	3.9	4.6
BN24	19-Nov-13	10:28	Amandine, Tateti	Tube 6	20.2	43000	3.9	4.6
BN25	20-Nov-13	12:00	Amandine, Tateti	Water table in BN25 piezometer	1.135	510	10.6	10.9
BN25	20-Nov-13		Amandine, Tateti	Tube 1	6.0	1079	10.6	10.9
BN25	20-Nov-13		Amandine, Tateti	Tube 2	9.0	1028	10.6	10.9
BN25	20-Nov-13		Amandine, Tateti	Tube 3	11.5	3340	10.6	10.9
BN25	20-Nov-13	09:20	Amandine, Tateti	Tube 4	12.8	Blocked	Blocked	Blocked
BN26	13-Nov-13	07:25	Peter, Amandine, Julie, Martin	Water table in BN26 piezometer	1.74	485	3.8	4.9

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN26	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 1	1.4	Blocked	Blocked	Blocked
BN26	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 2	6.2	4890	3.8	4.9
BN26	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 3	12.0	5370	3.8	4.9
BN26	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 4	13.9	Blocked	Blocked	Blocked
BN26	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 5	15.4	10130	3.8	4.9
BN26	13-Nov-13		Peter, Amandine, Julie, Martin	Tube 6	17.6	Blocked	Blocked	Blocked
BN26	13-Nov-13	08:04	Peter, Amandine, Julie, Martin	Tube 7	24.2	43600	3.8	4.9
BN27	13-Nov-13	09:22	Peter, Martin, Amandine, Julie	Water table in BN27 piezometer	1.33	680	5.9	6.0
BN27	13-Nov-13		Peter, Martin, Amandine, Julie	Tube 1	6.0	2530	5.9	6.0
BN27	13-Nov-13		Peter, Martin, Amandine, Julie	Tube 2	9.0	2630	5.9	6.0
BN27	13-Nov-13		Peter, Martin, Amandine, Julie	Tube 3	12.0	2850	5.9	6.0
BN27	13-Nov-13		Peter, Martin, Amandine, Julie	Tube 4	14.4	3840	5.9	6.0
BN27	13-Nov-13	09:54	Peter, Martin, Amandine, Julie	Tube 5	17.5	13960	5.9	6.0
BN27	13-Nov-13		Peter, Martin, Amandine, Julie	Tube 6	21.0	40700	5.9	6.0
BN28	19-Nov-13	17:30	Amandine, Peter	Water table in BN28 piezometer	0.80	859	12.0	12.1
BN28	19-Nov-13		Amandine, Peter	Tube 1	6.0	2128	12.0	12.1
BN28	19-Nov-13		Amandine, Peter	Tube 2	3.0	Blocked	Blocked	Blocked
BN28	19-Nov-13		Amandine, Peter	Tube 3	12.0	2382	12.0	12.1
BN28	19-Nov-13		Amandine, Peter	Tube 4	15.0	Blocked	Blocked	Blocked
BN28	19-Nov-13	17:53	Amandine, Peter	Tube 5	17.0	26000	12.0	12.1
BN28	19-Nov-13		Amandine, Peter	Tube 6	19.7	39500	12.0	12.1
BN29	20-Nov-13	09:13	Amandine, Peter	Water table in BN29 piezometer	0.85	394	5.4	5.7
BN29	20-Nov-13		Amandine, Peter	Tube 1	6.0	2780	5.4	5.7
BN29	20-Nov-13		Amandine, Peter	Tube 2	9.4	8130	5.4	5.7
BN29	20-Nov-13		Amandine, Peter	Tube 3	12.0	Blocked	Blocked	Blocked
BN29	20-Nov-13		Amandine, Peter	Tube 4	15.0	32900	5.4	5.7
BN29	20-Nov-13		Amandine, Peter	Tube 5	18.4	38800	5.4	5.7
BN29	20-Nov-13	10:16	Amandine, Peter	Tube 6	20.6	41800	5.4	5.7
BN32	20-Nov-13	12:31	Amandine, Tateti	Water table in BN32 piezometer	1.55	844	12.5	13.0
BN32	20-Nov-13		Amandine, Tateti	Tube 1	1.3	Blocked	Blocked	Blocked
BN32	20-Nov-13		Amandine, Tateti	Tube 2	9.0	1379	12.5	13.0
BN32	20-Nov-13		Amandine, Tateti	Tube 3	12.0	1448	12.5	13.0

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN32	20-Nov-13		Amandine, Tateti	Tube 4	15.0	7240	12.5	13.0
BN32	20-Nov-13		Amandine, Tateti	Tube 5	18.0	27900	12.5	13.0
BN32	20-Nov-13		Amandine, Tateti	Tube 6	21.0	44400	12.5	13.0
BN32	20-Nov-13		Amandine, Tateti	Tube 7	23.7	46200	12.5	13.0
BN32	20-Nov-13	13:08	Amandine, Tateti	Tube 8	25.6	46800	12.5	13.0
BN33	20-Nov-13	11:17	Amandine, Tateti	Water table in BN33 piezometer	1.715	1130	12.4	13.1
BN33	20-Nov-13		Amandine, Tateti	Tube 1	6.0	933	12.4	13.1
BN33	20-Nov-13		Amandine, Tateti	Tube 2	9.0	906	12.4	13.1
BN33	20-Nov-13		Amandine, Tateti	Tube 3	12.0	937	12.4	13.1
BN33	20-Nov-13		Amandine, Tateti	Tube 4	15.0	14100	12.4	13.1
BN33	20-Nov-13		Amandine, Tateti	Tube 5	18.0	37700	12.4	13.1
BN33	20-Nov-13		Amandine, Tateti	Tube 6	21.0	44500	12.4	13.1
BN33	20-Nov-13	11:49	Amandine, Tateti	Tube 7	24.0	46300	12.4	13.1
BN33	20-Nov-13		Amandine, Tateti	Tube 8	27.0	46800	12.4	13.1
BN34	13-Nov-13	10:53	Peter, Amandine, Martin, Julie	Water table in BN34 piezometer	1.59	1640	2.9	3.4
BN34	13-Nov-13		Peter, Amandine, Martin, Julie	Tube 1	6.0	4570	2.9	3.4
BN34	13-Nov-13		Peter, Amandine, Martin, Julie	Tube 2	9.0	11470	2.9	3.4
BN34	13-Nov-13		Peter, Amandine, Martin, Julie	Tube 3	12.0	27300	2.9	3.4
BN34	13-Nov-13		Peter, Amandine, Martin, Julie	Tube 4	13.0	31200	2.9	3.4
BN34	13-Nov-13		Peter, Amandine, Martin, Julie	Tube 5	18.0	40100	2.9	3.4
BN34	13-Nov-13		Peter, Amandine, Martin, Julie	Tube 6	20.4	43200	2.9	3.4
BN34	13-Nov-13	11:20	Peter, Amandine, Martin, Julie	Tube 7	13.6	Blocked	Blocked	Blocked
RESULTS – MONITORING BORE SAMPLING, FEBRUARY 2014								
BN1	20-Feb-14	08:35	Eriina, Hendry, Teretia, I Maamau, Julie	Water table in BN1B piezometer	1.66	1048	6.6	7.2
BN1	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	BN1 Tube 1	6.4	1022	6.6	7.2
BN1	20-Feb-14	09:39	Eriina, Hendry, Teretia, I Maamau, Julie	BN1 Tube 2	9.0	17330	6.6	7.2
BN1	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	BN1 Tube 3	12.6	16350	6.6	7.2
BN1	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	BN1 Tube 4	14.5	21800	6.6	7.2
BN1	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	BN1 Tube 5	17.3	33500	6.6	7.2
BN1	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	BN1 Tube 6	19.2	37000	6.6	7.2
BN2	20-Feb-14	10:17	Eriina, Hendry, Teretia, I Maamau, Julie	Water table in BN2B piezometer, BN2B	1.64	226	5.2	5.9
BN2	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	2B Tube 1, BN2B	6.4	3250	5.2	5.9

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN2	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 2	9.1	6960	5.2	5.9
BN2	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	2B Tube 2 , BN2B	12.3	5140	5.2	5.9
BN2	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 3	15.1	19730	5.2	5.9
BN2	20-Feb-14	10:32	Eriina, Hendry, Teretia, I Maamau, Julie	Tube 4	18.8	35200	5.2	5.9
BN2	20-Feb-14	11:02	Eriina, Hendry, Teretia, I Maamau, Julie	Tube 5	21.7	40100	5.2	5.9
BN4	20-Feb-14	11:17	Eriina, Hendry, Teretia, I Maamau, Julie	Water table in BN4C piezometer	1.38	2594	------	------
BN4	20-Feb-14	11:29	Eriina, Hendry, Teretia, I Maamau, Julie	Tube 1	19.2	33000	------	------
BN4	20-Feb-14	00:00	Eriina, Hendry, Teretia, I Maamau, Julie	Tube 2	23.9	39300	------	------
BN4	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 3	25.7	40500	------	------
BN4	20-Feb-14	00:00	Eriina, Hendry, Teretia, I Maamau, Julie	Tube 4	28.3	40800	------	------
BN7	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Water table in BN7B piezometer	2.57	1254	9.6	10.1
BN7	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 1	5.8	1335	9.6	10.1
BN7	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 2	8.8	1463	9.6	10.1
BN7	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 3	11.9	5320	9.6	10.1
BN7	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 4	14.4	20210	9.6	10.1
BN7	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 5	17.6	30100	9.6	10.1
BN7	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 6	19.4	36400	9.6	10.1
BN11	21-Feb-14		Dominic, Julie, Teretia	Water table in BN11B piezometer, BN11B	1.35	549	9.4	10.4
BN11	21-Feb-14		Dominic, Julie, Teretia	Tube 1, BN11B	4.5	No tube	No tube	No tube
BN11	21-Feb-14		Dominic, Julie, Teretia	Tube 1	6.4	Blocked	Blocked	Blocked
BN11	21-Feb-14		Dominic, Julie, Teretia	Tube 2, BN11B	11.5	3010	9.4	10.4
BN11	21-Feb-14		Dominic, Julie, Teretia	Tube 2	14.6	6120	9.4	10.4
BN11	21-Feb-14		Dominic, Julie, Teretia	Tube 3	16.6	23100	9.4	10.4
BN11	21-Feb-14	10:44	Dominic, Julie, Teretia	Tube 4	19.6	34200	9.4	10.4
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Water table in BN13B piezometer	2.25	1745	3.8	4.2
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 1	6.2	3660	3.8	4.2
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 2	9.2	7670	3.8	4.2
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 3	12.1	8650	3.8	4.2
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 4	15.1	10110	3.8	4.2
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 5	18.2	32800	3.8	4.2
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 6	21.0	37500	3.8	4.2
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 7	24.1	41100	3.8	4.2

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN13	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 8	27.2	41600	3.8	4.2
BN15	20-Feb-14	08:00	Eriina, Hendry, Teretia, I Maamau, Julie	Water table in BN15B piezometer	2.425	591	4.8	7.6
BN15	20-Feb-14	08:30	Eriina, Hendry, Teretia, I Maamau, Julie	Tube 1	12.0	8360	4.8	7.6
BN15	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 2	15.0	14740	4.8	7.6
BN15	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 3	18.0	31200	4.8	7.6
BN15	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 4	21.0	37200	4.8	7.6
BN15	20-Feb-14		Eriina, Hendry, Teretia, I Maamau, Julie	Tube 5	23.0	39200	4.8	7.6
BN19	21-Feb-14		Teretia, Julie	Water table in BN19 piezometer	1.46	1244	------	------
BN19	21-Feb-14		Teretia, Julie	Tube 1	6.0	1192	------	------
BN19	21-Feb-14		Teretia, Julie	Tube 2	9.2	Blocked	Blocked	Blocked
BN19	21-Feb-14		Teretia, Julie	Tube 3	11.0	1209	------	------
BN19	21-Feb-14		Teretia, Julie	Tube 4	14.4	1231	------	------
BN20	21-Feb-14	11:30	Dominic, Teretia, Julie	Water table in BN20B piezometer	0.55	514	------	------
BN20	21-Feb-14		Dominic, Teretia, Julie	Tube 1	6.0	577	------	------
BN20	21-Feb-14		Dominic, Teretia, Julie	Tube 2	8.0	590	------	------
BN20	21-Feb-14		Dominic, Teretia, Julie	Tube 3	11.6	636	------	------
BN20	21-Feb-14		Dominic, Teretia, Julie	Tube 4	15.2	668	------	------
BN21	22-Feb-14	11:35	Iriina, Julie	Water table in BN21 piezometer	0.79	397	14.6	14.7
BN21	22-Feb-14		Iriina, Julie	Tube 1	6.0	1708	14.6	14.7
BN21	22-Feb-14		Iriina, Julie	Tube 2	9.0	1883	14.6	14.7
BN21	22-Feb-14		Iriina, Julie	Tube 3	12.0	2150	14.6	14.7
BN21	22-Feb-14		Iriina, Julie	Tube 4	15.0	2550	14.6	14.7
BN21	22-Feb-14		Iriina, Julie	Tube 5	18.0	3280	14.6	14.7
BN21	22-Feb-14		Iriina, Julie	Tube 6	21.0	28300	14.6	14.7
BN22	19-Feb-14	09:09	Teretia, Enna, Amini, Amit, Peter, Julie	Water table in BN22 piezometer	0.730	9760	------	------
BN22	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 1	6.5	11250	------	------
BN22	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 2	9.3	11320	------	------
BN22	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 3	10.9	12360	------	------
BN22	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 4	13.9	20650	------	------
BN22	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 5	15.6	35600	------	------
BN22	19-Feb-14	09:29	Teretia, Enna, Amini, Amit, Peter, Julie	Tube 6	21.0	43300	------	------
BN23	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Water table in BN23 piezometer	dry	-		

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN23	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Water table in BN23B piezometer	2.54	569	7.0	7.1
BN23	19-Feb-14	08:05	Teretia, Enna, Amini, Amit, Peter, Julie	Tube 1	6.0	2240	7.0	7.1
BN23	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 2	9.6	3220	7.0	7.1
BN23	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 3	12.0	6340	7.0	7.1
BN23	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 4	12.8	14900	7.0	7.1
BN23	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 5	2.4	Blocked	Blocked	Blocked
BN23	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 6	20.0	30800	7.0	7.1
BN24	21-Feb-14		Teretia, Dominic, Julie	Water table in BN24 piezometer	1.71	773	4.8	5.4
BN24	21-Feb-14		Teretia, Dominic, Julie	Tube 1	6.2	3260	4.8	5.4
BN24	21-Feb-14		Teretia, Dominic, Julie	Tube 2	3.4	Blocked	Blocked	Blocked
BN24	21-Feb-14		Teretia, Dominic, Julie	Tube 3	10.8	Blocked	Blocked	Blocked
BN24	21-Feb-14		Teretia, Dominic, Julie	Tube 4	11.4	Blocked	Blocked	Blocked
BN24	21-Feb-14		Teretia, Dominic, Julie	Tube 5	17.2	27000	4.8	5.4
BN24	21-Feb-14		Teretia, Dominic, Julie	Tube 6	20.2	39300	4.8	5.4
BN25	19-Feb-14	15:41	Teretia, Enna, Amini, Amit, Peter, Julie	Water table in BN25 piezometer	0.920	196	------	------
BN25	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 1	6.0	835	------	------
BN25	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 2	9.0	907	------	------
BN25	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 3	11.5	1344	------	------
BN25	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 4	12.8	4780	Blocked	Blocked
BN26	22-Feb-14	11:03	Eriina, Julie	Water table in BN26 piezometer	1.46	343	4.0	5.2
BN26	22-Feb-14		Eriina, Julie	Tube 1	1.4	Blocked	Blocked	Blocked
BN26	22-Feb-14		Eriina, Julie	Tube 2	6.2	4310	4.0	5.2
BN26	22-Feb-14		Eriina, Julie	Tube 3	12.0	4610	4.0	5.2
BN26	22-Feb-14		Eriina, Julie	Tube 4	13.9	Blocked	Blocked	Blocked
BN26	22-Feb-14		Eriina, Julie	Tube 5	15.4	9340	4.0	5.2
BN26	22-Feb-14		Eriina, Julie	Tube 6	17.6	Blocked	Blocked	Blocked
BN26	22-Feb-14		Eriina, Julie	Tube 7	24.2	38300	4.0	5.2
BN27	22-Feb-14	10:31	Iriina, Julie	Water table in BN27 piezometer	1.13	582	5.9	5.9
BN27	22-Feb-14		Iriina, Julie	Tube 1	6.0	2550	5.9	5.9
BN27	22-Feb-14		Iriina, Julie	Tube 2	9.0	2630	5.9	5.9
BN27	22-Feb-14		Iriina, Julie	Tube 3	12.0	3110	5.9	5.9
BN27	22-Feb-14		Iriina, Julie	Tube 4	14.4	3910	5.9	5.9

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN27	22-Feb-14		Iriina, Julie	Tube 5	17.5	14590	5.9	5.9
BN27	22-Feb-14		Iriina, Julie	Tube 6	21.0	36100	5.9	5.9
BN28	22-Feb-14	08:00	Iriina, Julie	Water table in BN28 piezometer	0.86	644	12.0	12.2
BN28	22-Feb-14		Iriina, Julie	Tube 1	6.0	2150	12.0	12.2
BN28	22-Feb-14		Iriina, Julie	Tube 2	3.0	Blocked	Blocked	Blocked
BN28	22-Feb-14		Iriina, Julie	Tube 3	12.0	2320	12.0	12.2
BN28	22-Feb-14		Iriina, Julie	Tube 4	15.0	Blocked	Blocked	Blocked
BN28	22-Feb-14		Iriina, Julie	Tube 5	17.0	23900	12.0	12.2
BN28	22-Feb-14	09:00	Iriina, Julie	Tube 6	19.7	35500	12.0	12.2
BN29	19-Feb-14	14:44	Iriina, Julie	Water table in BN29 piezometer	0.85	346	6.5	6.9
BN29	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 1	6.0	1738	6.5	6.9
BN29	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 2	9.4	6990	6.5	6.9
BN29	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 3	12.0	Blocked	Blocked	Blocked
BN29	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 4	15.0	32000	6.5	6.9
BN29	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 5	18.4	39000	6.5	6.9
BN29	19-Feb-14	15:00	Teretia, Enna, Amini, Amit, Peter, Julie	Tube 6	20.6	39400	6.5	6.9
BN32	19-Feb-14	10:44	Teretia, Enna, Amini, Amit, Peter, Julie	Water table in BN32 piezometer	1.27	768	12.5	13.0
BN32	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 1	1.3	Blocked	Blocked	Blocked
BN32	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 2	9.0	1375	12.5	13.0
BN32	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 3	12.0	1530	12.5	13.0
BN32	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 4	15.0	7150	12.5	13.0
BN32	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 5	18.0	25900	12.5	13.0
BN32	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 6	21.0	44600	12.5	13.0
BN32	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 7	23.7	44500	12.5	13.0
BN32	19-Feb-14		Teretia, Enna, Amini, Amit, Peter, Julie	Tube 8	25.6	47000	12.5	13.0
BN33	18-Feb-14	08:20	Teretia, Eriina, Amini, Amit	Water table in BN33 piezometer	1.620	425	12.3	12.9
BN33	18-Feb-14		Teretia, Eriina, Amini, Amit	Tube 1	6.0	967	12.3	12.9
BN33	18-Feb-14		Teretia, Eriina, Amini, Amit	Tube 2	9.0	970	12.3	12.9
BN33	18-Feb-14		Teretia, Eriina, Amini, Amit	Tube 3	12.0	1106	12.3	12.9
BN33	18-Feb-14		Teretia, Eriina, Amini, Amit	Tube 4	15.0	15950	12.3	12.9
BN33	18-Feb-14		Teretia, Eriina, Amini, Amit	Tube 5	18.0	36600	12.3	12.9
BN33	18-Feb-14		Teretia, Eriina, Amini, Amit	Tube 6	21.0	44400	12.3	12.9

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN33	18-Feb-14		Teretia, Eriina, Amini, Amit	Tube 7	24.0	44600	12.3	12.9
BN33	18-Feb-14		Teretia, Eriina, Amini, Amit	Tube 8	27.0	46700	12.3	12.9
BN34	21-Feb-14	15:00	Teretia, Julie	Water table in BN34 piezometer	1.45	1688	2.8	3.3
BN34	21-Feb-14		Teretia, Julie	Tube 1	6.0	4470	2.8	3.3
BN34	21-Feb-14		Teretia, Julie	Tube 2	9.0	10290	2.8	3.3
BN34	21-Feb-14		Teretia, Julie	Tube 3	12.0	23040	2.8	3.3
BN34	21-Feb-14		Teretia, Julie	Tube 4	13.0	27400	2.8	3.3
BN34	21-Feb-14		Teretia, Julie	Tube 5	18.0	35700	2.8	3.3
BN34	21-Feb-14		Teretia, Julie	Tube 6	20.4	37900	2.8	3.3
BN34	21-Feb-14		Teretia, Julie	Tube 7	13.6	Blocked	Blocked	Blocked
RESULTS – MONITORING BORE SAMPLING, JUNE 2014								
BN1	3-Jun-14		Amit, Tateti, Burebure	Water table in BN1B piezometer	0.84	480	6.7	7.4
BN1	3-Jun-14		Amit, Tateti, Burebure	BN1 Tube 1	6.4	764	6.7	7.4
BN1	3-Jun-14		Amit, Tateti, Burebure	BN1 Tube 2	9.0	15400	6.7	7.4
BN1	3-Jun-14		Amit, Tateti, Burebure	BN1 Tube 3	12.6	15330	6.7	7.4
BN1	3-Jun-14		Amit, Tateti, Burebure	BN1 Tube 4	14.5	16020	6.7	7.4
BN1	3-Jun-14		Amit, Tateti, Burebure	BN1 Tube 5	17.3	31400	6.7	7.4
BN1	3-Jun-14		Amit, Tateti, Burebure	BN1 Tube 6	19.2	35600	6.7	7.4
BN2	3-Jun-14		Amit, Tateti, Burebure	Water table in BN2B piezometer, BN2B	1.74	257	7.6	7.8
BN2	3-Jun-14		Amit, Tateti, Burebure	2B Tube 1, BN2B	6.4	1602	7.6	7.8
BN2	3-Jun-14		Amit, Tateti, Burebure	Tube 2	9.1	3710	7.6	7.8
BN2	3-Jun-14		Amit, Tateti, Burebure	2B Tube 2 , BN2B	12.3	2890	7.6	7.8
BN2	3-Jun-14		Amit, Tateti, Burebure	Tube 3	15.1	16300	7.6	7.8
BN2	3-Jun-14		Amit, Tateti, Burebure	Tube 4	18.8	29800	7.6	7.8
BN2	3-Jun-14		Amit, Tateti, Burebure	Tube 5	21.7	36800	7.6	7.8
BN4	3-Jun-14		Amit, Tateti, Burebure	Water table in BN4C piezometer	1.45	1255	2.2	5.2
BN4	3-Jun-14		Amit, Tateti, Burebure	Tube 1	19.2	32700	2.2	5.2
BN4	3-Jun-14		Amit, Tateti, Burebure	Tube 2	23.9	38300	2.2	5.2
BN4	3-Jun-14		Amit, Tateti, Burebure	Tube 3	25.7	40000	2.2	5.2
BN4	3-Jun-14		Amit, Tateti, Burebure	Tube 4	28.3	41200	2.2	5.2
BN7	3-Jun-14		Amit, Tateti, Burebure	Water table in BN7B piezometer	2.61	1134	9.4	9.9
BN7	3-Jun-14		Amit, Tateti, Burebure	Tube 1	5.8	1062	9.4	9.9

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN7	3-Jun-14		Amit, Tateti, Burebure	Tube 2	8.8	1417	9.4	9.9
BN7	3-Jun-14		Amit, Tateti, Burebure	Tube 3	11.9	6900	9.4	9.9
BN7	3-Jun-14		Amit, Tateti, Burebure	Tube 4	14.4	15440	9.4	9.9
BN7	3-Jun-14		Amit, Tateti, Burebure	Tube 5	17.6	31300	9.4	9.9
BN7	3-Jun-14		Amit, Tateti, Burebure	Tube 6	19.4	35400	9.4	9.9
BN11	4-Jun-14		Amit, Tateti, Burebure	Water table in BN11B piezometer, BN11B	1.44	561	12.4	12.7
BN11	4-Jun-14		Amit, Tateti, Burebure	Tube 1, BN11B	4.5	No tube	No tube	No tube
BN11	4-Jun-14		Amit, Tateti, Burebure	Tube 1	6.4	Blocked	Blocked	Blocked
BN11	4-Jun-14		Amit, Tateti, Burebure	Tube 2, BN11B	11.5	2008	12.4	12.7
BN11	4-Jun-14		Amit, Tateti, Burebure	Tube 2	14.6	3620	12.4	12.7
BN11	4-Jun-14		Amit, Tateti, Burebure	Tube 3	16.6	15790	12.4	12.7
BN11	4-Jun-14		Amit, Tateti, Burebure	Tube 4	19.6	33150	12.4	12.7
BN13	3-Jun-14		Amit, Tateti, Burebure	Water table in BN13B piezometer	2.32	661	3.6	4.6
BN13	3-Jun-14		Amit, Tateti, Burebure	Tube 1	6.2	6370	3.6	4.6
BN13	3-Jun-14		Amit, Tateti, Burebure	Tube 2	9.2	7290	3.6	4.6
BN13	3-Jun-14		Amit, Tateti, Burebure	Tube 3	12.1	8610	3.6	4.6
BN13	3-Jun-14		Amit, Tateti, Burebure	Tube 4	15.1	15370	3.6	4.6
BN13	3-Jun-14		Amit, Tateti, Burebure	Tube 5	18.2	31900	3.6	4.6
BN13	3-Jun-14		Amit, Tateti, Burebure	Tube 6	21.0	36800	3.6	4.6
BN13	3-Jun-14		Amit, Tateti, Burebure	Tube 7	24.1	40200	3.6	4.6
BN13	3-Jun-14		Amit, Tateti, Burebure	Tube 8	27.2	41200	3.6	4.6
BN15	4-Jun-14		Amit, Tateti, Burebure	Water table in BN15B piezometer	2.480	682	4.8	7.5
BN15	4-Jun-14		Amit, Tateti, Burebure	Tube 1	12.0	7990	4.8	7.5
BN15	4-Jun-14		Amit, Tateti, Burebure	Tube 2	15.0	13400	4.8	7.5
BN15	4-Jun-14		Amit, Tateti, Burebure	Tube 3	18.0	32100	4.8	7.5
BN15	4-Jun-14		Amit, Tateti, Burebure	Tube 4	21.0	39300	4.8	7.5
BN15	4-Jun-14		Amit, Tateti, Burebure	Tube 5	23.0	42300	4.8	7.5
BN19	3-Jun-14		Amit, Tateti, Burebure	Water table in BN19 piezometer	1.40	931	------	------
BN19	3-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	1054	------	------
BN19	3-Jun-14		Amit, Tateti, Burebure	Tube 2	9.2	Blocked	Blocked	Blocked
BN19	3-Jun-14		Amit, Tateti, Burebure	Tube 3	11.0	1026	------	------
BN19	3-Jun-14		Amit, Tateti, Burebure	Tube 4	14.4	1024	------	------

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN20	4-Jun-14		Amit, Tateti, Burebure	Water table in BN20B piezometer	0.69	489	------	------
BN20	4-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	528	------	------
BN20	4-Jun-14		Amit, Tateti, Burebure	Tube 2	8.0	528	------	------
BN20	4-Jun-14		Amit, Tateti, Burebure	Tube 3	11.6	533	------	------
BN20	4-Jun-14		Amit, Tateti, Burebure	Tube 4	15.2	551	------	------
BN21	3-Jun-14		Amit, Tateti, Burebure	Water table in BN21 piezometer	0.98	452	18.2	18.6
BN21	3-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	1019	18.2	18.6
BN21	3-Jun-14		Amit, Tateti, Burebure	Tube 2	9.0	1045	18.2	18.6
BN21	3-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	1071	18.2	18.6
BN21	3-Jun-14		Amit, Tateti, Burebure	Tube 4	15.0	1270	18.2	18.6
BN21	3-Jun-14		Amit, Tateti, Burebure	Tube 5	18.0	1524	18.2	18.6
BN21	3-Jun-14		Amit, Tateti, Burebure	Tube 6	21.0	16400	18.2	18.6
BN22	3-Jun-14		Amit, Tateti, Burebure	Water table in BN22 piezometer	0.890	479	3.5	4.9
BN22	3-Jun-14		Amit, Tateti, Burebure	Tube 1	6.5	4800	3.5	4.9
BN22	3-Jun-14		Amit, Tateti, Burebure	Tube 2	9.3	5010	3.5	4.9
BN22	3-Jun-14		Amit, Tateti, Burebure	Tube 3	10.9	5130	3.5	4.9
BN22	3-Jun-14		Amit, Tateti, Burebure	Tube 4	13.9	9680	3.5	4.9
BN22	3-Jun-14		Amit, Tateti, Burebure	Tube 5	15.6	27900	3.5	4.9
BN22	3-Jun-14		Amit, Tateti, Burebure	Tube 6	21.0	39300	3.5	4.9
BN23	3-Jun-14		Amit, Tateti, Burebure	Water table in BN23 piezometer	2.04	-		
BN23	3-Jun-14		Amit, Tateti, Burebure	Water table in BN23B piezometer	2.64	521	10.7	10.9
BN23	3-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	977	10.7	10.9
BN23	3-Jun-14		Amit, Tateti, Burebure	Tube 2	9.6	1598	10.7	10.9
BN23	3-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	3580	10.7	10.9
BN23	3-Jun-14		Amit, Tateti, Burebure	Tube 4	12.8	13240	10.7	10.9
BN23	3-Jun-14		Amit, Tateti, Burebure	Tube 5	2.4	Blocked	Blocked	Blocked
BN23	3-Jun-14		Amit, Tateti, Burebure	Tube 6	20.0	29200	10.7	10.9
BN24	3-Jun-14		Amit, Tateti, Burebure	Water table in BN24 piezometer	1.82	759	4.9	5.4
BN24	3-Jun-14		Amit, Tateti, Burebure	Tube 1	6.2	3210	4.9	5.4
BN24	3-Jun-14		Amit, Tateti, Burebure	Tube 2	3.4	Blocked	Blocked	Blocked
BN24	3-Jun-14		Amit, Tateti, Burebure	Tube 3	10.8	Blocked	Blocked	Blocked
BN24	3-Jun-14		Amit, Tateti, Burebure	Tube 4	11.4	Blocked	Blocked	Blocked

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN24	3-Jun-14		Amit, Tateti, Burebure	Tube 5	17.2	27100	4.9	5.4
BN24	3-Jun-14		Amit, Tateti, Burebure	Tube 6	20.2	42600	4.9	5.4
BN25	3-Jun-14		Amit, Tateti, Burebure	Water table in BN25 piezometer	1.020	145	------	------
BN25	3-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	716	------	------
BN25	3-Jun-14		Amit, Tateti, Burebure	Tube 2	9.0	780	------	------
BN25	3-Jun-14		Amit, Tateti, Burebure	Tube 3	11.5	1114	------	------
BN25	3-Jun-14		Amit, Tateti, Burebure	Tube 4	12.8	Blocked	Blocked	Blocked
BN26	4-Jun-14		Amit, Tateti, Burebure	Water table in BN26 piezometer	1.58	308	5.1	5.7
BN26	4-Jun-14		Amit, Tateti, Burebure	Tube 1	1.4	Blocked	Blocked	Blocked
BN26	4-Jun-14		Amit, Tateti, Burebure	Tube 2	6.2	3190	5.1	5.7
BN26	4-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	3370	5.1	5.7
BN26	4-Jun-14		Amit, Tateti, Burebure	Tube 4	13.9	Blocked	Blocked	Blocked
BN26	4-Jun-14		Amit, Tateti, Burebure	Tube 5	15.4	7560	5.1	5.7
BN26	4-Jun-14		Amit, Tateti, Burebure	Tube 6	17.6	Blocked	Blocked	Blocked
BN26	4-Jun-14		Amit, Tateti, Burebure	Tube 7	24.2	37200	5.1	5.7
BN27	4-Jun-14		Amit, Tateti, Burebure	Water table in BN27 piezometer	1.24	416	14.6	14.9
BN27	4-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	1415	14.6	14.9
BN27	4-Jun-14		Amit, Tateti, Burebure	Tube 2	9.0	1495	14.6	14.9
BN27	4-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	1598	14.6	14.9
BN27	4-Jun-14		Amit, Tateti, Burebure	Tube 4	14.4	1954	14.6	14.9
BN27	4-Jun-14		Amit, Tateti, Burebure	Tube 5	17.5	9790	14.6	14.9
BN27	4-Jun-14		Amit, Tateti, Burebure	Tube 6	21.0	33200	14.6	14.9
BN28	5-Jun-14		Amit, Tateti, Burebure	Water table in BN28 piezometer	0.86	604	12.3	12.9
BN28	5-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	1594	12.3	12.9
BN28	5-Jun-14		Amit, Tateti, Burebure	Tube 2	3.0	Blocked	Blocked	Blocked
BN28	5-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	1590	12.3	12.9
BN28	5-Jun-14		Amit, Tateti, Burebure	Tube 4	15.0	Blocked	Blocked	Blocked
BN28	5-Jun-14		Amit, Tateti, Burebure	Tube 5	17.0	17910	12.3	12.9
BN28	5-Jun-14		Amit, Tateti, Burebure	Tube 6	19.7	31800	12.3	12.9
BN29	5-Jun-14		Amit, Tateti, Burebure	Water table in BN29 piezometer	0.92	328	7.0	7.4
BN29	5-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	1738	7.0	7.4
BN29	5-Jun-14		Amit, Tateti, Burebure	Tube 2	9.4	4240	7.0	7.4

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN29	5-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	Blocked	Blocked	Blocked
BN29	5-Jun-14		Amit, Tateti, Burebure	Tube 4	15.0	28100	7.0	7.4
BN29	5-Jun-14		Amit, Tateti, Burebure	Tube 5	18.4	33600	7.0	7.4
BN29	5-Jun-14		Amit, Tateti, Burebure	Tube 6	20.6	36400	7.0	7.4
BN32	5-Jun-14		Amit, Tateti, Burebure	Water table in BN32 piezometer	1.38	465	14.5	14.7
BN32	5-Jun-14		Amit, Tateti, Burebure	Tube 1	1.3	Blocked	Blocked	Blocked
BN32	5-Jun-14		Amit, Tateti, Burebure	Tube 2	9.0	821	14.5	14.7
BN32	5-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	837	14.5	14.7
BN32	5-Jun-14		Amit, Tateti, Burebure	Tube 4	15.0	2810	14.5	14.7
BN32	5-Jun-14		Amit, Tateti, Burebure	Tube 5	18.0	21200	14.5	14.7
BN32	5-Jun-14		Amit, Tateti, Burebure	Tube 6	21.0	38700	14.5	14.7
BN32	5-Jun-14		Amit, Tateti, Burebure	Tube 7	23.7	41100	14.5	14.7
BN32	5-Jun-14		Amit, Tateti, Burebure	Tube 8	25.6	41500	14.5	14.7
BN33	5-Jun-14		Amit, Tateti, Burebure	Water table in BN33 piezometer	1.640	539	12.6	13.3
BN33	5-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	972	12.6	13.3
BN33	5-Jun-14		Amit, Tateti, Burebure	Tube 2	9.0	959	12.6	13.3
BN33	5-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	967	12.6	13.3
BN33	5-Jun-14		Amit, Tateti, Burebure	Tube 4	15.0	8920	12.6	13.3
BN33	5-Jun-14		Amit, Tateti, Burebure	Tube 5	18.0	31300	12.6	13.3
BN33	5-Jun-14		Amit, Tateti, Burebure	Tube 6	21.0	39000	12.6	13.3
BN33	5-Jun-14		Amit, Tateti, Burebure	Tube 7	24.0	40800	12.6	13.3
BN33	5-Jun-14		Amit, Tateti, Burebure	Tube 8	27.0	41400	12.6	13.3
BN34	5-Jun-14		Amit, Tateti, Burebure	Water table in BN34 piezometer	1.49	850	6.1	6.1
BN34	5-Jun-14		Amit, Tateti, Burebure	Tube 1	6.0	2350	6.1	6.1
BN34	5-Jun-14		Amit, Tateti, Burebure	Tube 2	9.0	8890	6.1	6.1
BN34	5-Jun-14		Amit, Tateti, Burebure	Tube 3	12.0	23900	6.1	6.1
BN34	5-Jun-14		Amit, Tateti, Burebure	Tube 4	13.0	24600	6.1	6.1
BN34	5-Jun-14		Amit, Tateti, Burebure	Tube 5	18.0	34100	6.1	6.1
BN34	5-Jun-14		Amit, Tateti, Burebure	Tube 6	20.4	36600	6.1	6.1
BN34	5-Jun-14		Amit, Tateti, Burebure	Tube 7	13.6	Blocked	Blocked	Blocked
RESULTS – MONITORING BORE SAMPLING, AUGUST 2014								
BN1	14-Aug-14	13:40	Amit, Tateti	Water table in BN1B piezometer	1.56	331	6.8	7.4

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN1	14-Aug-14		Amit, Tateti	BN1 Tube 1	6.4	955	6.8	7.4
BN1	14-Aug-14	13:52	Amit, Tateti	BN1 Tube 2	9.0	11100	6.8	7.4
BN1	14-Aug-14		Amit, Tateti	BN1 Tube 3	12.6	14090	6.8	7.4
BN1	14-Aug-14		Amit, Tateti	BN1 Tube 4	14.5	18640	6.8	7.4
BN1	14-Aug-14		Amit, Tateti	BN1 Tube 5	17.3	29600	6.8	7.4
BN1	14-Aug-14		Amit, Tateti	BN1 Tube 6	19.2	33600	6.8	7.4
BN2	14-Aug-14	12:40	Amit, Tateti	Water table in BN2B piezometer, BN2B	1.70	443	7.5	7.9
BN2	14-Aug-14	13.06	Amit, Tateti	2B Tube 1, BN2B	6.4	1340	7.5	7.9
BN2	14-Aug-14	12:46	Amit, Tateti	Tube 2	9.1	4190	7.5	7.9
BN2	14-Aug-14		Amit, Tateti	2B Tube 2 , BN2B	12.3	1591	7.5	7.9
BN2	14-Aug-14		Amit, Tateti	Tube 3	15.1	11080	7.5	7.9
BN2	14-Aug-14	12:56	Amit, Tateti	Tube 4	18.8	29500	7.5	7.9
BN2	14-Aug-14	13.34	Amit, Tateti	Tube 5	21.7	36700	7.5	7.9
BN4	12-Aug-14		Amit, Tateti	Water table in BN4C piezometer	1.67	1045	2.8	6.5
BN4	12-Aug-14		Amit, Tateti	Tube 1	19.2	24300	2.8	6.5
BN4	12-Aug-14		Amit, Tateti	Tube 2	23.9	35400	2.8	6.5
BN4	12-Aug-14		Amit, Tateti	Tube 3	25.7	37200	2.8	6.5
BN4	12-Aug-14		Amit, Tateti	Tube 4	28.3	38400	2.8	6.5
BN7	12-Aug-14		Amit, Tateti	Water table in BN7B piezometer	2.58	618	12.1	12.4
BN7	12-Aug-14	12:58	Amit, Tateti	Tube 1	5.8	801	12.1	12.4
BN7	12-Aug-14		Amit, Tateti	Tube 2	8.8	843	12.1	12.4
BN7	12-Aug-14		Amit, Tateti	Tube 3	11.9	1626	12.1	12.4
BN7	12-Aug-14		Amit, Tateti	Tube 4	14.4	12610	12.1	12.4
BN7	12-Aug-14		Amit, Tateti	Tube 5	17.6	23200	12.1	12.4
BN7	12-Aug-14	14:15	Amit, Tateti	Tube 6	19.4	32200	12.1	12.4
BN11	13-Aug-14	14:30	Amit, Tateti	Water table in BN11B piezometer, BN11B	1.33	337	13.5	13.6
BN11	13-Aug-14	14:50	Amit, Tateti	Tube 1, BN11B	4.5	No tube	No tube	No tube
BN11	13-Aug-14		Amit, Tateti	Tube 1	6.4	Blocked	Blocked	Blocked
BN11	13-Aug-14	14:40	Amit, Tateti	Tube 2, BN11B	11.5	1834	13.5	13.6
BN11	13-Aug-14		Amit, Tateti	Tube 2	14.6	2880	13.5	13.6
BN11	13-Aug-14		Amit, Tateti	Tube 3	16.6	13030	13.5	13.6
BN11	13-Aug-14	15:30	Amit, Tateti	Tube 4	19.6	30100	13.5	13.6

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN13	16-Aug-14	10:50	Amit, Tateti	Water table in BN13B piezometer	2.18	512	3.7	4.8
BN13	16-Aug-14	10:50	Amit, Tateti	Tube 1	6.2	5890	3.7	4.8
BN13	16-Aug-14	11:00	Amit, Tateti	Tube 2	9.2	5950	3.7	4.8
BN13	16-Aug-14		Amit, Tateti	Tube 3	12.1	5990	3.7	4.8
BN13	16-Aug-14		Amit, Tateti	Tube 4	15.1	13150	3.7	4.8
BN13	16-Aug-14		Amit, Tateti	Tube 5	18.2	29200	3.7	4.8
BN13	16-Aug-14		Amit, Tateti	Tube 6	21.0	34600	3.7	4.8
BN13	16-Aug-14		Amit, Tateti	Tube 7	24.1	37500	3.7	4.8
BN13	16-Aug-14	12:15	Amit, Tateti	Tube 8	27.2	38200	3.7	4.8
BN15	12-Aug-14	13:40	Amit, Tateti	Water table in BN15B piezometer	2.470	515	6.4	8.9
BN15	12-Aug-14	13:58	Amit, Tateti	Tube 1	12.0	5330	6.4	8.9
BN15	12-Aug-14		Amit, Tateti	Tube 2	15.0	7350	6.4	8.9
BN15	12-Aug-14		Amit, Tateti	Tube 3	18.0	24600	6.4	8.9
BN15	12-Aug-14		Amit, Tateti	Tube 4	21.0	32700	6.4	8.9
BN15	12-Aug-14	14:40	Amit, Tateti	Tube 5	23.0	35600	6.4	8.9
BN19	13-Aug-14	08:00	Amit, Tateti	Water table in BN19 piezometer	1.08	873	------	------
BN19	13-Aug-14	08:10	Amit, Tateti	Tube 1	6.0	948	------	------
BN19	13-Aug-14		Amit, Tateti	Tube 2	9.2	Blocked	Blocked	Blocked
BN19	13-Aug-14		Amit, Tateti	Tube 3	11.0	957	------	------
BN19	13-Aug-14	08:50	Amit, Tateti	Tube 4	14.4	990	------	------
BN20	13-Aug-14		Amit, Tateti	Water table in BN20B piezometer	0.55	387	------	------
BN20	13-Aug-14	10:10	Amit, Tateti	Tube 1	6.0	480	------	------
BN20	13-Aug-14		Amit, Tateti	Tube 2	8.0	480	------	------
BN20	13-Aug-14		Amit, Tateti	Tube 3	11.6	509	------	------
BN20	13-Aug-14	10:40	Amit, Tateti	Tube 4	15.2	526	------	------
BN21	12-Aug-14	09:20	Amit, Tateti	Water table in BN21 piezometer	0.97	278	18.4	18.9
BN21	12-Aug-14	09:28	Amit, Tateti	Tube 1	6.0	872	18.4	18.9
BN21	12-Aug-14		Amit, Tateti	Tube 2	9.0	880	18.4	18.9
BN21	12-Aug-14		Amit, Tateti	Tube 3	12.0	905	18.4	18.9
BN21	12-Aug-14		Amit, Tateti	Tube 4	15.0	1015	18.4	18.9
BN21	12-Aug-14		Amit, Tateti	Tube 5	18.0	1233	18.4	18.9
BN21	12-Aug-14	10:40	Amit, Tateti	Tube 6	21.0	12030	18.4	18.9

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN22	13-Aug-14	09:15	Amit, Tateti	Water table in BN22 piezometer	1.090	550	4.2	5.2
BN22	13-Aug-14		Amit, Tateti	Tube 1	6.5	3990	4.2	5.2
BN22	13-Aug-14		Amit, Tateti	Tube 2	9.3	4120	4.2	5.2
BN22	13-Aug-14		Amit, Tateti	Tube 3	10.9	4190	4.2	5.2
BN22	13-Aug-14		Amit, Tateti	Tube 4	13.9	4610	4.2	5.2
BN22	13-Aug-14		Amit, Tateti	Tube 5	15.6	23100	4.2	5.2
BN22	13-Aug-14	10:10	Amit, Tateti	Tube 6	21.0	36100	4.2	5.2
BN23	14-Aug-14		Amit, Tateti	Water table in BN23 piezometer	2.03	-		
BN23	14-Aug-14		Amit, Tateti	Water table in BN23B piezometer	2.59	303	12.0	12.1
BN23	14-Aug-14		Amit, Tateti	Tube 1	6.0	395	12.0	12.1
BN23	14-Aug-14		Amit, Tateti	Tube 2	9.6	815	12.0	12.1
BN23	14-Aug-14		Amit, Tateti	Tube 3	12.0	2250	12.0	12.1
BN23	14-Aug-14		Amit, Tateti	Tube 4	12.8	8000	12.0	12.1
BN23	14-Aug-14		Amit, Tateti	Tube 5	2.4	Blocked	Blocked	Blocked
BN23	14-Aug-14	11:20	Amit, Tateti	Tube 6	20.0	23300	12.0	12.1
BN24	12-Aug-14	15:00	Amit, Tateti	Water table in BN24 piezometer	1.74	352	6.0	6.1
BN24	12-Aug-14	15:10	Amit, Tateti	Tube 1	6.2	2600	6.0	6.1
BN24	12-Aug-14		Amit, Tateti	Tube 2	3.4	Blocked	Blocked	Blocked
BN24	12-Aug-14		Amit, Tateti	Tube 3	10.8	Blocked	Blocked	Blocked
BN24	12-Aug-14		Amit, Tateti	Tube 4	11.4	Blocked	Blocked	Blocked
BN24	12-Aug-14		Amit, Tateti	Tube 5	17.2	19500	6.0	6.1
BN24	12-Aug-14	15:40	Amit, Tateti	Tube 6	20.2	34000	6.0	6.1
BN25	14-Aug-14	09:10	Amit, Tateti	Water table in BN25 piezometer	1.070	304	------	------
BN25	14-Aug-14	09:20	Amit, Tateti	Tube 1	6.0	722	------	------
BN25	14-Aug-14		Amit, Tateti	Tube 2	9.0	720	------	------
BN25	14-Aug-14		Amit, Tateti	Tube 3	11.5	1232	------	------
BN25	14-Aug-14	10:00	Amit, Tateti	Tube 4	12.8	Blocked	Blocked	Blocked
BN26	12-Aug-14	08:00	Amit, Tateti	Water table in BN26 piezometer	1.54	280	5.6	6.0
BN26	12-Aug-14	08:15	Amit, Tateti	Tube 1	1.4	Blocked	Blocked	Blocked
BN26	12-Aug-14		Amit, Tateti	Tube 2	6.2	2800	5.6	6.0
BN26	12-Aug-14		Amit, Tateti	Tube 3	12.0	2880	5.6	6.0
BN26	12-Aug-14		Amit, Tateti	Tube 4	13.9	Blocked	Blocked	Blocked

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN26	12-Aug-14		Amit, Tateti	Tube 5	15.4	Blocked	Blocked	Blocked
BN26	12-Aug-14		Amit, Tateti	Tube 6	17.6	Blocked	Blocked	Blocked
BN26	12-Aug-14	09:20	Amit, Tateti	Tube 7	24.2	Blocked	Blocked	Blocked
BN27	12-Aug-14	10:50	Amit, Tateti	Water table in BN27 piezometer	1.24	553	14.9	15.4
BN27	12-Aug-14	10:59	Amit, Tateti	Tube 1	6.0	1095	14.9	15.4
BN27	12-Aug-14		Amit, Tateti	Tube 2	9.0	1141	14.9	15.4
BN27	12-Aug-14		Amit, Tateti	Tube 3	12.0	1216	14.9	15.4
BN27	12-Aug-14		Amit, Tateti	Tube 4	14.4	1451	14.9	15.4
BN27	12-Aug-14		Amit, Tateti	Tube 5	17.5	7410	14.9	15.4
BN27	12-Aug-14	11:48	Amit, Tateti	Tube 6	21.0	28800	14.9	15.4
BN28	16-Aug-14	13:30	Amit, Tateti	Water table in BN28 piezometer	0.72	628	12.4	13.4
BN28	16-Aug-14	13:40	Amit, Tateti	Tube 1	6.0	1209	12.4	13.4
BN28	16-Aug-14		Amit, Tateti	Tube 2	3.0	Blocked	Blocked	Blocked
BN28	16-Aug-14		Amit, Tateti	Tube 3	12.0	1256	12.4	13.4
BN28	16-Aug-14		Amit, Tateti	Tube 4	15.0	Blocked	Blocked	Blocked
BN28	16-Aug-14		Amit, Tateti	Tube 5	17.0	15280	12.4	13.4
BN28	16-Aug-14	14:30	Amit, Tateti	Tube 6	19.7	30500	12.4	13.4
BN29	14-Aug-14	08:00	Amit, Tateti	Water table in BN29 piezometer	0.82	273	8.3	8.7
BN29	14-Aug-14		Amit, Tateti	Tube 1	6.0	968	8.3	8.7
BN29	14-Aug-14		Amit, Tateti	Tube 2	9.4	3230	8.3	8.7
BN29	14-Aug-14		Amit, Tateti	Tube 3	12.0	Blocked	Blocked	Blocked
BN29	14-Aug-14		Amit, Tateti	Tube 4	15.0	23600	8.3	8.7
BN29	14-Aug-14		Amit, Tateti	Tube 5	18.4	31300	8.3	8.7
BN29	14-Aug-14	09:05	Amit, Tateti	Tube 6	20.6	34200	8.3	8.7
BN32	16-Aug-14	09:20	Amit, Tateti	Water table in BN32 piezometer	1.36	486	15.0	15.1
BN32	16-Aug-14	09:30	Amit, Tateti	Tube 1	1.3	Blocked	Blocked	Blocked
BN32	16-Aug-14		Amit, Tateti	Tube 2	9.0	804	15.0	15.1
BN32	16-Aug-14		Amit, Tateti	Tube 3	12.0	821	15.0	15.1
BN32	16-Aug-14		Amit, Tateti	Tube 4	15.0	2340	15.0	15.1
BN32	16-Aug-14		Amit, Tateti	Tube 5	18.0	21380	15.0	15.1
BN32	16-Aug-14		Amit, Tateti	Tube 6	21.0	35900	15.0	15.1
BN32	16-Aug-14		Amit, Tateti	Tube 7	23.7	38400	15.0	15.1

Borehole	Date	Time	Operator	Sample tube #	Depth (m)	EC (uS/cm)	Depth to F/W limit (m): Lin plot	Depth to F/W limit (m): Log plot
BN32	16-Aug-14	10:40	Amit, Tateti	Tube 8	25.6	40400	15.0	15.1
BN33	16-Aug-14	08:00	Amit, Tateti	Water table in BN33 piezometer	1.600	396	12.9	13.5
BN33	16-Aug-14		Amit, Tateti	Tube 1	6.0	944	12.9	13.5
BN33	16-Aug-14		Amit, Tateti	Tube 2	9.0	986	12.9	13.5
BN33	16-Aug-14		Amit, Tateti	Tube 3	12.0	996	12.9	13.5
BN33	16-Aug-14		Amit, Tateti	Tube 4	15.0	6180	12.9	13.5
BN33	16-Aug-14		Amit, Tateti	Tube 5	18.0	27900	12.9	13.5
BN33	16-Aug-14		Amit, Tateti	Tube 6	21.0	36400	12.9	13.5
BN33	16-Aug-14		Amit, Tateti	Tube 7	24.0	36300	12.9	13.5
BN33	16-Aug-14	09:10	Amit, Tateti	Tube 8	27.0	38800	12.9	13.5
BN34	13-Aug-14	11:00	Amit, Tateti	Water table in BN34 piezometer	1.49	685	6.4	6.7
BN34	13-Aug-14		Amit, Tateti	Tube 1	6.0	1810	6.4	6.7
BN34	13-Aug-14		Amit, Tateti	Tube 2	9.0	7560	6.4	6.7
BN34	13-Aug-14		Amit, Tateti	Tube 3	12.0	22100	6.4	6.7
BN34	13-Aug-14		Amit, Tateti	Tube 4	13.0	22300	6.4	6.7
BN34	13-Aug-14		Amit, Tateti	Tube 5	18.0	30800	6.4	6.7
BN34	13-Aug-14		Amit, Tateti	Tube 6	20.4	34500	6.4	6.7
BN34	13-Aug-14		Amit, Tateti	Tube 7	13.6	Blocked	Blocked	Blocked

Annex 5. Piezometer location and construction, Bonriki

Drilling logs, Bonriki water reserve, November 2013

This annex contains the details of the nine new piezometers installed during the groundwater investigations in Bonriki, from 13 to 21 November, 2013. The drilling description logs for the nine new piezometers and construction photos are also presented.

Abbreviations:	
m	Metres
TOP	Measured from the top of the pipe
MASL	Meters above sea level
MBGL	Metres below ground level
UTM	Universal transverse mercator
WL	Water level (m)
EC	Electrical conductivity (µS/cm)

Figure A5.1: *Approximate locations of Bonriki new piezometers – BN1B, BN4C, BN7B, BN13B, BN15B, BN20B, BN23B, BN35 and BN36.*

Table A5.1: *Drilling log BN1B, Bonriki.*

Location	Bonriki Water Reserve, Tarawa			**Date start:** 14/11/13 8:20	
Site	Supplement to BN1			**Date finish:** 14/11/13 10:20	
Piezometer No.	BN1B			**Drill method:** Excavator	
Driller	MacDow				
Depth (m)	**Material (lithology) description**	**Water**	**Technical description**		**Notes**
0	0.0 - 0.30m: **Soil,** black to grey, sand, roots and organic matter		Full pipe	Backfill sand	Bailed during 1 hr until clear
0.1					
0.2					
0.3	0.30 - 2.20m: **Gravelly sand,** fine to medium, white				
0.4					
0.5					
0.6					
0.7					
0.8					
0.9					
1					
1.1					
1.2					
1.3					
1.4					
1.5					
1.6				1.60 - 2.60m: Gravel	
1.7					
1.8					
1.9					
2					
2.1			2.00 - 2.50m: Screen pipe		
2.2	2.20 - 2.40m: **Sandy gravel,** coral boulders				
2.3		2.30m: First water			
2.4	2.40 - 2.60m: **Coral rock** hard formation				
2.5					
2.6			2.50 - 2.60m: Full pipe and bottom cap		

Figure A5.2: *Digging at piezometer – BN1B, Bonriki (14/11/13).*

Figure A5.3: *Lithology log at piezometer – BN1B, Bonriki (14/11/13).*

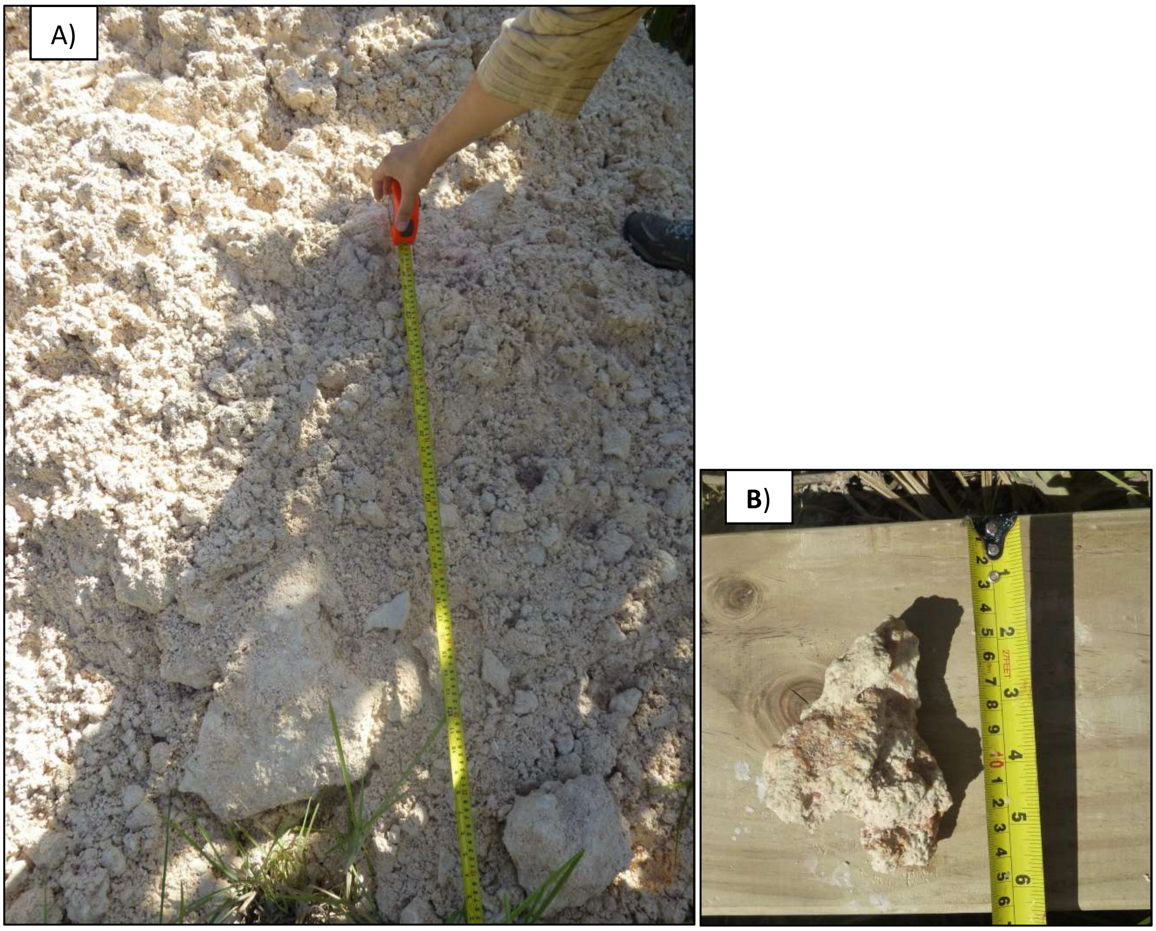


Figure A5.4: *Rock samples at piezometer – BN1B, Bonriki (14/11/13). A) Gravelly sand + coral boulders (depth 2.20 - 2.40m); B) Coral boulder.*

Table A5.2: Drilling log BN4C, Bonriki.

Location	Bonriki Water Reserve, Tarawa	**Date start:** 15/11/13 14:00
Site	Supplement to BN4	**Date finish:** 15/11/13 15:30
Piezometer No.	BN4C	**Drill method:** Excavator
Driller	MacDow	

Depth (m)	Material (lithology) description	Water	Technical description		Notes
0	0.0 - 0.21m: **Soil**, grey sand and gravel, roots and organic matter		Full pipe	Backfill sand	Bailed during 1 hr until clear
0.1					
0.2	0.21 - 0.40m: **Gravelly sand,** fine to medium, white, dense				
0.3					
0.4	0.40 - 1.64m: **Silt,** fine to very fine black, grey formation, anoxic environment, impermeable layer				
0.5					
0.6					
0.7					
0.8					
0.9					
1					
1.1					
1.2					
1.3					
1.4					
1.5					
1.6		1.64m: First water			
1.7	1.64 - 3.20m: **Silty sand**, fine to medium, cobbles of coral, boulders				
1.8					
1.9					
2		**Flow calculation: 0.6477 l/s**			
2.1				2.10 - 3.20m: Gravel	
2.2					
2.3					
2.4					
2.5					
2.6			2.60 - 3.10m: Screen pipe		
2.7					
2.8					
2.9					
3					
3.1			3.10 - 3.20m: Full pipe and bottom cap		
3.2					

Figure A5.5: *Lithology log at piezometer – BN4C, Bonriki (15/11/13).*

Table A5.3: *Drilling log BN7B, Bonriki.*

Location	Bonriki Water Reserve, Tarawa	**Date start:** 15/11/13 8:00
Site	Supplement to BN7	**Date finish:** 15/11/13 10:45
Piezometer No.	BN7B	**Drill method:** Excavator
Driller	MacDow	

Depth (m)	Material (lithology) description	Water	Technical description		Notes
0	0 - 0.60m: **Soil,** black to grey sand, roots and organic matter	2.53m: First water	Full pipe	Backfill sand	Bailed during 1 hr until clear
0.1					
0.2					
0.3					
0.4					
0.5					
0.6	0.60 - 2.10m: **Gravelly sand**, fine to medium				
0.7					
0.8					
0.9					
1					
1.1					
1.2					
1.3					
1.4					
1.5					
1.6					
1.7					
1.8					
1.9					
2					
2.1				1.98- 2.76m: Gravel	
2.2	2.10 - 2.51m: **Gravelly sand**, fine to medium, boulders of conglomerats		2.16 - 2.66m: Screen pipe		
2.3					
2.4					
2.5					
2.6	2.51 - 2.76m: Reef flate, **beach rock**, hard pan, conglomerat formation		2.66 - 2.76m: Full pipe and bottom cap		
2.7					
2.76					

Figure A5.6: *Lithology log at piezometer – BN7B, Bonriki (15/11/13).*

Figure A5.7: *Rock samples at piezometer – BN7B, Bonriki (15/11/13). Gravelly sand, fine to medium.*

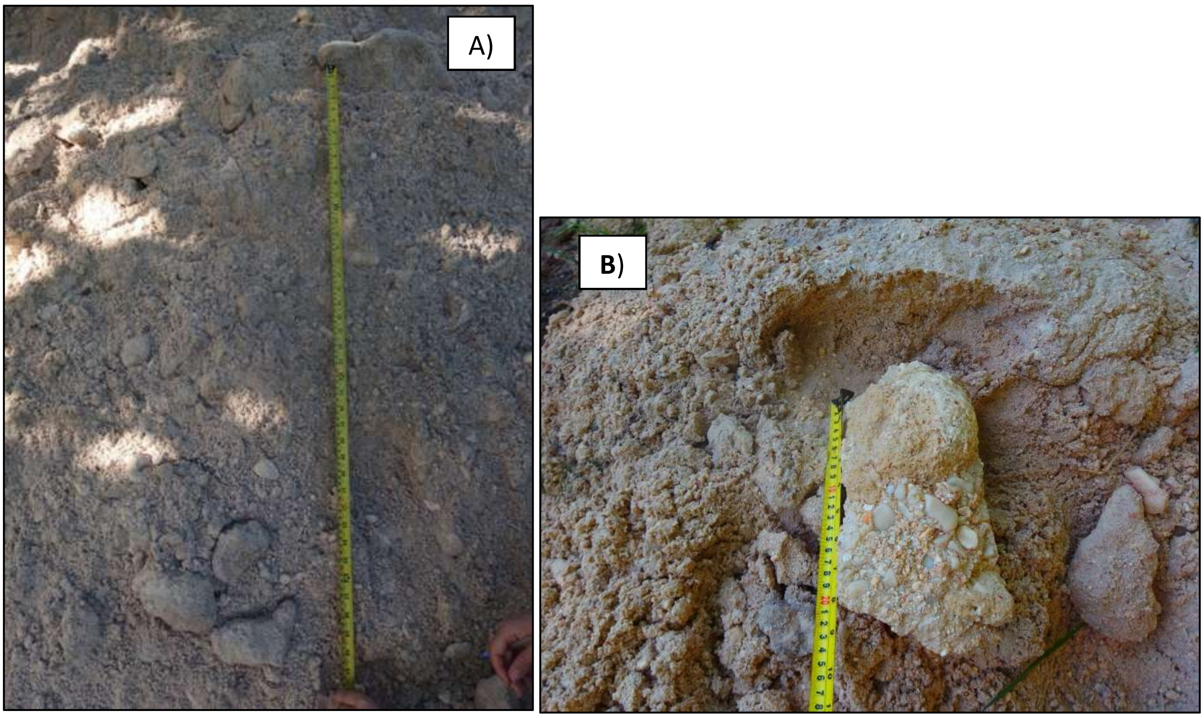


Figure A5.8: *Rock samples at piezometer – BN7B, Bonriki (15/11/13). A) Gravelly sand fine to medium + boulders of conglomerate (depth 2.10 - 2.51m); B) Boulders of conglomerate.*

Figure A5.9: *Rock samples at piezometer – BN7B, Bonriki (15/11/13). Beach rock (conglomerate formation).*

Table A5.4: *Drilling log BN13B, Bonriki.*

Location	Bonriki Water Reserve, Tarawa	**Date start:** 15/11/13 11:15
Site	Supplement to BN13	**Date finish:** 15/11/13 13:00
Piezometer No.	BN13B	**Drill method:** Excavator
Driller	MacDow	

Depth (m)	Material (lithology) description	Water	Technical description		Notes
0	0.0 - 0.30m: **Soil**, filled with grey gravel and organic matter black to grey sand		Full pipe	Backfill sand	Bailed during 1 hr until clear
0.1					
0.2					
0.3	0.30 - 2.20m:**Sandy gravel to gravelly sand,** yellow, fine to medium sand (mm to cm) to medium gravel with some cobbles (coral pieces) (cm to dm) lightly cimented				
0.4					
0.5					
0.6					
0.7					
0.8					
0.9					
1					
1.1					
1.2					
1.3					
1.4					
1.5					
1.6					
1.7					
1.8					
1.9					
2					
2.1				2.08 - 3.18m: Gravel	
2.2					
2.3	2.20 - 2.80m: **Gravel** and coral boulders (dm), pieces of coral color grey to green and fresh coral white				
2.4		2.40m: First water			
2.5					
2.6			2.58 - 3.08m: Screen pipe		
2.7					
2.8					
2.9					
3			3.08 - 3.18m: Full pipe and bottom cap		
3.1					
3.18					

Figure A5.10: *Lithology log at piezometer – BN13B, Bonriki (15/11/13).*

Figure A5.11: *Rock samples at piezometer – BN13B, Bonriki (15/11/13).Gravelly sandy gravel to gravelly sand.*

Figure A5.12: *Rock samples at piezometer – BN13B, Bonriki (15/11/13). Coral boulders, pieces of fresh colour, white and grey to green.*

Tabla A5.5: *Drilling log BN15B, Bonriki.*

Location	Bonriki Water Reserve, Tarawa	**Date start:** 14/11/13 10:30
Site	Supplement to BN15	**Date finish:** 14/11/13 11:45
Piezometer No.	BN15B	**Drill method:** Excavator
Driller	MacDow	

Depth (m)	Material (lithology) description	Water	Technical description		Notes
0	0.0 - 0.50m: **Soil,** black to grey sand, roots and organic matter		Full pipe	Backfill sand	Bailed during 1 hr until clear
0.1					
0.2					
0.3					
0.4					
0.5	0.50 - 1.50m: **Silty sand**, fine to medium, white				
0.6					
0.7					
0.8					
0.9					
1					
1.1					
1.2					
1.3					
1.4					
1.5	1.50 - 2.10m: G**ravelly sand**, medium to coarse coral boulders				
1.6					
1.7					
1.8					
1.9					
2					
2.1	2.10 - 3.10m: **Sandy gravel,** medium sand to coarse, coral boulders				
2.2					
2.3				2.35 - 3.25m: Gravel	
2.4					
2.5					
2.6					
2.7			2.65 - 3.15m: Screen pipe		
2.8					
2.9					
3					
3.1	3.10 - 3.25m: **Coral rock** hard formation		3.15 - 3.25m: Full pipe and bottom cap		
3.2					
3.25					

Figure A5.13: *Lithology log at piezometer – BN15B, Bonriki (14/11/13).*

Figure A5.14: *Rock samples at piezometer – BN15B, Bonriki (14/11/13). Silty sand, fine to medium.*

Figure A5.15: *Rock samples at piezometer – BN15B, Bonriki (14/11/13). Sandy gravel.*

Table A5.6: Drilling log BN20B, Bonriki.

Location	Bonriki Water Reserve, Tarawa	**Date start:** 16/11/13 11:25
Site	Supplement to BN20	**Date finish:** 16/11/13 12:20
Piezometer No.	BN20B	**Drill method:** Excavator
Driller	MacDow	

Depth (m)	Material (lithology) description	Water	Technical description		Notes
0	0.0 - 0.50m: **Soil,** black to grey sand and gravel, roots and organic matter	1.10m: First water	Full pipe	Backfill sand	Bailed during 1 hr until clear
0.1					
0.2					
0.3					
0.4					
0.5	0.50 - 1.50m: **Gravelly sand**, yellow, fine to medium				
0.6					
0.7					
0.8					
0.9					
1					
1.1					
1.2					
1.3					
1.4					
1.5					
1.6	1.50 - 2.60m: **Sandy gravel**, medium to coarse (dm), coral cobbles, few boulders, white			1.50 - 2.60 m: Gravel	
1.7					
1.8					
1.9					
2					
2.1			2.00 - 2.50m: Screen pipe		
2.2					
2.3					
2.4					
2.5					
2.6			2.50 - 2.60m: Full pipe and bottom cap		

Figure A5.16: *Lithology log at piezometer – BN20B, Bonriki (16/11/13).*

Figure A5.17: *Rock samples at piezometer – BN20B, Bonriki (16/11/13).Sandy gravel.*

Table A5.7: Drilling log BN23, Bonriki.

Location	Bonriki Water Reserve, Tarawa	**Date start:** 14/11/13 13:40
Site	Supplement to BN23	**Date finish:** 14/11/13 14:50
Piezometer No.	BN23B	**Drill method:** Excavator
Driller	MacDow	

Depth (m)	Material (lithology) description	Water	Technical description	Monitors	Notes
0					
0.1					
0.2					
0.3					
0.4	0.0 - 0.90m: **Soil,** black to grey sand and gravel, roots and organic matter				
0.5					
0.6					
0.7					
0.8					
0.9					
1					
1.1					
1.2				Backfill sand	
1.3					
1.4			Full pipe		
1.5	0.90 - 2.30m: **Gravelly sand**, medium to coarse and coral cobbles				
1.6					
1.7					
1.8					Bailed during 1 hr until clear
1.9					
2					
2.1					
2.2					
2.3					
2.4					
2.5					
2.6					
2.7	2.30 - 3.20m: **Silty sand**, fine to mediun with gravel and coral boulders				
2.8		2.80m: First water			
2.9					
3					
3.1				2.48 - 3.58 m: Gravel	
3.2			2.98 - 3.48m: Screen pipe		
3.3					
3.4	3.20 - 3.58m: **Coral rock** hard formation				
3.5			3.48 - 3.58m: Full pipe and bottom cap		
3.58					

Figure A5.18: *Lithology log at piezometer – BN23B, Bonriki (14/11/13).*

Figure A5.19: *Rock samples at piezometer – BN23B, Bonriki (14/11/13). Silty sand, fine to medium, with gravel and coral boulders.*

Table A5.8: *Drilling log BN35, Bonriki.*

<table>
<tr><td>Location</td><td colspan="3">Bonriki Water Reserve, Tarawa</td><td colspan="2">Date start: 16/11/13 8:35</td></tr>
<tr><td>Site</td><td colspan="3">Closed to the Rain Gauge Station (PUB)</td><td colspan="2">Date finish: 16/11/13 10:15</td></tr>
<tr><td>Piezometer No.</td><td colspan="3">BN35</td><td colspan="2">Drill method: Excavator</td></tr>
<tr><td>Driller</td><td colspan="3">MacDow</td><td colspan="2"></td></tr>
<tr><td colspan="6"></td></tr>
<tr><th>Depth (m)</th><th>Material (lithology) description</th><th>Water</th><th>Technical description</th><th>Monitors</th><th>Notes</th></tr>
<tr><td>0</td><td rowspan="2">0.0 - 0.20m: Grey filled materials</td><td rowspan="38">2.57m: First water</td><td rowspan="30">Full pipe</td><td rowspan="25">Backfill sand</td><td rowspan="38">Bailed during 1 hr until clear</td></tr>
<tr><td>0.1</td></tr>
<tr><td>0.2</td><td rowspan="6">0.20 - 0.74m: Soil, black to grey sand and gravel, roots and organic matter</td></tr>
<tr><td>0.3</td></tr>
<tr><td>0.4</td></tr>
<tr><td>0.5</td></tr>
<tr><td>0.6</td></tr>
<tr><td>0.7</td></tr>
<tr><td>0.8</td><td rowspan="10">0.74 - 1.76m: Gravelly sand, fine to medium, white (cm to dm)</td></tr>
<tr><td>0.9</td></tr>
<tr><td>1</td></tr>
<tr><td>1.1</td></tr>
<tr><td>1.2</td></tr>
<tr><td>1.3</td></tr>
<tr><td>1.4</td></tr>
<tr><td>1.5</td></tr>
<tr><td>1.6</td></tr>
<tr><td>1.7</td></tr>
<tr><td>1.8</td><td rowspan="20">1.76 - 3.67m: Sandy gravel, white (cm to dm), coral cobbles</td></tr>
<tr><td>1.9</td></tr>
<tr><td>2</td></tr>
<tr><td>2.1</td></tr>
<tr><td>2.2</td></tr>
<tr><td>2.3</td></tr>
<tr><td>2.4</td></tr>
<tr><td>2.5</td><td rowspan="13">2.57 - 3.67 m: Gravel</td></tr>
<tr><td>2.6</td></tr>
<tr><td>2.7</td></tr>
<tr><td>2.8</td></tr>
<tr><td>2.9</td></tr>
<tr><td>3</td><td rowspan="6">3.07 - 3.57m: Screen pipe</td></tr>
<tr><td>3.1</td></tr>
<tr><td>3.2</td></tr>
<tr><td>3.3</td></tr>
<tr><td>3.4</td></tr>
<tr><td>3.5</td></tr>
<tr><td>3.6</td><td rowspan="2">3.57 - 3.67m: Full pipe and bottom cap</td></tr>
<tr><td>3.67</td></tr>
</table>

Figure A5.20: *Lithology log at piezometer – BN35, Bonriki (16/11/13).*

Figure A5.21: *Rock samples at piezometer – BN35, Bonriki (16/11/13). Gravelly sand.*

__Table A5.9:__ Drilling log BN36, Bonriki.

Location	Bonriki Water Reserve, Tarawa	**Date start:** 16/11/13 13:10
Site	North - Western side of the Bonriki reserve, approx. 200m to the NW of BN11	**Date finish:** 16/11/13 15:00
Piezometer No.	BN36	**Drill method:** Excavator
Driller	MacDow	

Depth (m)	Material (lithology) description	Water	Technical description	Monitors	Notes
0	0.0 - 0.30m: **Soil,** black to grey sand, roots and organic matter	1.90m: First water	Full pipe	Backfill sand	Bailed during 1 hr until clear
0.1					
0.2					
0.3	0.30 - 2.00m: **Gravelly sand**, medium, white, very dense to dense				
0.4					
0.5					
0.6					
0.7					
0.8					
0.9					
1					
1.1					
1.2					
1.3					
1.4					
1.5					
1.6					
1.7					
1.8				1.70 - 2.80m: Gravel	
1.9					
2	2.00 - 3.50m: **Gravelly sand**, with cobbles fresh coral , sandstone boulders with cobbles, lightly to slightly cimented				
2.1					
2.2					
2.3			2.20 - 2.70m: Screen pipe		
2.4					
2.5					
2.6					
2.7					
2.8			2.70 - 2.80m: Full pipe and bottom cap		
2.9				Backfill sand	
3					
3.1					
3.2					
3.3					
3.4					
3.5	3.50 - 4.00m: **Gravelly sand**, with sandstone boulders with green coral boulders, slightly cimented				
3.6					
3.7					
3.8					
3.9					
4					

Figure A5.22: *Lithology log at piezometer – BN36, Bonriki (16/11/13).*

Figure A5.23: *Rock samples at piezometer – BN36, Bonriki (16/11/13). Gravelly sand with sandstone boulders.*

Figure A5.24: *Excavator digging piezometer pit – BN1.*

Figure A5.25: *Machine-cut PVC screen.*

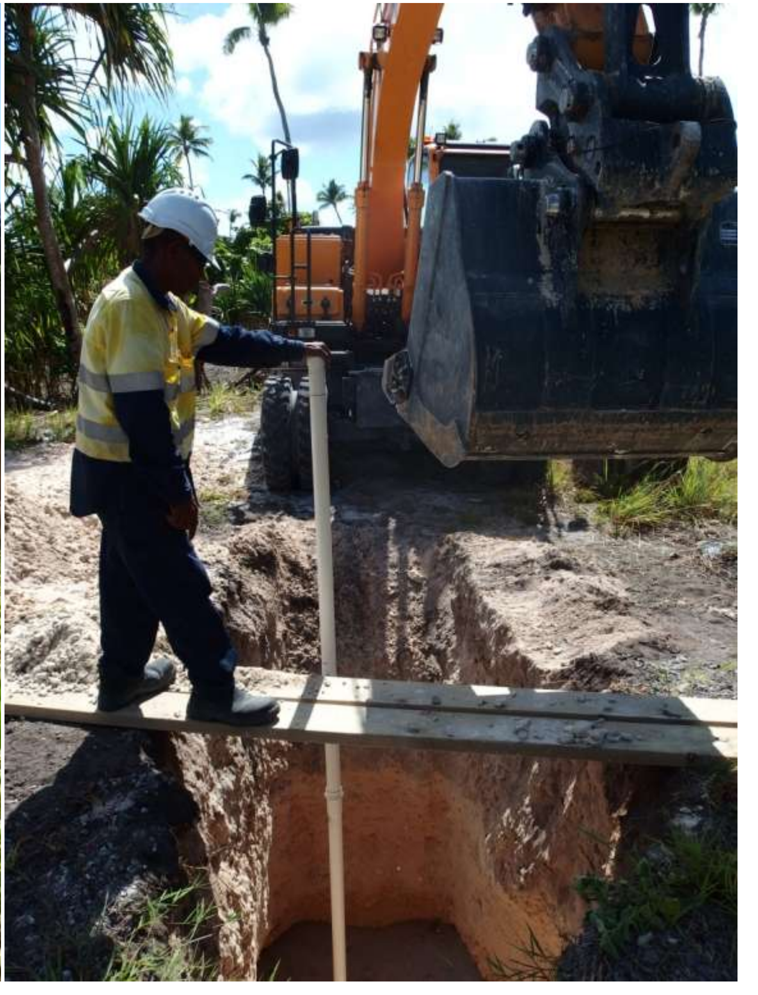


Figure A5.26: *Positioning of piezometer – BN23.*

Figure A5.27: *Measurement of gravel pack.*

Figure A5.28: *Gravel pack and piezometer placement.*

Figure A5.29: *Bailing of piezometer to clear silt and develop well until clear sample is obtained – BN1.*

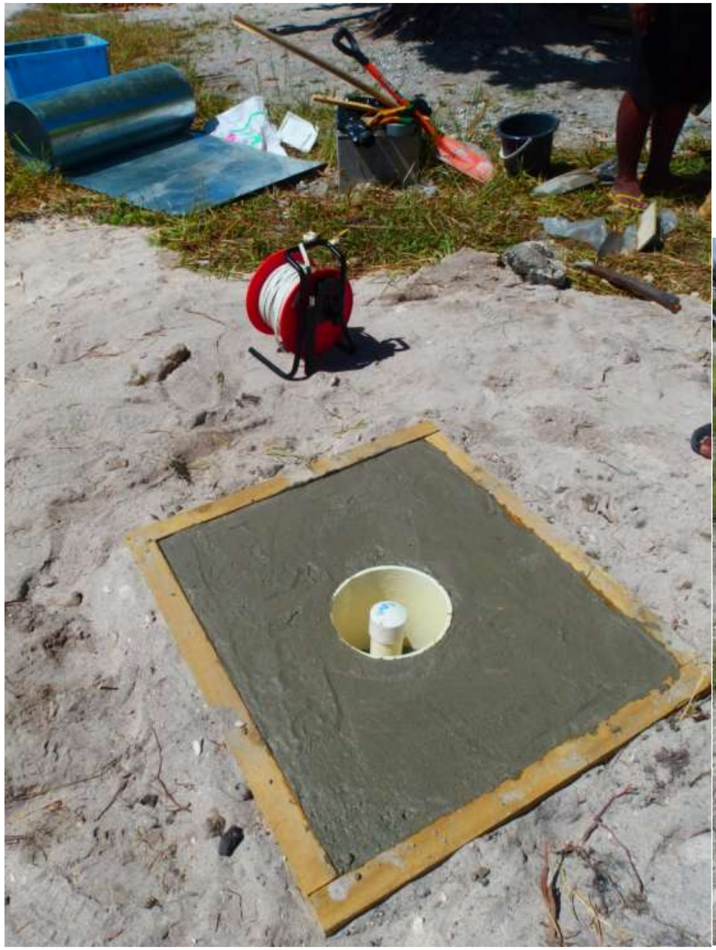


Figure A5.30: *Construction of monitoring headworks – BN15.* ***Figure A5.31:*** *Finished borehole cover – BN1.*

Annex 6. Monitoring borehole and infiltration gallery pumping station survey, Bonriki water reserve

Summary of the survey data for monitoring bores and infiltration galleries

This annex contains the details of the survey data relating to the georeferencing of measurement points for monitoring bores and infiltration galleries, for the use of groundwater science investigations and management.

The survey was undertaken by surveying staff of the Geoscience Division of the Secretariat of the Pacific Community, and staff from the Ministry of Fisheries and Mineral Resources Development, between 2013 and 2014.

Figure A6.1: *Locations of Bonriki monitoring bores and infiltration galleries.*

Table A6.1: *Elevation and location data for the Bonriki monitoring bores – Bonriki water reserve.*

Bonriki monitor-ing bore	Easting UTM2	Northing UTM	Elevation of measuring point (MP) relative to TGZ3 (m)	Elevation of MP relative to average mean sea level 2013 (m)	Comments
BN1	738862.7	153397.0	3.715	2.455	Reference point – notched locking lug
BN1B*	738862.8	153393.7	3.452	2.192	TOP PVC piezometer for reference point
BN2	738708.6	153311.3	3.34	2.08	Reference point – notched locking lug
BN2B	738719.5	153284.6	3.968	2.708	Reference point – notched locking lug
BN4	738517.5	153123.4	3.296	2.036	Reference point -notched locking lug
BN4C	738519.1	153121.8	3.27	2.01	TOP PVC piezometer for reference point
BN7	739333.0	153010.0	4.346	3.086	Reference point – notched locking lug
BN7B	739335.2	153004.8	4.316	3.056	TOP PVC piezometer for reference point
BN11	738124.2	153521.1	3.919	2.659	Reference point – notched locking lug
BN11A	738121.1	153521.9	3.716	2.456	Reference point -notched locking lug
BN13	739217.7	152939.0	4.235	2.975	Reference point – notched locking lug
BN13B	739221.0	152938.9	3.99	2.73	TOP PVC piezometer for reference point
BN15	738949.9	153153.2	4.283	3.023	Reference point – notched locking lug
BN15B	738952.4	153154.7	4.206	2.946	TOP PVC piezometer for reference point
BN19	738202.6	153160.8	3.597	2.337	Reference point – notched locking lug
BN20	738255.3	153365.7	3.143	1.883	Reference point -notched locking lug
BN20B	738258.0	153362.7	2.55	1.29	TOP PVC piezometer for reference point
BN21	738267.0	152983.3	3.267	2.007	Reference point – notched locking lug
BN22	739073.9	152882.5	3.143	1.883	Reference point -notched locking lug
BN23	738949.3	153241.9	4.59	3.33	Notched metal locking lug for lid as reference point
BN24	739104.6	153066.7	4.06	2.8	Reference point – notched locking lug
BN25*	739251.3	152701.9	3.534	2.274	Reference point – notched locking lug
BN26	738618.0	152876.4	3.399	2.139	Reference point – notched locking lug
BN27	738378.6	153083.4	3.467	2.207	Reference point – notched locking lug
BN28	738586.4	153051.6	3.33	2.07	Reference point – notched locking lug
BN29	739521.6	152825.1	3.057	1.797	Reference point – notched locking lug
BN32	739103.8	152722.1	3.352	2.092	Reference point – notched locking lug
BN33	739342.2	152698.2	3.588	2.328	Reference point – notched locking lug
BN34	738558.5	153507.3	3.338	2.078	Reference point – notched locking lug
BN35	738847.3	153004.9	3.922	2.662	TOP PVC piezometer for reference point
BN36*	737991.4	153660.1	3.625	2.365	TOP PVC piezometer for reference point

*Follow-up surveys provided by MRMRD, March 2014.

[2] UTM Zone 59N WGS84.

[3] TGZ University of Hawaii.

Table A6.2: *Height of surveyed measurement points relative to the ground and top of pipe (TOP).*

Borehole number	Height from ground level to measuring point (m)	Height from TOP to the measuring point (m)	Height of PVC above ground level (m)
BN1	0.39	BN1B installed	NA
BN2A	0.42	NO PVC	NA
BN2B	0.59	0.51	0.03
BN4	0.2	No PVC	NA
BN7	0.2	No PVC	NA
BN11A	0.635	0.725	0.023
BN11B	0.522	No PVC	No PVC
BN13	0.32	No PVC	NA
BN15	0.31	No PVC	NA
BN19	0.54	0.45	0.13
BN20	0.61	No PVC	NA
BN21	0.498	0.0455	0.122
BN22	0.47	0.49	0.15
BN23	0.62	0.55	0.12
BN24	0.59	0.58	0.03
BN25	0.638	0.743	0.023
BN26	0.502	0.303	0.189
BN27	0.61	0.44	0.15
BN28	0.66	0.63	0.03
BN29	0.28	0.48	0.1
BN32	0.398	0.122	0.146
BN33	0.26	0.2	0.1
BN34	0.452	0.173	0.359

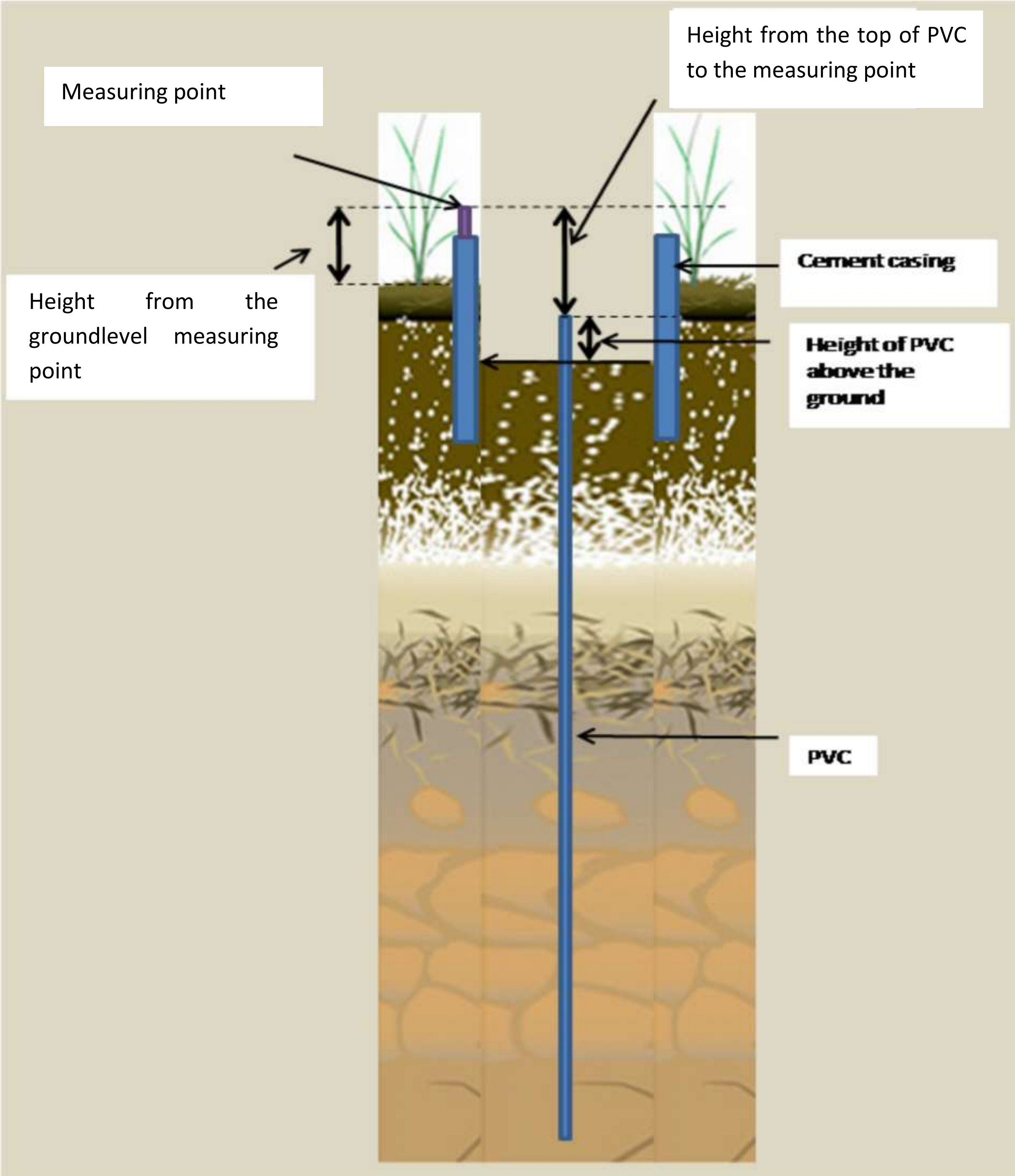


Figure A6.2: *Diagrammatic sketch of the surveyed measuring point and the TOP PVC piezometer.*

Table A6.3: *Elevation and location data for the gallery pumping stations, undertaken by MFMRD – Bonriki water reserve.*

Gallery pumping station	Easting UTM[4]	Northing UTM	Elevation relative to TGZ[5] (m)	Elevation relative to average mean sea level 2013 (m)	Comments
Gallery 1	739463.7	152834.6	5.213	3.953	
Gallery 2	739337.0	152911.9	4.952	3.692	Concrete slab used as MP
Gallery 3	739052.3	152891.7	3.016	1.756	Concrete slab used as MP
Gallery 4	739078.4	152956.2	2.95	1.69	
Gallery 5	739091.2	153056.9	4.28	3.02	
Gallery 6	738933.2	153246.6	4.287	3.027	
Gallery 7	738831.2	153032.5	4.317	3.057	
Gallery 8	738739.0	153044.7	4.116	2.856	
Gallery 9	738629.4	153059.3	3.74	2.48	
Gallery 10	738533.1	153068.0	3.02	1.76	
Gallery 11	738433.2	153081.7	3.33	2.07	
Gallery 12	738327.3	153094.6	3.613	2.353	Concrete slab used as MP
Gallery 13	738230.5	153105.5	3.665	2.405	
Gallery 14	738510.4	153304.8	3.185	1.925	
Gallery 15	738513.1	153406.4	4.287	3.027	
Gallery 16	738139.4	153473.0	3.461	2.201	
Gallery 17	738142.7	153561.7	3.528	2.268	
Gallery 18	738679.4	153177.4	2.807	1.547	
Gallery 19	738544.0	153503.9	3.8	2.54	
Gallery 20	739341.8	152703.0	3.493	2.233	
Gallery 21	739093.0	152734.1	3.344	2.084	
Gallery 22	738131.1	152863.0	3.427	2.167	Concrete slab used as MP

[4] UTM Zone 59N WGS84.
[5] TGZ University of Hawaii.

Table A6.4: *Gallery well depth and depth to horizontal pipes and water levels relative to RTK-surveyed measurement points.*

Galleries	Total depth of gallery well (m)*	Depth to top of gallery horizontal pipes (m)*	Water level (m)*
1	4.72	4.22	3.33
2	Cannot access closed		
3	Cannot access filled up		
4	2.72	2.22	1.27
5	3.83	3.15	2.42
6	3.71	3.59	2.47
7	3.57	3.07	2.53
8	4.01	3.78	2.41
9	3.72	3.28	2.12
10	2.81	-	1.6
11	3	2.63	1.64
12	Cannot access closed		
13	3.35	-	2
14	2.87	2.53	1.53
15	4.03	3.3	2.58
16	3.17	-	1.62
17	2.88	2.71	1.67
18	2.07	-	1.68
19	3.68	3.22	2.02
20	3.22	2.9	1.58
21	3.68	3.22	2.02
22	Cannot access filled up		
*** Relative to RTK measurement point**			

Annex 7. EM34 survey data, Bonriki

Summary of the survey results for the EM-34 survey, undertaken at Bonriki water reserve, February 2014

This annex contains the details and results of the EM-34 geophysical survey.

The survey was undertaken by Water and Sanitation Programme staff of the Geoscience Division of the Secretariat of the Pacific Community, and staff from the Ministry of Public Works and Utilities, in February 2014.

- **EM-34 Method**

The basic principle of operation of the EM-34 (EM) is illustrated in Figure 7.1, below. The EM-34 method uses two coils, a transmitter and a receiver. The two coils are held by operators and are separated by a cable at a defined distance of 10 m, 20 m or 40 m. Depending on the investigation design, the coils can be placed in either a vertical or a horizontal position during the survey.

When the transmitter coil is switched on, it radiates an electromagnetic field, which induces electrical currents (called eddy currents, *Je*) on the earth's surface below the coil. These eddy currents, in turn, generate a secondary magnetic field (*Bs*). The secondary magnetic field is influenced by factors such as coil spacing and operating frequency, and, most significantly, by ground conductivity. The receiver coil detects and measures the magnetic field, and, based on the ratio of the secondary to primary magnetic field, it computes apparent conductivity (or EM conductivity).

The depth of exploration depends on the separation between the transmitter coil and the receiver coil, as well as on the coil orientation (coil axis/dipole horizontal or vertical). McNeill (1980) outlines the factors for a successful survey due to their influence on conductivity, including geological and physical factors, such as moisture content, dissolved electrolyte content, temperature, phase state of pore water, and the composition of colloids in the ground.

This equipment exhibits a number of features that enhance its use for groundwater surveys, including portability and ruggedness, survey productivity, good resolution, reliable operation over a wide range of air temperatures, linearity between meter reading and ground conductivity over a large range of ground conductivity values, and relatively simple interpretative techniques for ground with conductivity stratification.

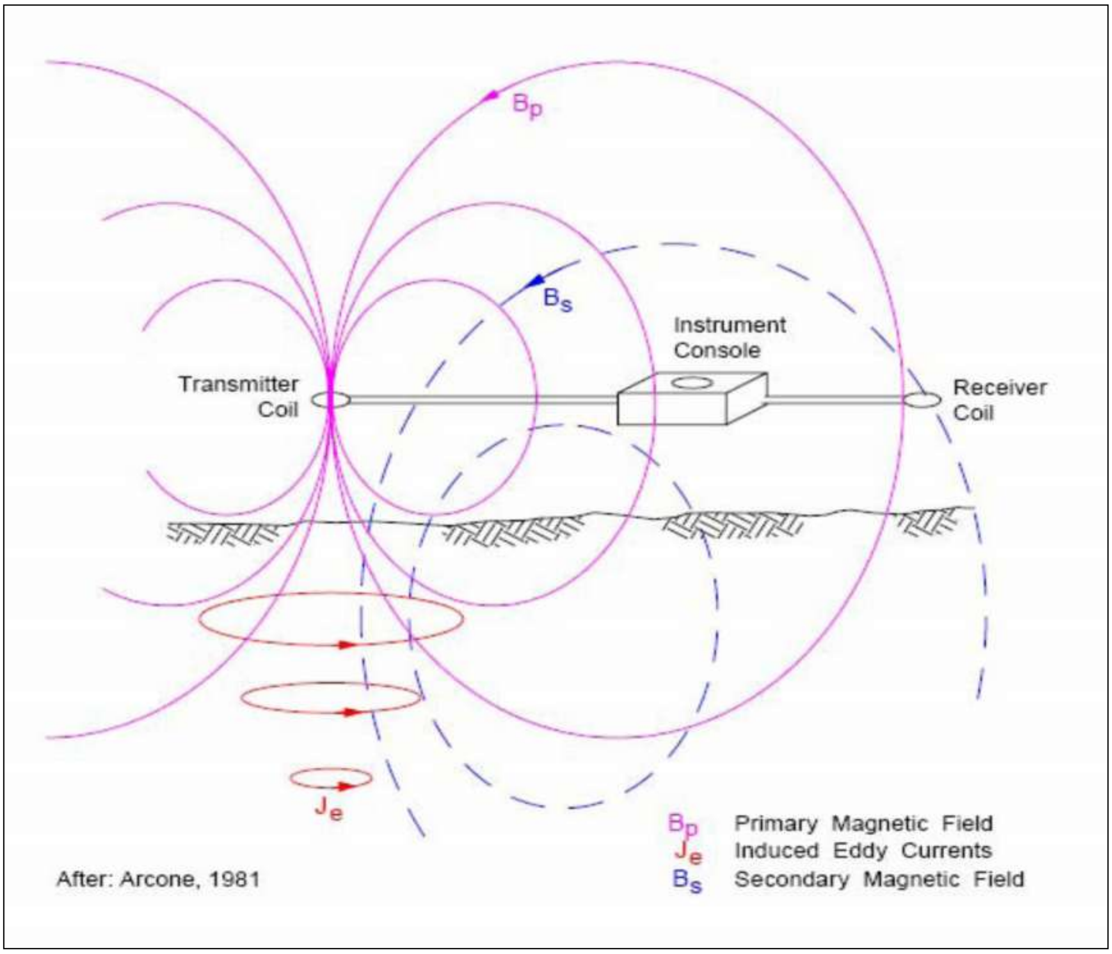


Figure A7.1: *EM principle of operation (NGA 2000).*

For this survey, a 40 m cable was used to measure conductivity at 10 m, 20 m and 40 m. 20 m spacing was used between these points.

- **EM-34 Calibration**

EM-34 measurements used to estimate freshwater lens thickness should be calibrated against known freshwater thickness, measured from multi-depth monitoring bores. The relationship between measured EM-34 apparent ground conductivity readings and known freshwater lens thicknesses is best represented and interpreted using a logarithmic relationship (Falkland 2004).

The relationship between EM-34 conductivity readings and freshwater lens thickness measured at Bonriki multi-level monitoring was used to determine the estimated freshwater lens thickness at the bores. This was done as follows:

1) Salinity readings and water level depths from multi-depth tubes at the monitoring bores were recorded to determine the freshwater lens thickness.
2) EM-34 measurements were taken at the boreholes of known salinity, using both vertical and horizontal dipole (vertical coil alignment) and the 10 m, 20 m and 40 m coil spacing. The apparent ground conductivity readings were then compared against 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 EM-34 readings were calibrated to is 2,500 µS/cm.

The salinity reading, EM apparent conductivity and estimated freshwater lens at each bore is indicated in the Table 7.1.

Table A7.1: *Calibration parameters used for the EM-34 survey.*

Bore ID	EM-34 separations			Estimated maximum freshwater thickness (m)[1]			Actual depth of freshwater (m)
	10 m	20 m	40 m	10 m	20 m	40 m	
BN1	19.5	55.5	128.8	3.4	0.3	1.6	6.6
BN2	12.0	36.9	114.2	10.0	13.7	5.9	4.3
BN33	9.9	36.5	107.1	13.6	14.9	11.3	11.3
BN32	11.1	33.1	105.6	11.4	30.0	13.0	11.7
BN29	20.8	55.4	132.4	2.8	0.3	1.1	6.0
BN25	20.1	46.5	141.4	3.1	1.9	0.5	11.2
BN23	13.2	38.7	117.3	8.4	9.4	4.5	4.5
BN24	25.2	52.4	124.3	1.5	0.6	2.4	1.7
BN28	16.3	35.2	103.5	5.4	19.5	15.7	11.3
BN11	13.9	32.4	100.2	7.6	34.7	21.2	9.0
BN7	7.4	51.5	127.8	19.6	0.7	1.7	7.5
BN26	17.1	35.3	96.3	4.8	19.1	30.3	3.7
BN21	5.8	19.3	81.1	24.8	521.0	120.8	13.9
BN27	6.9	22.7	79.7	21.1	257.9	137.2	4.8
BN34	31.4	72.2	147.8	0.6	0.0	0.3	1.8

Figure 7.2 presents the logarithmic curves and equations which are used to calculate freshwater thickness. The 10 m spacing measurements, made in February 2014, provides the best fit, when compared to 20 m spacing and 40 m spacing measurements. Therefore, the 10 m spacing log equation was used for estimating freshwater lens thickness.

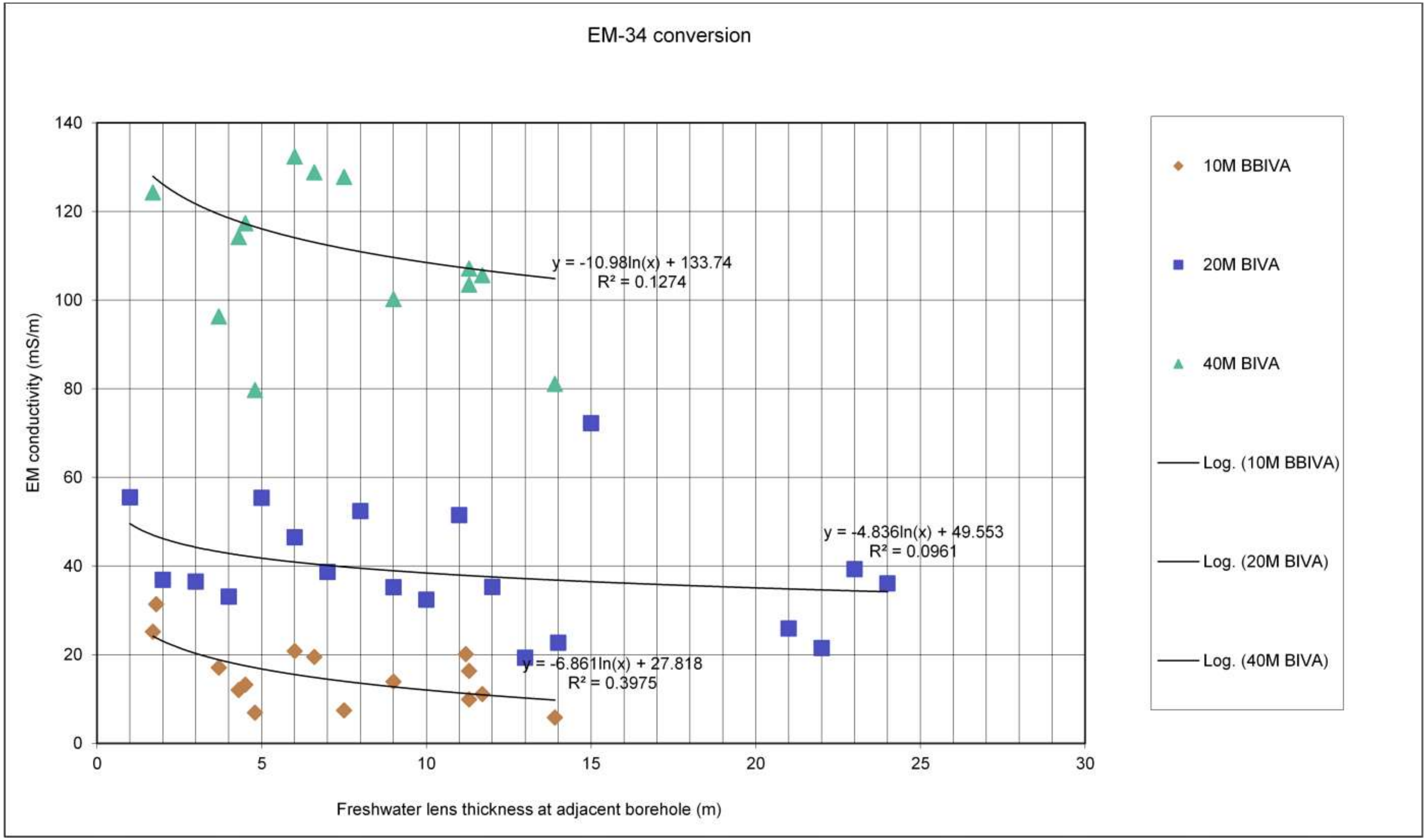


Figure A7.2: *Calibration data used to estimate the freshwater lens thickness for 10 m, 20 m, and 40 m separations.*

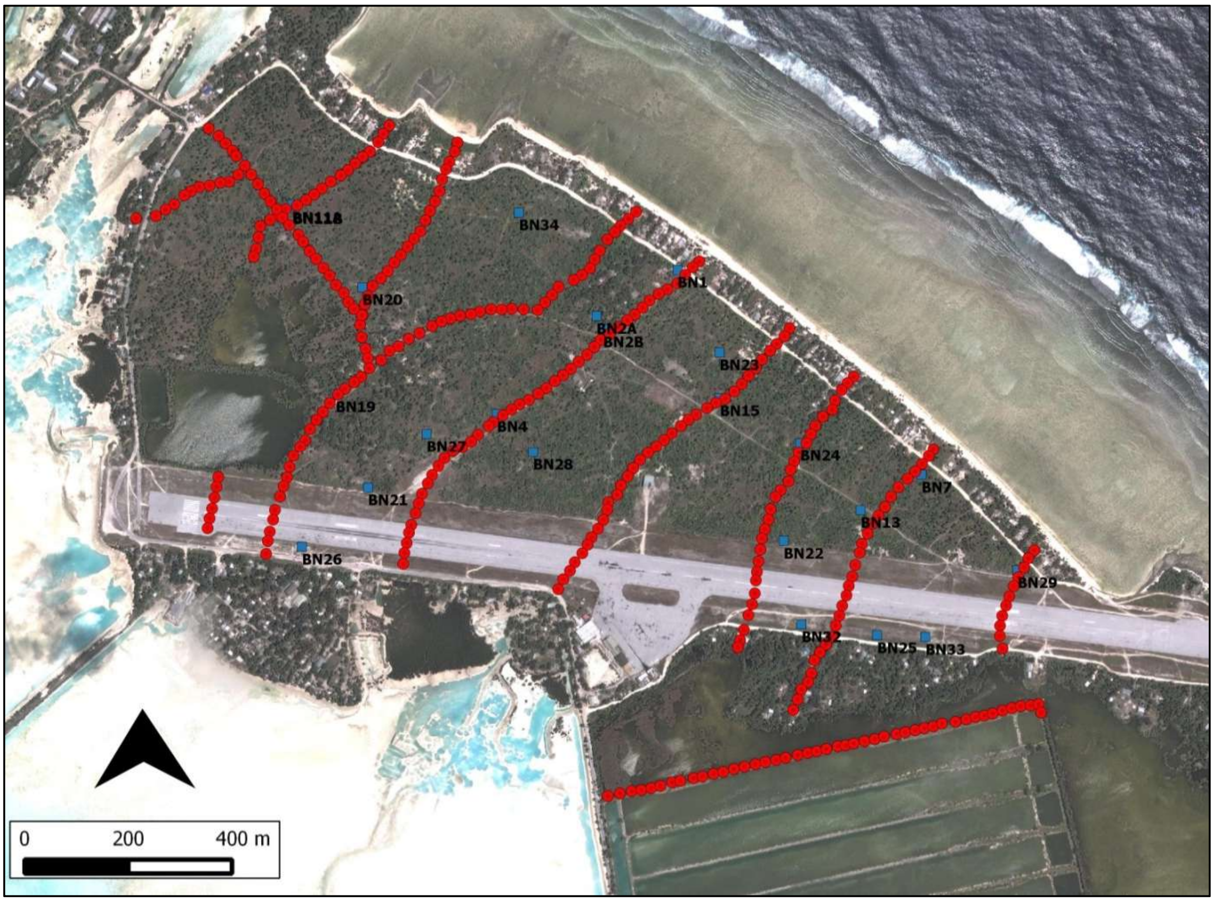


Figure A7.3: *Locations of EM-34 profiles and 20 boreholes selected for EM-34 calibrations, Bonriki.*

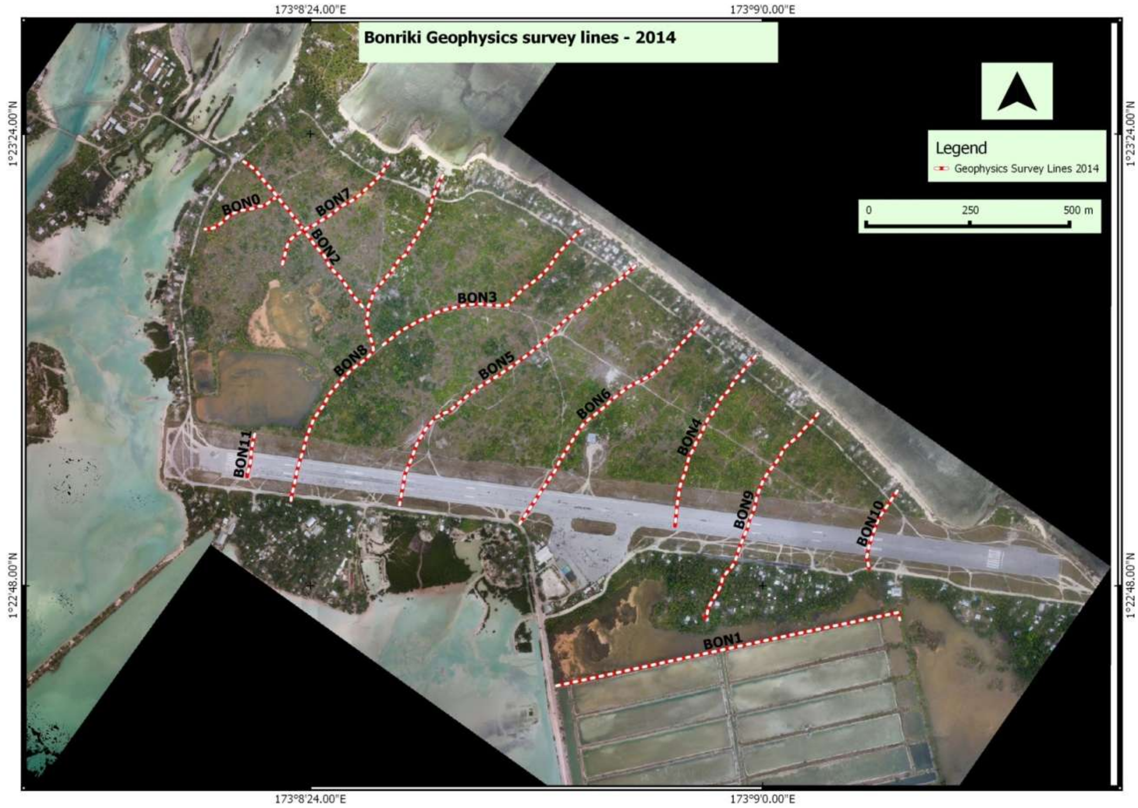


Figure A7.4: *Locations of geophysics survey lines, 2014 (EM-34 profiles).*

A summary of all the survey lines in the various target villages, the maximum freshwater lens thickness is presented in Table 7.2.

Table A7.2: *Summary page of the survey lines.*

Survey No.	Date	Start waypoint	End waypoint	width of island from lagoon to ocean side (m)	maximum estimated freshwater thickness (m)
BON0	22/02/2004	BON0X1	BON0X9	180	12.8
BON1	22/02/2004	BON1X1	BON1X45	900	0.1
BON2	22/02/2004	BON2X1	BON2X24	480	13.2
BON3	23/02/2004	BON3X1	BON3X30	600	11.9
BON4	23/02/2004	BON4X1	BON4X24	480	11.8
BON5	24/02/2014	BON5X1	BON5X43	860	21.7
BON6	24/02/2014	BON6X1	BON5X35	700	22.0
BON7	26/02/2104	BON7X1	BON7X20	400	10.8
BON8	26/02/2104	BON8X1	BON8X45	900	16.5
BON9	26/02/2104	BON9X1	BON9X29	580	16.2
BON10	27/02/2014	BON10X1	BON10X11	220	13.4
BON12	27/02/2014	BON10X1	BON10X6	120	15.3

Table A7.3: Survey lines.

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
					BON0						
BON0X1	20	12.8	34.2	101.0	**8.9**	23.9	19.7	1°23.153'	173°08.920'		Start from oceanside
BON0X2	40	14.3	31.8	97.4	**7.2**	39.3	27.4				
BON0X3	60	10.6	29.3	93.6	**12.3**	65.9	38.7				
BON0X4	80	10.4	28.9	93.6	**12.7**	71.6	38.7				
BON0X5	100	10.3	27.5	93.3	**12.8**	95.6	39.8				
BON0X6	120	13.4	26.6	87.6	**8.2**	115.2	66.8				
BON0X7	140	12.4	25.4	96.8	**9.5**	147.6	28.9				
BON0X8	160	10.4	28.0	91.4	**12.7**	86.2	47.3				
BON0X9	180	51.1	60.6	108.8	**0.0**	0.1	9.7				
					BON1						
BON1X1	20	72.6	86.4	194.2	**0.0**	0.0	0.0	1°23.153'	173°08.920'		Start from oceanside
BON1X2	40	107.7	113.8	148.8	**0.0**	0.0	0.3				
BON1X3	60	75.9	99.4	159.5	**0.0**	0.0	0.1				
BON1X4	80	61.9	87.0	129.7	**0.0**	0.0	1.4				
BON1X5	100	59.2	76.2	135.4	**0.0**	0.0	0.9				
BON1X6	120	50.3	87.6	119.5	**0.0**	0.0	3.7				
BON1X7	140	50.1	79.0	137.3	**0.0**	0.0	0.7				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON1X8	160	55.5	82.6	145.0	**0.0**	0.0	0.4				
BON1X9	180	51.3	76.1	129.0	**0.0**	0.0	1.5				
BON1X10	200	50.6	80.8	132.2	**0.0**	0.0	1.2				
BON1X11	220	54.3	88.3	131.5	**0.0**	0.0	1.2				
BON1X12	240	56.7	94.6	116.4	**0.0**	0.0	4.9				
BON1X13	260	70.5	101.0	137.1	**0.0**	0.0	0.7				
BON1X14	280	78.0	100.8	153.3	**0.0**	0.0	0.2				
BON1X15	300	76.2	111.9	178.4	**0.0**	0.0	0.0				
BON1X16	320	81.0	106.0	175.2	**0.0**	0.0	0.0				
BON1X17	340	73.2	95.3	163.5	**0.0**	0.0	0.1				
BON1X18	360	67.7	86.3	170.1	**0.0**	0.0	0.0				
BON1X19	380	70.9	99.5	140.9	**0.0**	0.0	0.5				
BON1X20	400	66.1	106.2	148.2	**0.0**	0.0	0.3				
BON1X21	420	59.7	73.6	112.1	**0.0**	0.0	7.2				
BON1X22	440	60.8	78.1	140.1	**0.0**	0.0	0.6				
BON1X23	460	72.9	96.4	137.6	**0.0**	0.0	0.7				
BON1X24	480	58.2	83.9	148.7	**0.0**	0.0	0.3				
BON1X25	500	60.1	85.7	128.2	**0.0**	0.0	1.7				
BON1X26	520	62.9	88.2	137.2	**0.0**	0.0	0.7				
BON1X27	540	45.8	63.0	148.2	**0.1**	0.1	0.3				
BON1X28	560	55.0	79.6	129.5	**0.0**	0.0	1.5				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON1X29	580	62.7	91.7	132.2	**0.0**	0.0	1.2				
BON1X30	600	56.4	87.0	131.5	**0.0**	0.0	1.2				
BON1X31	620	62.9	89.4	135.5	**0.0**	0.0	0.9				
BON1X32	640	56.8	87.0	131.5	**0.0**	0.0	1.2				
BON1X33	660	61.7	88.7	148.6	**0.0**	0.0	0.3				
BON1X34	680	68.1	86.0	149.2	**0.0**	0.0	0.2				
BON1X35	700	67.1	86.5	148.6	**0.0**	0.0	0.3				
BON1X36	720	68.1	86.0	149.2	**0.0**	0.0	0.2				
BON1X37	740	67.1	86.5	148.6	**0.0**	0.0	0.3				
BON1X38	760	56.9	87.0	150.9	**0.0**	0.0	0.2				
BON1X39	780	53.4	78.1	155.2	**0.0**	0.0	0.1				
BON1X40	800	54.0	94.5	144.7	**0.0**	0.0	0.4				
BON1X41	820	61.5	96.0	153.4	**0.0**	0.0	0.2				
BON1X42	840	61.1	108.1	167.6	**0.0**	0.0	0.0				
BON1X43	860	67.3	106.0	158.7	**0.0**	0.0	0.1				
BON1X44	880	66.0	91.2	160.1	**0.0**	0.0	0.1				
BON1X45	900	71.3	86.2	150.1	**0.0**	0.0	0.2				
						BON2					
BON2X1	20	18.7	57.6	119.9	**3.8**	0.2	3.5	1°23.153'	173°08.920'		Start from oceanside
BON2X2	40	16.3	44.5	116.7	**5.4**	2.8	4.7				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON2X3	60	15.8	40.7	117.7	**5.8**	6.2	4.3				
BON2X4	80	14.3	36.7	110.5	**7.2**	14.3	8.3				
BON2X5	100	13.8	35.6	104.6	**7.7**	17.9	14.2				
BON2X6	120	13.1	34.9	110.2	**8.5**	20.7	8.5				
BON2X7	140	13.7	34.1	117.1	**7.8**	24.4	4.6				
BON2X8	160	16.3	33.7	103.0	**5.4**	26.5	16.4				
BON2X9	180	12.8	34.4	99.8	**8.9**	23.0	22.0				
BON2X10	200	14.9	33.2	101.7	**6.6**	29.4	18.5				
BON2X11	220	12.2	32.8	98.7	**9.7**	32.0	24.3				
BON2X12	240	12.4	30.4	94.7	**9.5**	52.5	35.0				
BON2X13	260	13.4	29.3	96.2	**8.2**	65.9	30.5				
BON2X14	280	11.8	21.1	97.7	**10.3**	359.1	26.6				
BON2X15	300	12.2	28.7	95.9	**9.7**	74.6	31.4				
BON2X16	320	11.4	28.1	93.2	**10.9**	84.4	40.1				
BON2X17	340	10.2	23.1	94.6	**13.0**	237.5	35.3				
BON2X18	360	10.1	27.5	94.2	**13.2**	95.6	36.6				
BON2X19	380	11.3	26.9	88.4	**11.1**	108.2	62.1				
BON2X20	400	10.6	26.1	88.4	**12.3**	127.7	62.1				
BON2X21	420	10.8	26.2	90.4	**11.9**	125.1	51.8				
BON2X22	440	12.2	25.7	91.0	**9.7**	138.7	49.0				
BON2X23	460	13.6	27.1	97.6	**7.9**	103.8	26.9				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON2X24	480	13.3	26.9	93.2	**8.3**	108.2	40.1				
						BON3					
BON3X1	20	38.6	97.8	187.6	**0.2**	0.0	0.0	1°23.153'	173°08.920'		Start from oceanside
BON3X2	40	29.7	78.8	168.6	**0.8**	0.0	0.1				
BON3X3	60	24.3	68.0	146.7	**1.7**	0.0	0.4				
BON3X4	80	21.1	62.8	139.6	**2.7**	0.1	0.7				
BON3X5	100	20.7	59.9	129.7	**2.8**	0.1	1.5				
BON3X6	120	18.7	57.1	135.1	**3.8**	0.2	1.0				
BON3X7	140	18.4	52.2	134.9	**3.9**	0.6	1.0				
BON3X8	160	16.7	51.3	129.4	**5.1**	0.7	1.5				
BON3X9	180	16.3	49.7	132.9	**5.4**	1.0	1.2				
BON3X10	200	15.4	45.2	127.2	**6.1**	2.5	1.7				
BON3X11	220	14.8	42.1	126.2	**6.7**	4.7	1.9				
BON3X12	240	14.2	43.6	126.1	**7.3**	3.4	1.9				
BON3X13	260	12.1	42.2	116.1	**9.9**	4.6	3.8				
BON3X14	280	16.6	44.4	112.2	**5.1**	2.9	4.9				
BON3X15	300	15.9	42.3	113.4	**5.7**	4.5	4.5				
BON3X16	320	16.0	44.4	112.2	**5.6**	2.9	4.9				
BON3X17	340	18.3	44.5	102.2	**4.0**	2.8	9.9				
BON3X18	360	18.8	45.0	118.8	**3.7**	2.6	3.1				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON3X19	380	22.6	45.1	118.1	**2.1**	2.5	3.3				
BON3X20	400	37.3	49.2	113.7	**0.3**	1.1	4.4				PUB pump station
BON3X21	420	25.8	54.8	116.1	**1.3**	0.3	3.8				
BON3X22	440	14.1	36.0	101.2	**7.4**	16.5	10.7				
BON3X23	460	10.8	33.6	107.5	**11.9**	27.1	6.9				
BON3X24	480	11.3	30.6	98.6	**11.1**	50.4	12.8				
BON3X25	500	14.4	31.0	98.8	**7.1**	46.4	12.6				
BON3X26	520	13.5	28.3	92.7	**8.1**	81.0	19.3				
BON3X27	540	12.7	27.4	92.7	**9.1**	97.6	19.3				
BON3X28	560	13.7	28.4	91.4	**7.8**	79.4	21.2				
BON3X29	580	13.8	26.7	90.2	**7.7**	112.8	23.0				
BON3X30	600	13.0	26.7	86.2	**8.7**	112.8	30.4				
						BON4					
BON4X1	20	34.7	85.7	164.7	**0.4**	0.0	0.1	1°23.103'	173°08.987'		Start from oceanside
BON4X2	40	20.1	50.9	153.4	**3.1**	0.8	0.2				
BON4X3	60	24.2	60.9	132.4	**1.7**	0.1	1.1				
BON4X4	80	19.1	53.8	134.5	**3.6**	0.4	0.9				
BON4X5	100	18.7	52.5	132.3	**3.8**	0.5	1.1				
BON4X6	120	22.6	51.2	125.5	**2.1**	0.7	2.1				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON4X7	140	20.9	54.5	135.5	**2.7**	0.4	0.9				
BON4X8	160	32.8	50.6	127.7	**0.5**	0.8	1.7				
BON4X9	180	20.4	52.1	121.5	**2.9**	0.6	3.0				
BON4X10	200	13.9	39.6	119.1	**7.6**	7.8	3.8				
BON4X11	220	13.0	39.6	117.6	**8.7**	7.8	4.3				
BON4X12	240	16.8	43.2	116.1	**5.0**	3.7	5.0				
BON4X13	260	20.2	47.9	118.4	**3.0**	1.4	4.0				
BON4X14	280	15.8	42.4	108.4	**5.8**	4.4	10.1				
BON4X15	300	16.2	39.6	98.8	**5.4**	7.8	24.1				
BON4X16	320	14.3	34.4	110.0	**7.2**	23.0	8.7				
BON4X17	340	12.0	34.9	110.3	**10.0**	20.7	8.5				
BON4X18	360	11.7	29.6	102.9	**10.5**	61.9	16.6				
BON4X19	380	14.1	28.8	102.0	**7.4**	73.1	18.0				
BON4X20	400	17.7	33.8	100.9	**4.4**	26.0	19.9				
BON4X21	420	15.8	32.9	103.4	**5.8**	31.3	15.9				
BON4X22	440	14.1	32.8	101.2	**7.4**	32.0	19.4				
BON4X23	460	10.9	31.6	104.4	**11.8**	41.0	14.5				
BON4X24	480	12.5	37.8	103.3	**9.3**	11.4	16.0				
						BON5					
BON5X1	20	34.7	84.9	167.8	**0.4**	0.0	0.0	1°23.022'	173°08.826'		Start from oceanside

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON5X2	40	25.3	65.1	144.0	**1.4**	0.0	0.4				
BON5X3	60	20.7	58.8	133.7	**2.8**	0.1	1.0				BN1
BON5X4	80	16.6	53.1	126.2	**5.1**	0.5	2.0				
BON5X5	100	14.8	47.1	127.4	**6.7**	1.7	1.8				
BON5X6	120	11.4	42.7	124.2	**10.9**	4.1	2.4				
BON5X7	140	12.4	43.4	121.2	**9.5**	3.6	3.1				
BON5X8	160	12.2	42.0	117.9	**9.7**	4.8	4.2				
BON5X9	180	13.5	40.6	116.8	**8.1**	6.4	4.7				
BON5X10	200	12.6	39.2	114.7	**9.2**	8.5	5.7				
BON5X11	220	13.4	39.9	113.7	**8.2**	7.4	6.2				
BON5X12	240	12.6	39.7	113.2	**9.2**	7.7	6.5				BN2
BON5X13	260	14.3	37.7	115.3	**7.2**	11.6	5.4				
BON5X14	280	15.3	41.2	112.1	**6.2**	5.6	7.2				
BON5X15	300	16.3	44.5	118.1	**5.4**	2.8	4.2				
BON5X16	320	17.6	45.1	114.1	**4.4**	2.5	6.0				
BON5X17	340	21.5	46.9	107.6	**2.5**	1.7	10.8				PUB depot
BON5X18	360	27.7	51.9	146.7	**1.0**	0.6	0.3				PUB depot
BON5X19	380	21.2	45.8	121.5	**2.6**	2.2	3.0				
BON5X20	400	16.4	38.8	128.7	**5.3**	9.2	1.6				
BON5X21	420	16.0	36.1	109.8	**5.6**	16.1	8.8				
BON5X22	440	17.9	30.9	104.6	**4.2**	47.3	14.2				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON5X23	460	14.1	30.0	93.2	**7.4**	57.0	40.1				
BON5X24	480	15.7	32.8	100.6	**5.8**	32.0	20.5				
BON5X25	500	16.1	32.6	96.6	**5.5**	33.3	29.4				
BON5X26	520	17.6	34.5	107.2	**4.4**	22.5	11.2				
BON5X27	540	18.1	34.5	100.0	**4.1**	22.5	21.6				
BON5X28	560	20.8	33.9	99.8	**2.8**	25.5	22.0				
BON5X29	580	18.5	34.4	97.7	**3.9**	23.0	26.6				Old plane
BON5X30	600	16.6	33.3	97.0	**5.1**	28.8	28.4				
BON5X31	620	18.2	34.7	89.7	**4.1**	21.6	55.2				
BON5X32	640	15.4	28.7	91.5	**6.1**	74.6	46.9				
BON5X33	660	11.4	27.7	92.8	**10.9**	91.7	41.6				
BON5X34	680	12.6	25.3	87.6	**9.2**	150.7	66.8				
BON5X35	700	6.7	23.3	71.5	**21.7**	227.8	289.6				
BON5X36	720	8.3	20.5	88.1	**17.2**	406.5	63.9				
BON5X37	740	7.9	23.4	89.1	**18.2**	223.2	58.3				
BON5X38	760	8.3	23.3	84.9	**17.2**	227.8	85.5				
BON5X39	780	13.1	25.5	86.2	**8.5**	144.6	75.9				Runway
BON5X40	800	15.8	29.0	88.1	**5.8**	70.1	63.9				Centre from runway
BON5X41	820	17.8	32.5	92.5	**4.3**	34.0	42.8				
BON5X42	840	18.5	31.2	91.0	**3.9**	44.5	49.0				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON5X43	860	13.2	34.1	111.5	**8.4**	24.4	7.6				
						BON6					
BON6X1	20	30.9	83.3	178.2	**0.6**	0.0	0.0	1°23.153'	173°08.920'		Start from oceanside
BON6X2	40	21.6	48.4	142.4	**2.5**	1.3	0.5				
BON6X3	60	21.5	58.3	112.8	**2.5**	0.2	6.7				Road
BON6X4	80	16.9	50.6	130.7	**4.9**	0.8	1.3				
BON6X5	100	14.6	45.1	124.6	**6.9**	2.5	2.3				
BON6X6	120	13.1	34.1	123.2	**8.5**	24.4	2.6				
BON6X7	140	12.4	37.5	119.5	**9.5**	12.1	3.7				
BON6X8	160	13.2	43.4	119.0	**8.4**	3.6	3.8				
BON6X9	180	16.3	40.5	114.1	**5.4**	6.5	6.0				
BON6X10	200	14.5	40.0	114.5	**7.0**	7.2	5.8				BN15
BON6X11	220	18.5	36.7	95.6	**3.9**	14.3	32.3				
BON6X12	240	10.4	35.0	107.4	**12.7**	20.3	11.0				Road
BON6X13	260	11.2	34.1	104.1	**11.3**	24.4	14.9				
BON6X14	280	11.4	33.4	102.8	**10.9**	28.2	16.7				
BON6X15	300	12.6	32.7	105.0	**9.2**	32.6	13.7				
BON6X16	320	12.9	34.4	103.4	**8.8**	23.0	15.9				
BON6X17	340	12.2	33.5	102.6	**9.7**	27.6	17.0				
BON6X18	360	10.6	31.2	82.8	**12.3**	44.5	103.5				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON6X19	380	7.2	28.1	90.0	**20.2**	84.4	53.7				
BON6X20	400	6.6	27.8	93.0	**22.0**	89.8	40.9				Ridge approximately 5 m
BON6X21	420	8.5	27.6	97.0	**16.7**	93.6	28.4				
BON6X22	440	10.1	27.3	93.4	**13.2**	99.6	39.4				
BON6X23	460	13.5	36.7	97.5	**8.1**	14.3	27.1				Airport tower
BON6X24	480	13.4	33.6	91.5	**8.2**	27.1	46.9				
BON6X25	500	15.1	24.5	95.8	**6.4**	177.8	31.7				
BON6X26	520	10.9	33.9	97.5	**11.8**	25.5	27.1				
BON6X27	540	13.0	32.1	92.2	**8.7**	36.9	44.0				
BON6X28	560	8.3	25.3	94.0	**17.2**	150.7	37.3				
BON6X29	580	10.5	23.7	88.8	**12.5**	209.8	59.9				
BON6X30	600	10.3	23.7	83.1	**12.8**	209.8	100.7				
BON6X31	620	12.2	24.1	83.2	**9.7**	193.1	99.8				Runway
BON6X32	640	11.2	22.6	81.6	**11.3**	263.3	115.4				Centre of runway
BON6X33	660	8.5	20.0	94.5	**16.7**	450.8	35.7				
BON6X34	680	10.3	22.1	81.0	**12.8**	292.0	121.9				
BON6X35	700	11.1	21.2	93.7	**11.4**	351.7	38.3				Stop
					BON7						
BON7X1	20	30.4	97.5	189.5	**0.7**	0.0	0.0	1°23.636'	173°08.503'		Start from

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
											oceanside
BON7X2	40	30.7	79.5	151.1	**0.7**	0.0	0.2				
BON7X3	60	31.0	67.1	152.8	**0.6**	0.0	0.2				
BON7X4	80	29.7	62.6	126.2	**0.8**	0.1	2.0				
BON7X5	100	24.8	56.6	139.8	**1.6**	0.2	0.6				
BON7X6	120	20.5	55.1	132.8	**2.9**	0.3	1.1				
BON7X7	140	22.4	52.2	127.2	**2.2**	0.6	1.8				
BON7X8	160	24.8	52.0	126.6	**1.6**	0.6	1.9				
BON7X9	180	21.5	46.4	116.4	**2.5**	1.9	4.9				
BON7X10	200	17.5	41.4	112.2	**4.5**	5.4	7.1				
BON7X11	220	13.8	36.0	108.0	**7.7**	16.5	10.4				
BON7X12	240	13.1	34.6	103.2	**8.5**	22.0	16.1				BN11
BON7X13	260	14.1	33.7	100.7	**7.4**	26.5	20.3				
BON7X14	280	11.5	31.7	104.5	**10.8**	40.1	14.3				
BON7X15	300	11.6	30.4	99.9	**10.6**	52.5	21.8				
BON7X16	320	14.1	31.2	102.2	**7.4**	44.5	17.7				
BON7X17	340	13.4	32.2	81.3	**8.2**	36.2	118.6				
BON7X18	360	12.4	29.7	89.7	**9.5**	60.7	55.2				
BON7X19	380	12.3	28.4	94.5	**9.6**	79.4	35.7				
BON7X20	400	11.6	25.5	97.5	**10.6**	144.6	27.1				Stop
						BON8					

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON8X1	20	45.0	114.0	197.6	**0.1**	0.0	0.0	1°23.636'	173°08.503'		Start from oceanside
BON8X2	40	34.3	83.8	164.4	**0.4**	0.0	0.1				
BON8X3	60	28.1	68.4	145.2	**1.0**	0.0	0.4				
BON8X4	80	26.0	64.2	139.7	**1.3**	0.0	0.6				
BON8X5	100	21.5	60.4	131.9	**2.5**	0.1	1.2				
BON8X6	120	25.1	63.5	130.0	**1.5**	0.1	1.4				
BON8X7	140	19.9	56.3	126.1	**3.2**	0.2	2.0				
BON8X8	160	19.1	52.2	123.3	**3.6**	0.6	2.6				
BON8X9	180	16.2	46.3	116.1	**5.4**	2.0	5.0				
BON8X10	200	15.3	38.1	112.9	**6.2**	10.7	6.7				
BON8X11	220	14.8	37.7	101.3	**6.7**	11.6	19.2				
BON8X12	240	12.3	33.4	99.3	**9.6**	28.2	23.0				
BON8X13	260	10.2	29.0	94.5	**13.0**	70.1	35.7				
BON8X14	280	9.8	26.8	94.3	**13.8**	110.5	36.3				
BON8X15	300	9.1	25.5	86.3	**15.3**	144.6	75.2				
BON8X16	320	9.1	22.3	88.9	**15.3**	280.2	59.4				
BON8X17	340	9.3	21.9	81.5	**14.9**	304.3	116.5				
BON8X18	360	10.1	26.7	87.0	**13.2**	112.8	70.6				
BON8X19	380	11.6	26.3	85.4	**10.6**	122.5	81.7				
BON8X20	400	11.7	25.3	87.1	**10.5**	150.7	69.9				Stop

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON8X21	420	10.6	22.2	78.8	**12.3**	286.0	149.0				
BON8X22	440	11.7	27.5	78.1	**10.5**	95.6	158.8				
BON8X23	460	10.7	27.7	81.3	**12.1**	91.7	118.6				
BON8X24	480	11.7	25.2	81.7	**10.5**	153.8	114.4				
BON8X25	500	8.7	26.0	87.8	**16.2**	130.4	65.6				
BON8X26	520	12.5	26.7	78.5	**9.3**	112.8	153.1				
BON8X27	540	14.0	29.4	87.2	**7.5**	64.5	69.3				
BON8X28	560	15.3	28.4	86.8	**6.2**	79.4	71.9				
BON8X29	580	14.8	26.3	78.9	**6.7**	122.5	147.6				BN19
BON8X30	600	11.0	25.2	83.6	**11.6**	153.8	96.2				
BON8X31	620	14.0	21.1	81.2	**7.5**	359.1	119.7				
BON8X32	640	11.7	23.0	82.0	**10.5**	242.4	111.3				
BON8X33	660	10.0	24.5	79.9	**13.4**	177.8	134.8				
BON8X34	680	10.2	23.8	78.7	**13.0**	205.5	150.3				
BON8X35	700	11.2	23.5	78.1	**11.3**	218.6	158.8				
BON8X36	720	11.2	23.0	78.1	**11.3**	242.4	158.8				
BON8X37	740	9.5	22.6	79.1	**14.4**	263.3	144.9				
BON8X38	760	8.6	21.4	77.1	**16.5**	337.5	173.9				
BON8X39	780	9.5	21.8	72.4	**14.4**	310.7	266.8				
BON8X40	800	9.3	22.8	72.1	**14.9**	252.7	274.2				
BON8X41	820	12.1	24.4	80.9	**9.9**	181.5	123.0				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON8X42	840	12.6	24.0	86.2	**9.2**	197.1	75.9				
BON8X43	860	11.4	28.2	89.2	**10.9**	82.7	57.8				
BON8X44	880	12.4	31.2	93.7	**9.5**	44.5	38.3				
BON8X45	900	15.3	32.5	97.3	**6.2**	34.0	27.6				Stop
					BON9						
BON9X1	20	22.1	74.8	162.2	**2.3**	0.0	0.1	1°23.028'	173°09.070'		Start from oceanside
BON9X2	40	20.0	59.2	145.7	**3.1**	0.1	0.3				
BON9X3	60	18.5	56.7	133.4	**3.9**	0.2	1.1				
BON9X4	80	17.9	51.4	125.5	**4.2**	0.7	2.2				
BON9X5	100	15.4	43.9	121.9	**6.1**	3.2	3.0				
BON9X6	120	13.4	39.9	119.9	**8.2**	7.4	3.6				
BON9X7	140	12.3	40.7	111.5	**9.6**	6.2	7.7				
BON9X8	160	10.8	35.7	112.8	**11.9**	17.5	6.9				
BON9X9	180	9.6	36.7	104.2	**14.2**	14.3	15.1				Road
BON9X10	200	9.5	33.5	103.3	**14.4**	27.6	16.3				
BON9X11	220	9.1	32.1	108.3	**15.3**	36.9	10.4				
BON9X12	240	9.9	33.5	107.0	**13.6**	27.6	11.7				
BON9X13	260	11.4	36.5	112.7	**10.9**	14.9	6.9				
BON9X14	280	10.3	36.0	112.0	**12.8**	16.5	7.4				
BON9X15	300	11.2	33.9	110.3	**11.3**	25.5	8.6				Runway

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON9X16	320	11.9	32.3	108.5	**10.2**	35.4	10.2				Runway
BON9X17	340	9.1	30.1	105.6	**15.3**	55.8	13.3				Runway
BON9X18	360	9.0	30.3	106.1	**15.5**	53.6	12.7				
BON9X19	380	8.7	31.4	107.0	**16.2**	42.7	11.7				
BON9X20	400	10.0	33.0	106.7	**13.4**	30.7	12.0				
BON9X21	420	12.3	32.0	106.8	**9.6**	37.7	11.9				
BON9X22	440	10.5	30.4	105.3	**12.5**	52.5	13.6				Power main
BON9X23	460	14.1	33.7	104.1	**7.4**	26.5	15.2				
BON9X24	480	13.5	33.5	96.7	**8.1**	27.6	29.8				
BON9X25	500	12.6	32.5	95.3	**9.2**	34.0	33.9				
BON9X26	520	12.3	40.5	110.6	**9.6**	6.5	8.4				Power main
BON9X27	540	122.1	68.0	101.5	**0.0**	0.0	19.3				House
BON9X28	560	12.2	34.6	116.2	**9.7**	22.0	5.0				
BON9X29	580	22.7	39.7	106.6	**2.1**	7.7	12.1				Stop
					BON10						
BON10X1	20	24.0	71.4	158.8	**1.7**	0.0	0.1	1°22.921'	173°09.171'		Start from oceanside
BON10X2	40	18.8	54.0	132.0	**3.7**	0.4	1.2				Road
BON10X3	60	17.8	54.3	114.7	**4.3**	0.4	5.7				BN29
BON10X4	80	20.1	57.5	122.4	**3.1**	0.2	2.8				
BON10X5	100	16.6	50.2	125.1	**5.1**	0.9	2.2				

Waypoint	Distance from previous point	EM conductivity (mS/m)			Estimated maximum freshwater thickness (m)[1]			GPS		Bearing of coil orientation	Comments
	(m)	10 m	20 m	40 m	10 m	20 m	4 0m	N degrees	E degrees	degrees	E.g. nearby wells, babai pits, if ground is flat or not, if raining or wet ground, tree type, etc.
BON10X6	120	13.7	46.3	123.2	**7.8**	2.0	2.6				
BON10X7	140	13.3	43.3	118.2	**8.3**	3.6	4.1				Runway
BON10X8	160	11.9	39.3	113.2	**10.2**	8.3	6.5				Runway
BON10X9	180	10.9	34.5	113.3	**11.8**	22.5	6.4				Runway
BON10X10	200	10.0	31.9	105.9	**13.4**	38.5	12.6				
BON10X11	220	11.2	38.9	118.5	**11.3**	9.1	4.0				Stop
					BON11						
BON11X1	20	15.5	28.9	89.7	**6.0**	71.6	55.2	1°22.921'	173°09.171'		Start from lake
BON11X2	40	9.1	24.0	87.5	**15.3**	197.1	67.4				
BON11X3	60	10.0	25.4	85.5	**13.4**	147.6	80.9				
BON11X4	80	17.4	31.8	88.1	**4.6**	39.3	63.9				
BON11X5	100	24.1	38.9	97.1	**1.7**	9.1	28.1				
BON11X6	120	24.4	43.3	107.1	**1.6**	3.6	11.3				

Annex 8. Resistivity survey datasets, Bonriki

Summary of the survey results for the resistivity survey, undertaken at Bonriki water Reserve, February 2014

This annex contains the details and results of the geophysical resistivity survey at Bonriki water reserve, in February 2014.

The survey was undertaken by Water and Sanitation Programme staff of the Geoscience Division of the Secretariat of the Pacific Community, and staff from the Ministry of Public Works and Utilities.

The basic principle of operation in electrical resistivity methods is the injection of DC current into the ground using a pair of electrodes. This current causes a potential voltage difference in the ground, which is measured by a separate pair of electrodes. The voltage measured can then, using the parameters of the survey, be converted into an apparent resistivity value. This value can provide a range of information regarding the survey site. Different types of soil compositions have different resistivity. The depth of investigation is a function of the electrode spacing; the greater the spacing, the deeper the investigation. Common arrays include the dipole–dipole array, the pole–pole array, the Schlumberger array, and the Wenner array.

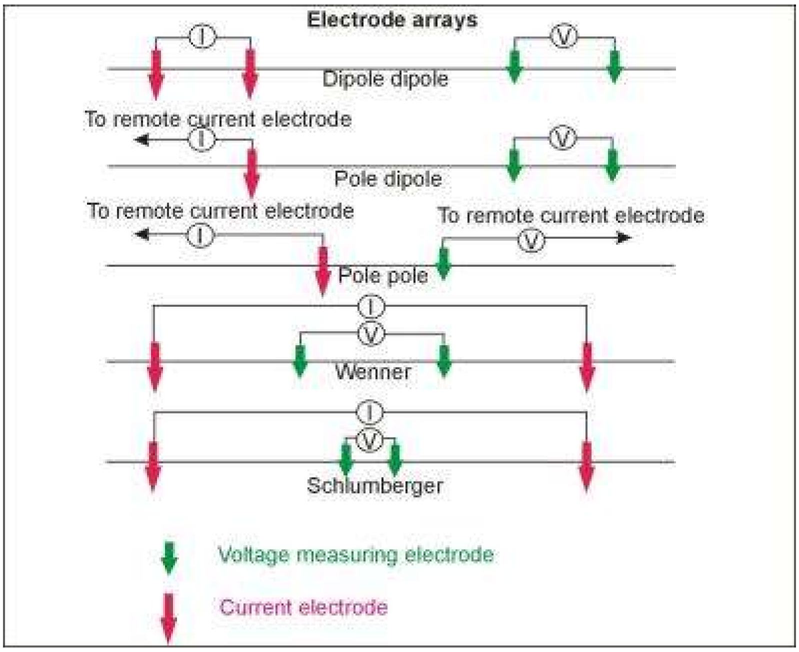


Figure A8.1: *Electrode arrays used to measure resistivity.*

Source: http://www.cflhd.gov/resources/agm/engApplications/RoadwaySubsidence/513ResistivityMethods.cfm

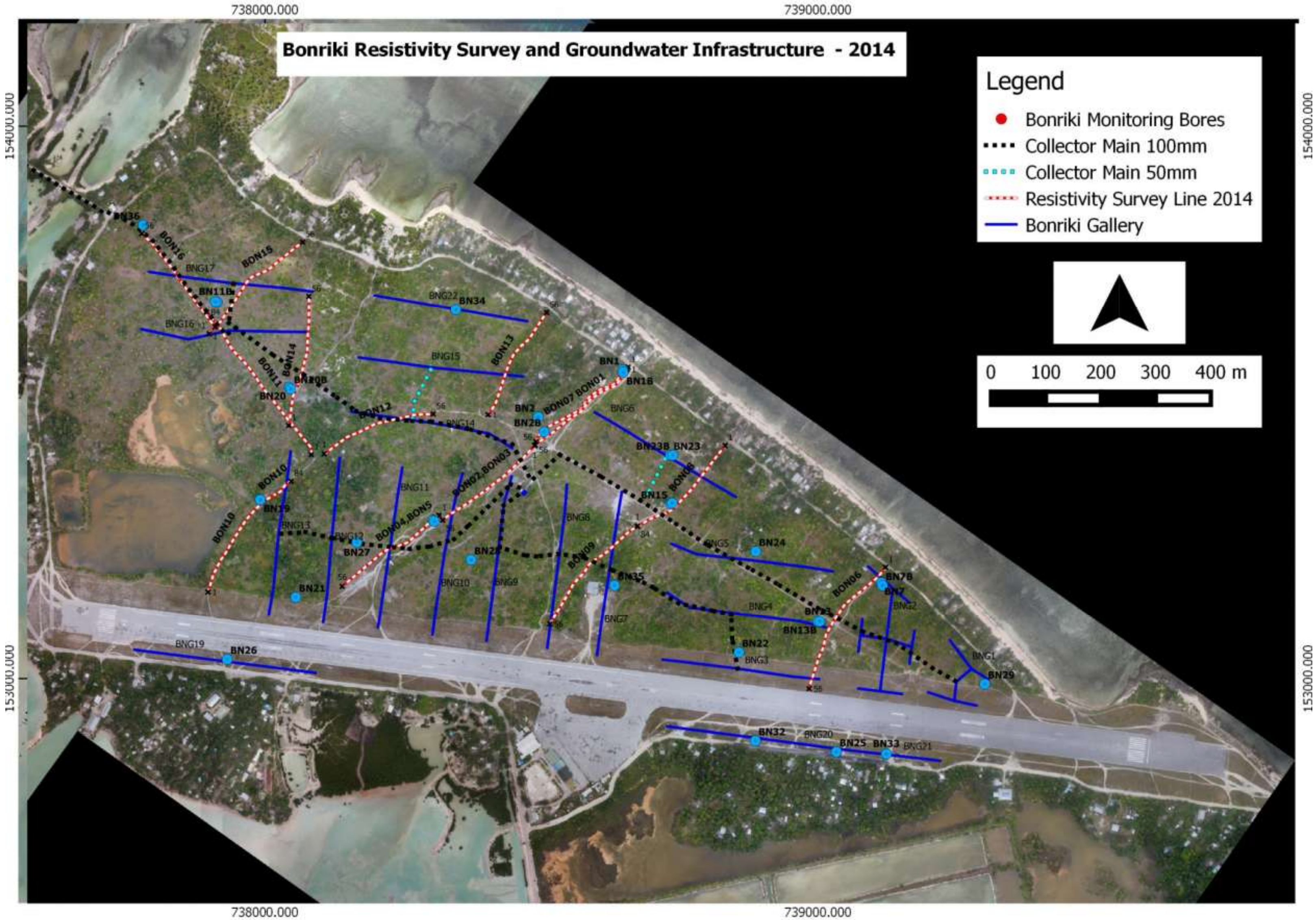


Figure A8.2: *Locations of 13 resistivity survey lines, Bonriki.*

Resistivity – Bonriki water reserve – February 2014

Survey Line: BON01

Location	E-W approx 220⁰ main road past PUB treatment plant, start at BN1	**Length**	220 m
Date	20/02/04	**Contact resistance**	Poor, values of 0.8 - 1.5K ohm-m, use of well water to reduce resistance
Array type	Dipole-Dipole		
Electrode Spacing	4 m	**Comments**	

Electrode No.	Northing	Easting	Comments
BON01_01	01^0 23.212’	173^0 08.807’	Next to BN1
BON01_56	01^0 23.140’	173^0 08.717’	

Survey Line: BON02

Location	E-W approx 220^0 main road past PUB treatment plant	**Length**	220 m
Date	21/02/04	**Contact resistance**	Values less than 1,000 ohm-m, use of sea water to reduce resistance, improved contact resistance over time
Array type	Dipole-Dipole		
Electrode Spacing	4 m	**Comments**	

Electrode No.	Northing	Easting	Comments
BON02_01	01^0 23.137’	173^0 08.716’	Start at end of BON01, near BN2
BON02_56	01^0 23.067’	173^0 08.622’	End

Survey Line: BON03W

Location	E-W approx 220^0 main road past PUB treatment plant	**Length**	220 m
Date	21/02/04	**Contact resistance**	Values approximately 500 ohm-m, use of sea water to reduce resistance
Array type	Wenner		
Electrode Spacing	4 m	**Comments**	Same survey line as BON02, improved contact resistance over time

Electrode No	Northing	Easting	Comments
BON03W_01	01^0 23.137’	173^0 08.716’	Start at end of BON01, near BN2
BON03W_56	01^0 23.067’	173^0 08.622’	End short of BN4

Survey Line: BON04

Location	E-W approx 220^0-250^0 main road past PUB treatment plant		**Length**	220 m
Date	22/02/04		**Contact resistance**	Values approximately 500 ohm-m, use of sea water to reduce resistance
Array type	Dipole- dipole			
Electrode Spacing	4 m		**Comments**	improved contact resistance over time, with sea water

Electrode No.	Northing	Easting	Comments
BON04_01	01^0 23.067’	173^0 08.623’	Start at end of BON02
BON04_05	01^0 23.063’	173^0 08.617’	BN4
BON04_20	01^0 23.041’	173^0 08.592’	Direction change at BON04_20 from 220^0 to 250^0
BON04 _26	01^0 23.037’	173^0 08.579’	Pipeline to treatment plant
BON04_31	01^0 23.037’	173^0 08.569’	Pump station 11 with pipe direction N-S and main line 260^0 directional change from 250^0 to 206^0 through to electrode 56
BON04_32	01^0 23.034’	173^0 08.568’	Pump station 11 with pipe direction N-S and main line 260^0
BON04_56	01^0 22.999’	173^0 08.527’	End of survey

Survey Line: BON05W

Location	E-W approx 011^0 -048^0 BN 7 Ocean side to runway		**Length**	220 m
Date	22/02/04		**Contact resistance**	Values approximately 500 ohm-m, use of sea water to reduce resistance
Array type	Wenner			
Electrode Spacing	4 m		**Comments**	Improved contact resistance over time, with sea water Same survey line as BON04

Electrode No.	Northing	Easting	Comments
BON05W_01	01^0 23.067’	173^0 08.623’	Start at end of BON02
BON05W_05	01^0 23.063’	173^0 08.617’	BN4
BON05W_20	01^0 23.041’	173^0 08.592’	Direction change at BON04_20 from 220^0 to 250^0
BON05W_26	01^0 23.037’	173^0 08.579’	Pipeline to treatment plant
BON05W_31	01^0 23.037’	173^0 08.569’	Pump station 11 with pipe direction N-S and

Electrode No.	Northing	Easting	Comments
			main line 260^0 directional change from 250^0 to 206^0 through to electrode 56
BON05W_32	01^0 23.034’	173^0 08.568’	Pump station 11 with pipe direction N-S and main line 260^0
BON05W_56	01^0 22.999’	173^0 08.527’	End of survey

Survey Line: BON06W

Location	E-W approx 220^0 -250^0 eastern end of water reserve	**Length**	220 m
Date	24/02/04	**Contact resistance**	Values approximately 500 -1000 ohm-m, use of sea water to reduce resistance
Array type	Wenner		
Electrode Spacing	4 m	**Comments**	Improved contact resistance over time, with sea water Attempted roll-along

Electrode No.	Northing	Easting	Comments
BON06W_56	01^0 22.923’	173^0 08.994’	Edge of runway safety zone bearing 011^0/191^0 end of survey
BON06W_36	01^0 22.963’	173^0 09.009’	Middle of intersecting road 018^0
BON06W_29	01^0 22.981	173^0 09.021’	Reef rock exposed
BON06W_21	01^0 23.088’	173^0 09.031’	Bearing change , reef rock exposed, bearing 048^0
BON06W_16	01^0 23.993’	173^0 09.037’	Reef rock exposure
BON06W_08	01^0 23.0005’	173^0 09.052’	Take out switch in line with BN7 and BN7B
BON06W_01	01^0 23.015’	173^0 09.061’	Start of survey road junction

Survey Line: BON07

Location	E-W from BN1 to BN2	**Length**	220 m
Date	24/02/04	**Contact resistance**	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of waterings
Array type	Wenner		
Electrode Spacing	4 m	**Comments**	Improved contact resistance over time, with sea water Repeat survey using 2000mA as opposed to 10mA max current and Wenner array

Electrode No	Northing	Easting	Comments
BON07_01	01^0 23.214’	173^0 08.808’	Start at BN1 220^0/030^0
BON07_04	01^0 23.210’	173^0 08.802’	Opposite **BN1**

BON07_18	01^0 23.191’	173^0 08.779’	Direction change 212^0 /032^0
BON07_19	01^0 23.175’	173^0 08.763’	Direction change 225^0 /028^0
BON07_50	01^0 23.152’	173^0 08.722’	Next to BN2
BON05W_52	01^0 23.149’	173^0 08.721’	Direction change 176^0 /358^0
BON05W_56	01^0 22.141’	173^0 08.718’	End of survey

Survey Line: BON08

Location	Along pump station 15
Date	26/02/04
Array type	Dipole-Dipole
Electrode Spacing	4 m

Length	336 m
Contact resistance	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of watering
Comments	Improved contact resistance over time, with sea water Attempted roll-along with Wenner array after electrode 56 to electrode 84

Electrode No.	Northing	Easting	Comments
BON08_01	01^0 23.082’	173^0 08.544’	Start at road junction (see map) 210^0/030^0
BON08_06	01^0 23.075’	173^0 08.540’	
BON08_15	01^0 23.068’	173^0 08.533’	Adjacent to small gravel mine Direction change 208^0 /028^0
BON08_23-24	01^0 23.062’	173^0 08.526’	Babwai pit 10 m on right Direction change 210^0/030^0
BON08_27	01^0 23.054’	173^0 08.520’	Direction change 208^0 /028^0
BON08_36	01^0 23.048’	173^0 08.515’	BN15
BON08_47	010 23.042’	173^0 08.503’	Direction change 230^0/050^0
BON08_56	010 23.036’	173^0 08.492’	End survey, start roll-along with Wenner array
BON08_70	010 23.027’	173^0 08.476’	034^0
BON08_77	010 23.019’	173^0 08.471’	040^0
BON08_84	010 23.014’	173^0 08.464’	052^0 End of roll-along

Survey Line: BON09

Location	Continue at end of BON08
Date	26/02/04
Array type	Wenner
Electrode Spacing	4 m

Length	336 m
Contact resistance	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of watering
Comments	Improved contact resistance over time, with sea water Roll-along with Wenner array after electrode 56

Electrode No.	Northing	Easting	Comments
BON09_01	01^{0} 23.035’	173^{0} 08.490’	Start at end of BON08 at bearing 230^{0}
BON09_07	01^{0} 23.033’	173^{0} 08.485’	Close to sinkhole 220^{0}
BON09_28	01^{0} 23.013’	173^{0} 08.464’	Midpoint 230^{0}
BON09_30	01^{0} 23.011’	173^{0} 08.461’	Direction change 200^{0}
BON09_35	01^{0} 23.007’	173^{0} 08.459’	Direction change 220^{0}
BON09_36	01^{0} 23.048’	173^{0} 08.515’	BN15
BON09_39	010 23.003’	173^{0} 08.445’	Direction change 205^{0}
BON09_56	010 22.584’	173^{0} 08.444’	Direction change 034^{0}
BON09_79	010 22.558’	173^{0} 08.439’	Close to runway 012^{0}
BON09_62	010 22.579’	173^{0} 08.471’	Direction change 012^{0}
BON09_57	010 22.585’	173^{0} 08.444’	Midpoint for roll-along – End survey

Survey Line: BON10

Location	Along BN19 Access Road
Date	27/02/04
Array type	Wenner
Electrode Spacing	4 m

Length	336 m
Contact resistance	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of watering
Comments	Improved contact resistance over time, with sea water Roll-along after electrode 56

Electrode No.	Northing	Easting	Comments
BON10_01	01^{0} 22.595’	173^{0} 08.237’	Start at bearing 008^{0}
BON10_05	01^{0} 23.000’	173^{0} 08.239’	Direction change 352^{0}
BON10_09	01^{0} 23.006’	173^{0} 08.241’	Edge of the lake 010^{0}
BON10_23	01^{0} 23.022’	173^{0} 08.249’	Direction change 022^{0}
BON10_50	01^{0} 23.049’	173^{0} 08.271’	Direction change BN19
BON10_56	01^{0} 23.052’	173^{0} 08.276’	Direction change 198^{0}
BON10_57	010 23.052’	173^{0} 08.282’	Start of roll-along 230^{0}
BON10_64	010 23.061’	173^{0} 08.286’	Direction change 048^{0}
BON10_84	010 23.076’	173^{0} 08.303’	End survey

Survey Line: BON11

Location	Access road along BN11 and BN36
Date	27/02/04
Array type	Wenner
Electrode Spacing	4 m

Length	336 m
Contact resistance	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of watering
Comments	Improved contact resistance over time, with sea water Roll-along with Wenner array after electrode 56

Electrode No.	Northing	Easting	Comments
BON11_01	01^0 23.076’	173^0 08.299’	Start at bearing 344^0
BON11_05	01^0 23.081’	173^0 08.298’	Direction change 312^0
BON11_28	01^0 23.105’	173^0 08.279’	Midpoint
BON11_43	01^0 23.022’	173^0 08.249’	Direction change 022^0
BON11_51	01^0 23.128’	173^0 08.263’	Direction change 316^0
BON11_56	01^0 23.134’	173^0 08.256’	End survey, Start of roll-along
BON11_57	010 23.134’	173^0 08.257’	Direction change 310^0
BON11_73	010 23.152’	173^0 08.244’	Directly opposite pumping station 16, 300^0
BON11_84	010 23.161’	173^0 08.237’	End survey, in with line with BN11

Survey Line: BON12

Location	Continuation of BON10	**Length**	220 m
Date	28/02/04	**Contact resistance**	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of watering
Array type	Wenner		
Electrode Spacing	4 m	**Comments**	Improved contact resistance over time, with sea water

Electrode No.	Northing	Easting	Comments
BON12_01	01^0 23.077’	173^0 08.836’	Start at bearing 046^0
BON12_14	01^0 23.087’	173^0 08.319’	Direction change 042^0
BON12_28	01^0 23.095’	173^0 08.336’	Midpoint
BON12_34	01^0 23.096’	173^0 08.342’	Direction change 022^0
BON12_40	01^0 23.098’	173^0 08.350’	Direction change 060^0
BON12_56	01^0 23.100’	173^0 08.370’	End survey, Start of roll-along

Survey Line: BON13

Location	N/a	**Length**	220 m
Date	28/02/04	**Contact resistance**	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of watering
Array type	Wenner		
Electrode Spacing	4 m	**Comments**	Improved contact resistance over time, with sea water

Electrode No.	Northing	Easting	Comments
BON13_01	01^0 23’10.2	173^0 08.39.7	Start at bearing 208^0
BON13_18	01^0 23’11.6	173^0 08.40.9	Direction change 018^0
BON13_26	01^0 23’12.9	173^0 08.41.3	Direction change 018^0 Close to midpoint

Electrode No.	Northing	Easting	Comments
BON13_32	01^0 23'13.4	173^0 08.41.7	Direction change 350^0
BON13_56	01^0 23'16.1	173^0 08.43.7	350^0 End survey, Start of roll-along

Survey Line: BON14

Location	Along BN20	**Length**	220 m
Date	28/02/04	**Contact resistance**	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of watering
Array type	Wenner		
Electrode Spacing	4 m	**Comments**	Improved contact resistance over time, with sea water

Electrode No.	Northing	Easting	Comments
BON14_01	01^0 23'09.4	173^0 08.28.6	Start at bearing 010^0
BON14_18	01^0 23'12.1	173^0 08.29.2	BN20 close to electrode 12, 016^0
BON14_28	01^0 23'13.5	173^0 08.29.5	Midpoint
BON14_39	01^0 23'14.6	173^0 08.29.6	Direction change 354^0
BON14_56	01^0 23'17.1	173^0 08.29.7	164^0 End survey, Start of roll-along

Survey Line: BON15

Location	Along pump station 16, going towards BN11	**Length**	220 m
Date	29/02/04	**Contact resistance**	Values approximately 500 ohm-m, use of sea water to reduce resistance an number of watering
Array type	Wenner		
Electrode Spacing	4 m	**Comments**	Improved contact resistance over time, with sea water

Electrode No.	Northing	Easting	Comments
BON15_01	01^0 23'14.8	173^0 08.23.8	Start at bearing 038^0
BON15_03	01^0 23'15.5	173^0 08.24.5	BN11, 016^0
BON15_28	01^0 23'18.2	173^0 08.26.4	Midpoint
BON15_48	01^0 23'19.6	173^0 08.28.5	Direction change 032^0
BON15_56	01^0 23'20.6	173^0 08.30.0	Direction change 026^0 End survey, Start of roll-along

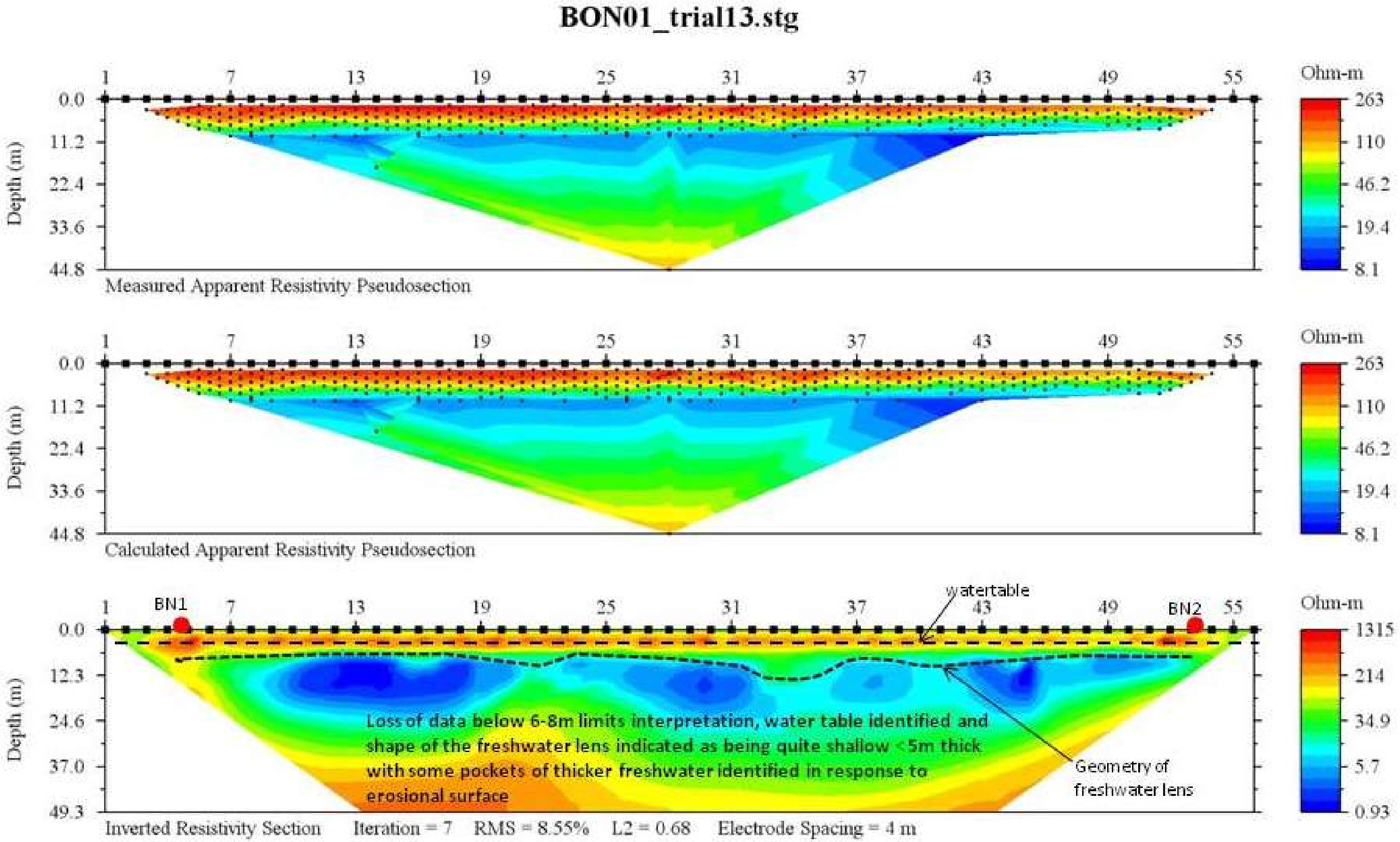
Survey Line: BON16

Location	Along pump station 16, going toward BN11	**Length**	220 m
Date	29/02/04	**Contact**	Values approximately 500 ohm-

Array type	Wenner
Electrode Spacing	4 m

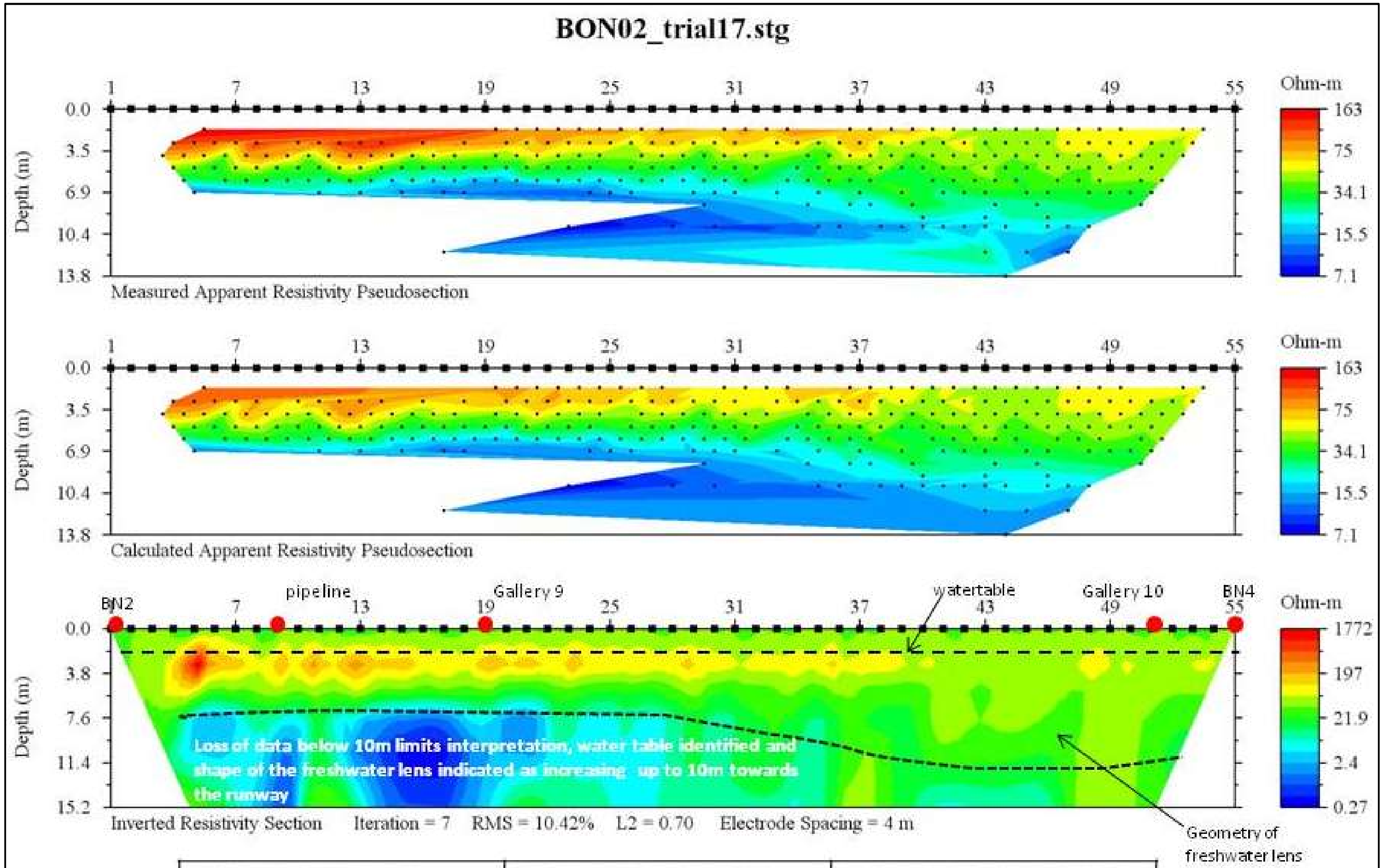
resistance	m, use of sea water to reduce resistance an number of watering
Comments	Improved contact resistance over time, with sea water

Electrode No.	Northing	Easting	Comments
BON16_01	01^0 23’15.3	173^0 08.24.3	Start at bearing 304^0
BON16_09	01^0 23’15.9	173^0 08.23.7	BN11, 016^0
BON16_28	01^0 23’18.2	173^0 08.22.4	Midpoint
BON16_42	01^0 23’19.9	173^0 08.20.9	Direction change 326^0
BON16_56	01^0 23’20.9	173^0 08.20.0	Direction change 314^0 End survey, Start of roll-along



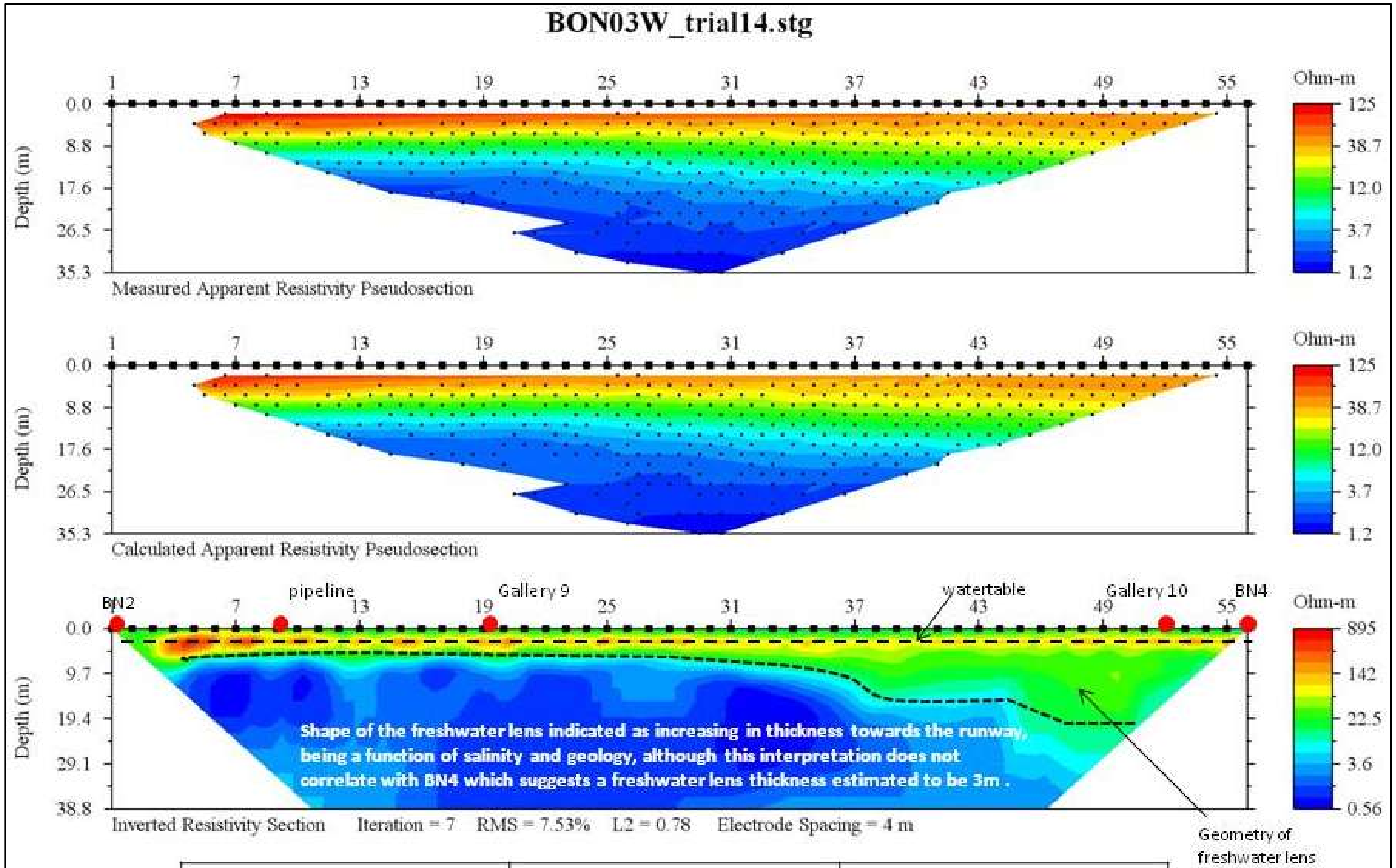
Bonriki Groundwater survey	Survey date: 20 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON01	Array Type: Dipole Dipole	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	

Figure A8.3: *Survey line BON01.*



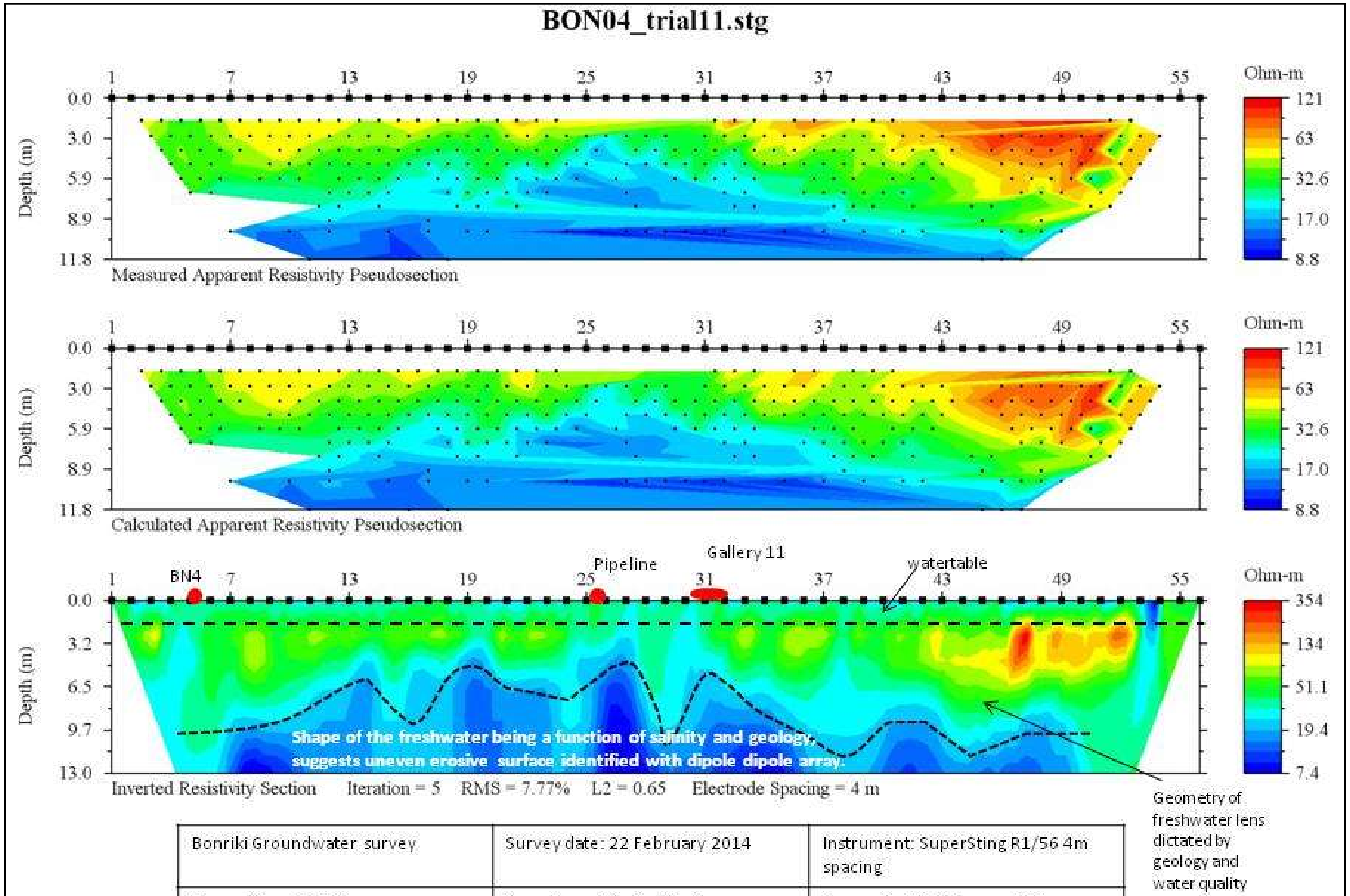
Bonriki Groundwater survey	Survey date: 21 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON02	Array Type: Dipole Dipole	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	

Figure A8.4: *Survey line BON02.*



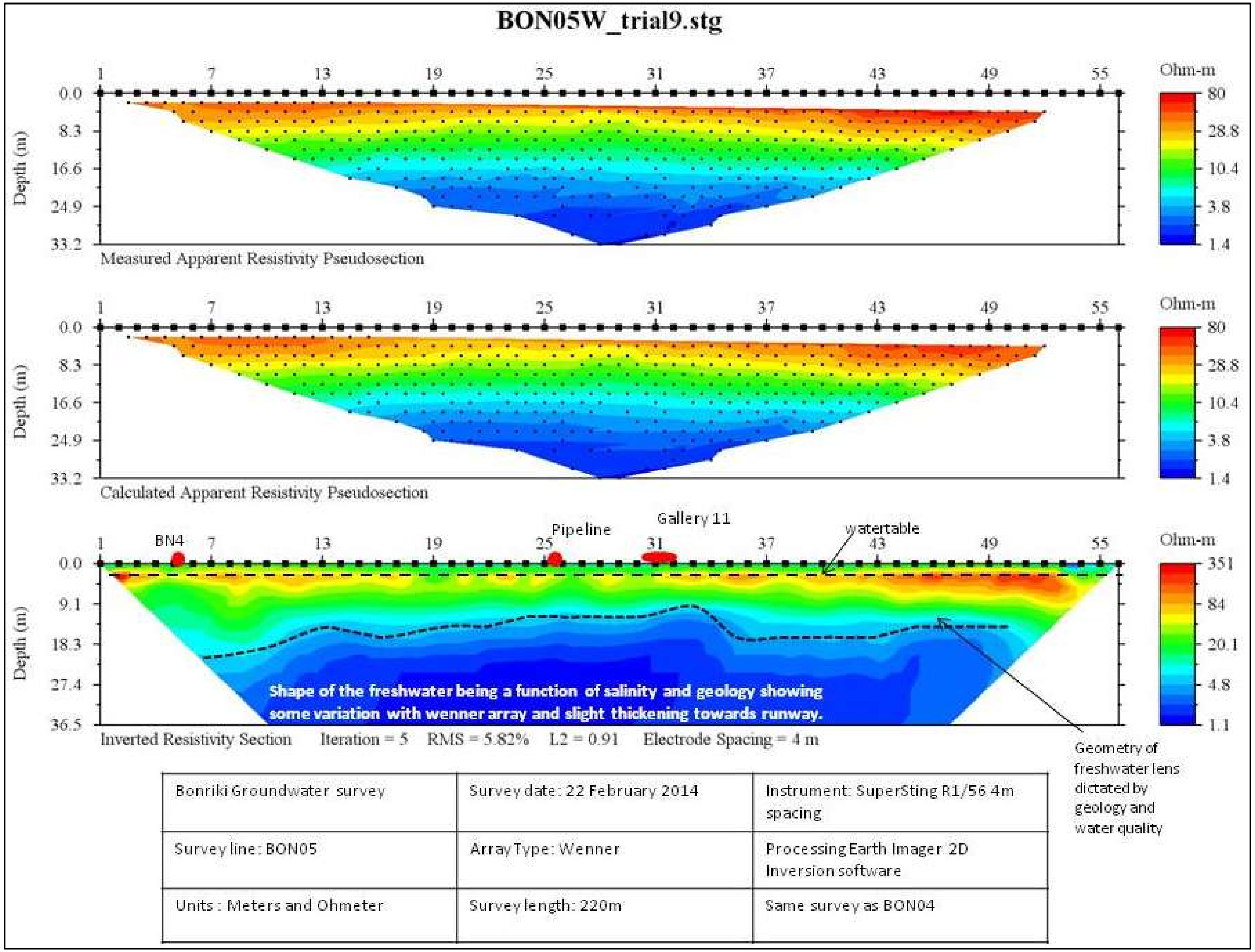
Bonriki Groundwater survey	Survey date: 21 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON03W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	Same survey as BON02

Figure A8.5: *Survey line BON03W.*



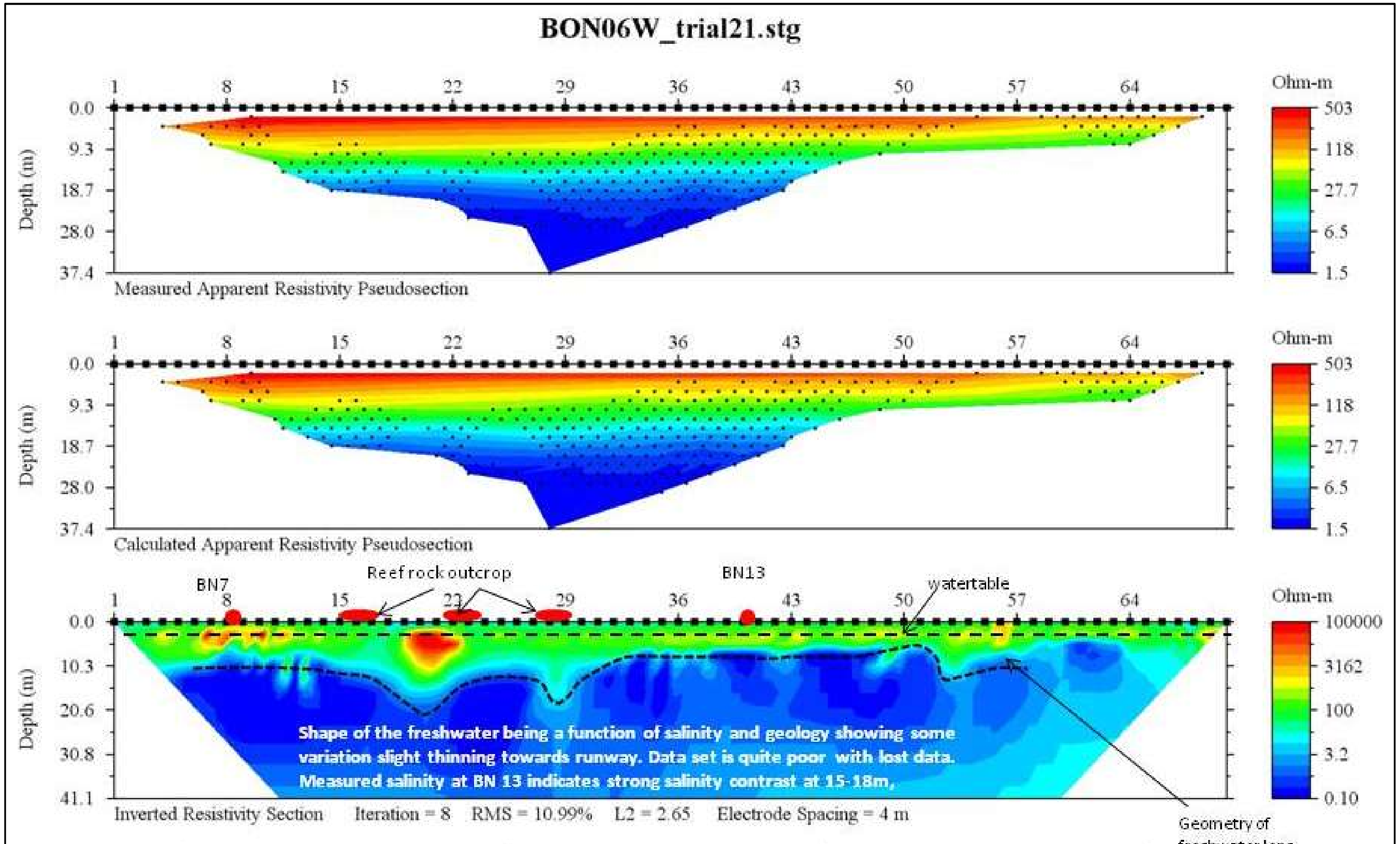
Bonriki Groundwater survey	Survey date: 22 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON04	Array Type: Dipole dipole	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	Same survey as BON05

Figure A8.6: *Survey line BON04.*



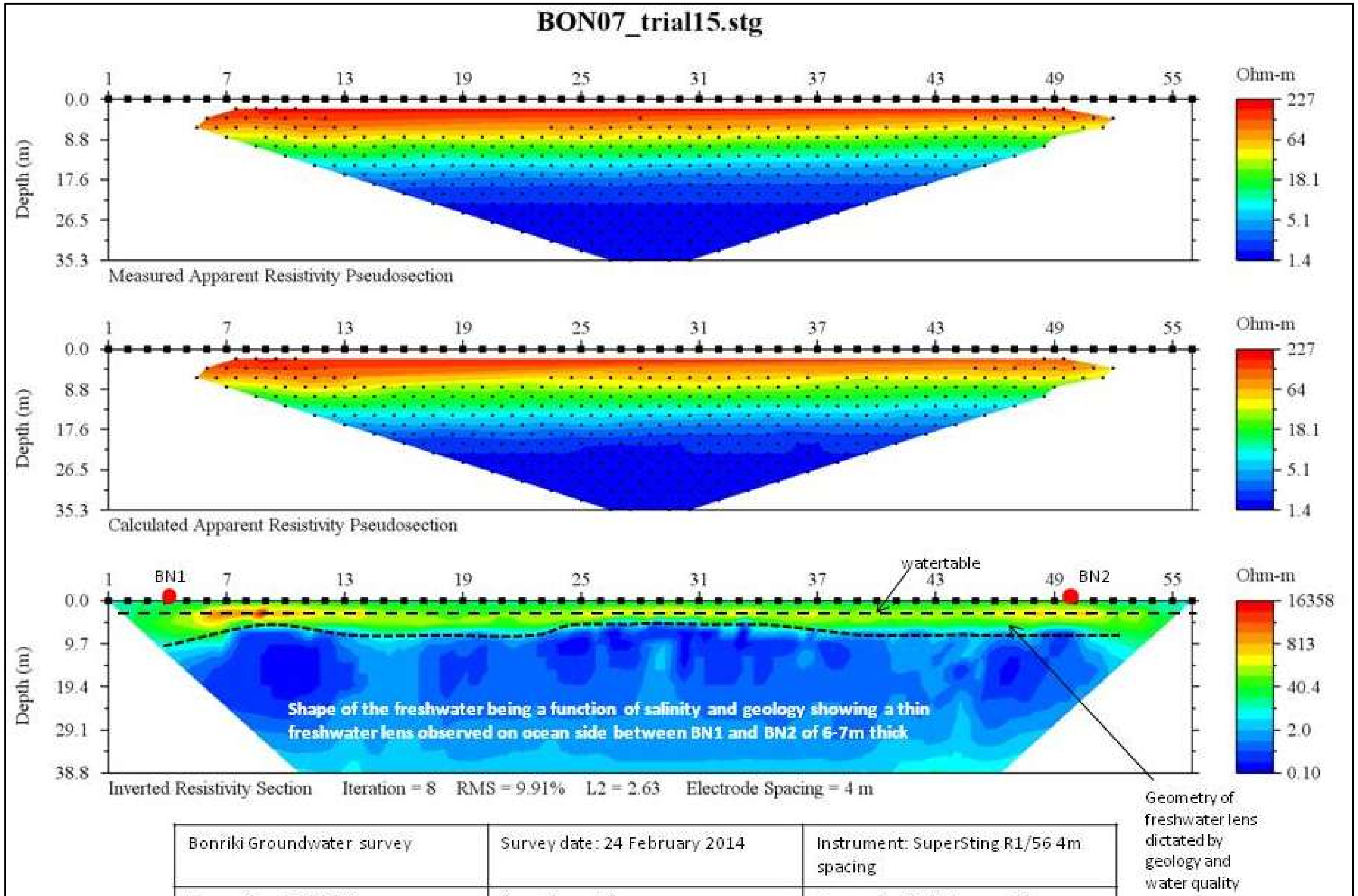
Bonriki Groundwater survey	Survey date: 22 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON05	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	Same survey as BON04

Figure A8.7: Survey line BON05W.



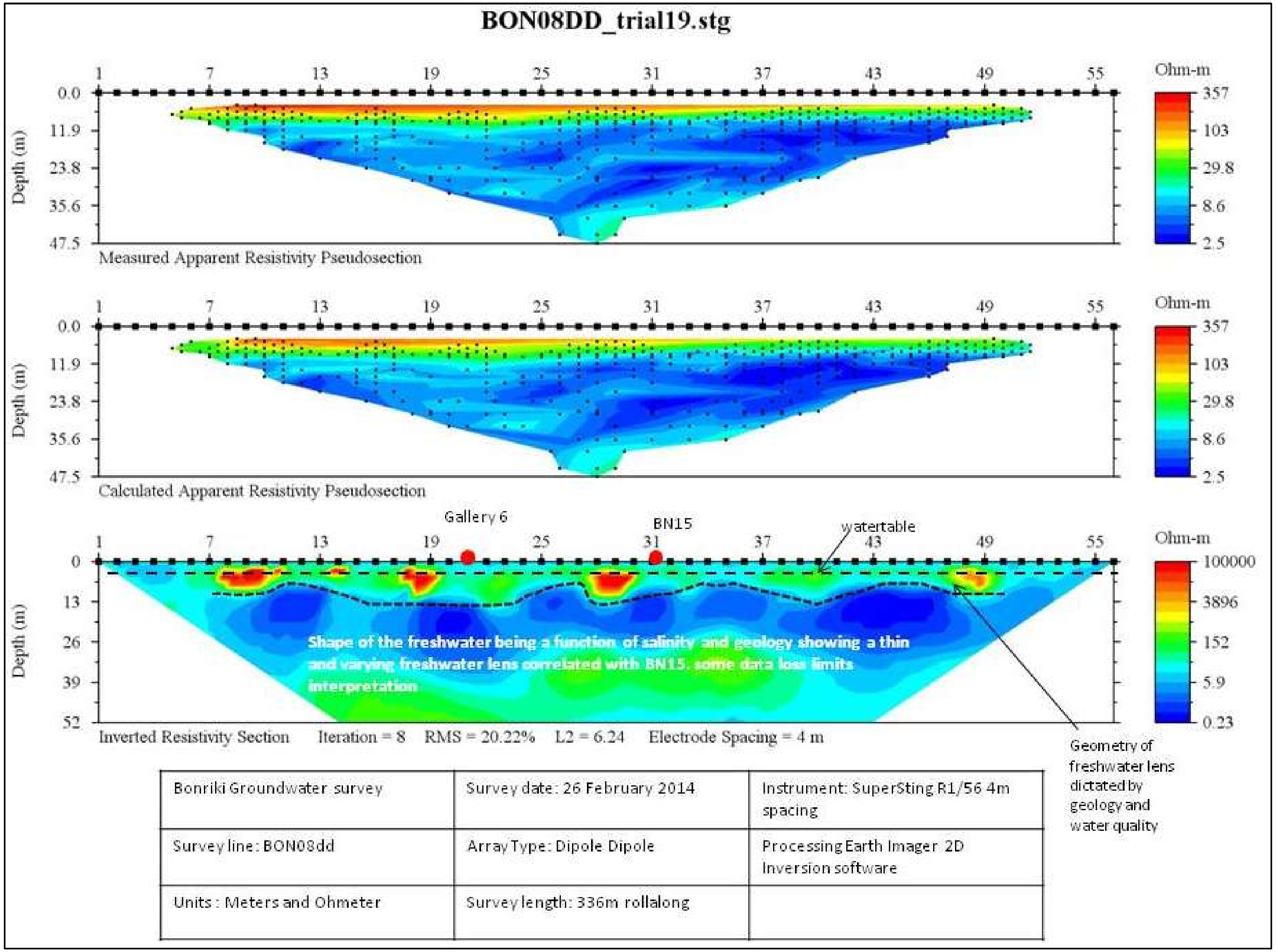
Bonriki Groundwater survey	Survey date: 24 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON06W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	

Figure A8.8: *Survey line BON06W.*



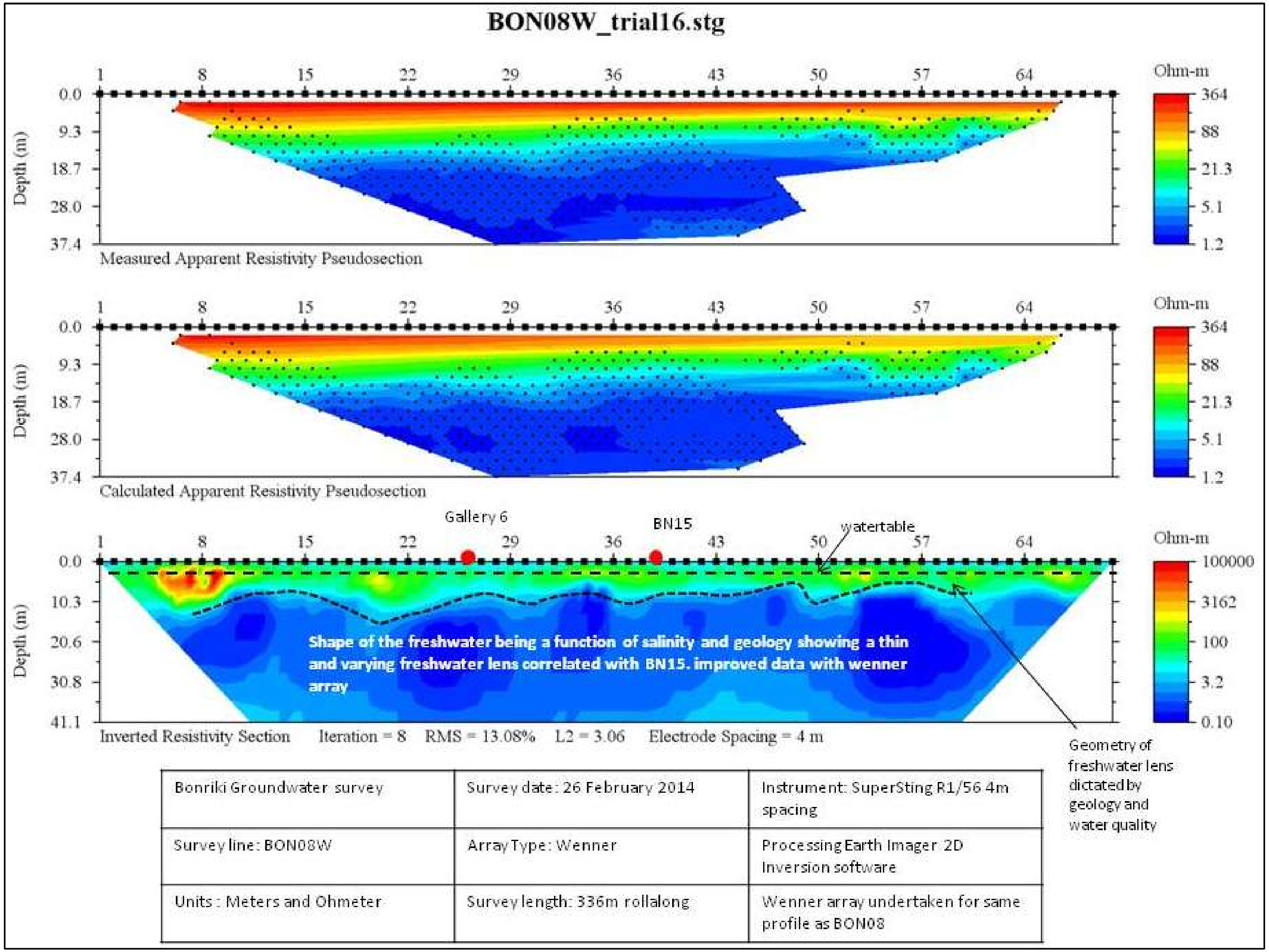
Bonriki Groundwater survey	Survey date: 24 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON07W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	Similar profile to BON1

Figure A8.9: *Survey line BON07.*



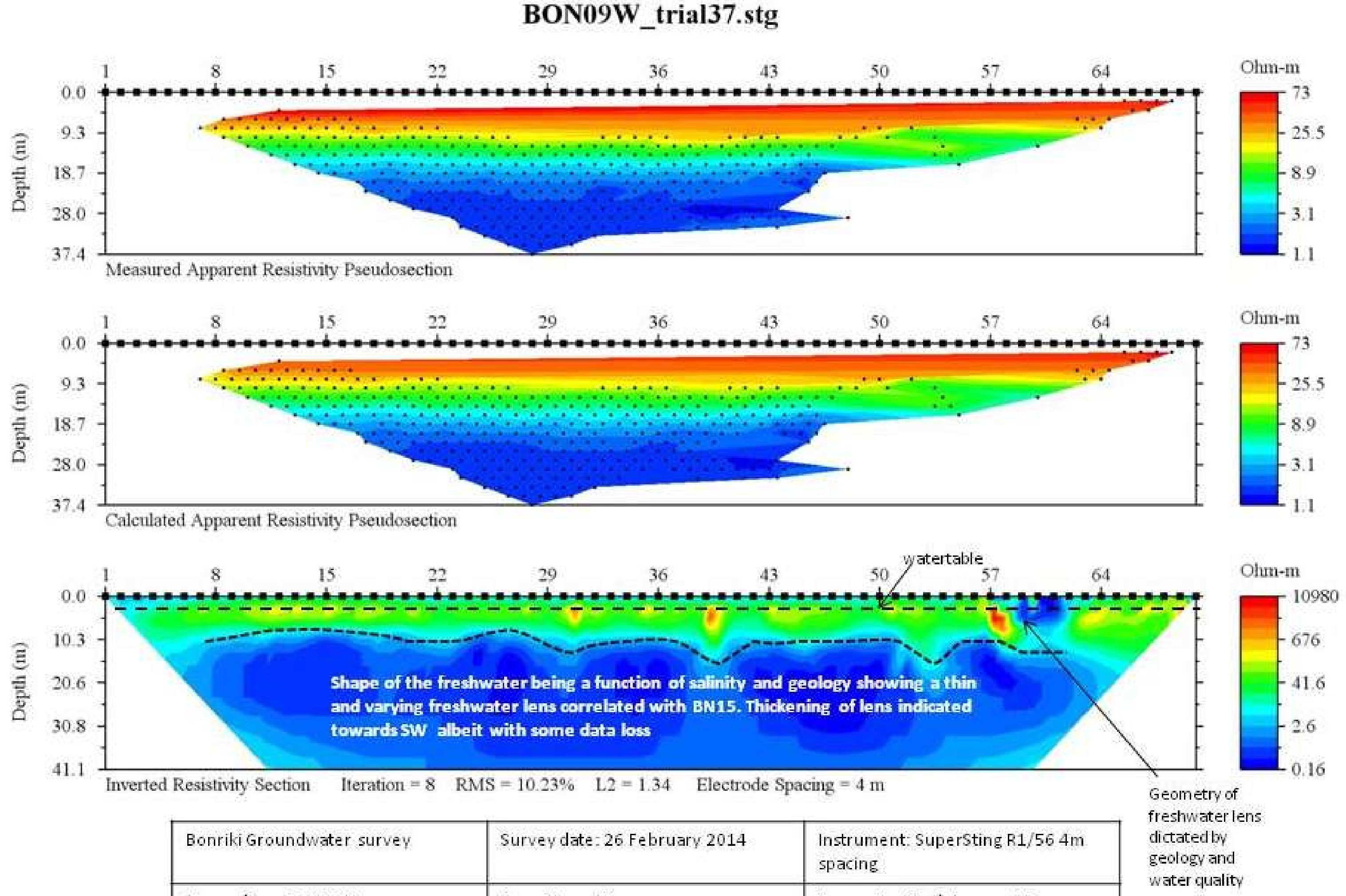
Bonriki Groundwater survey	Survey date: 26 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON08dd	Array Type: Dipole Dipole	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 336m rollalong	

Figure A8.10: *Survey line BON08DD.*



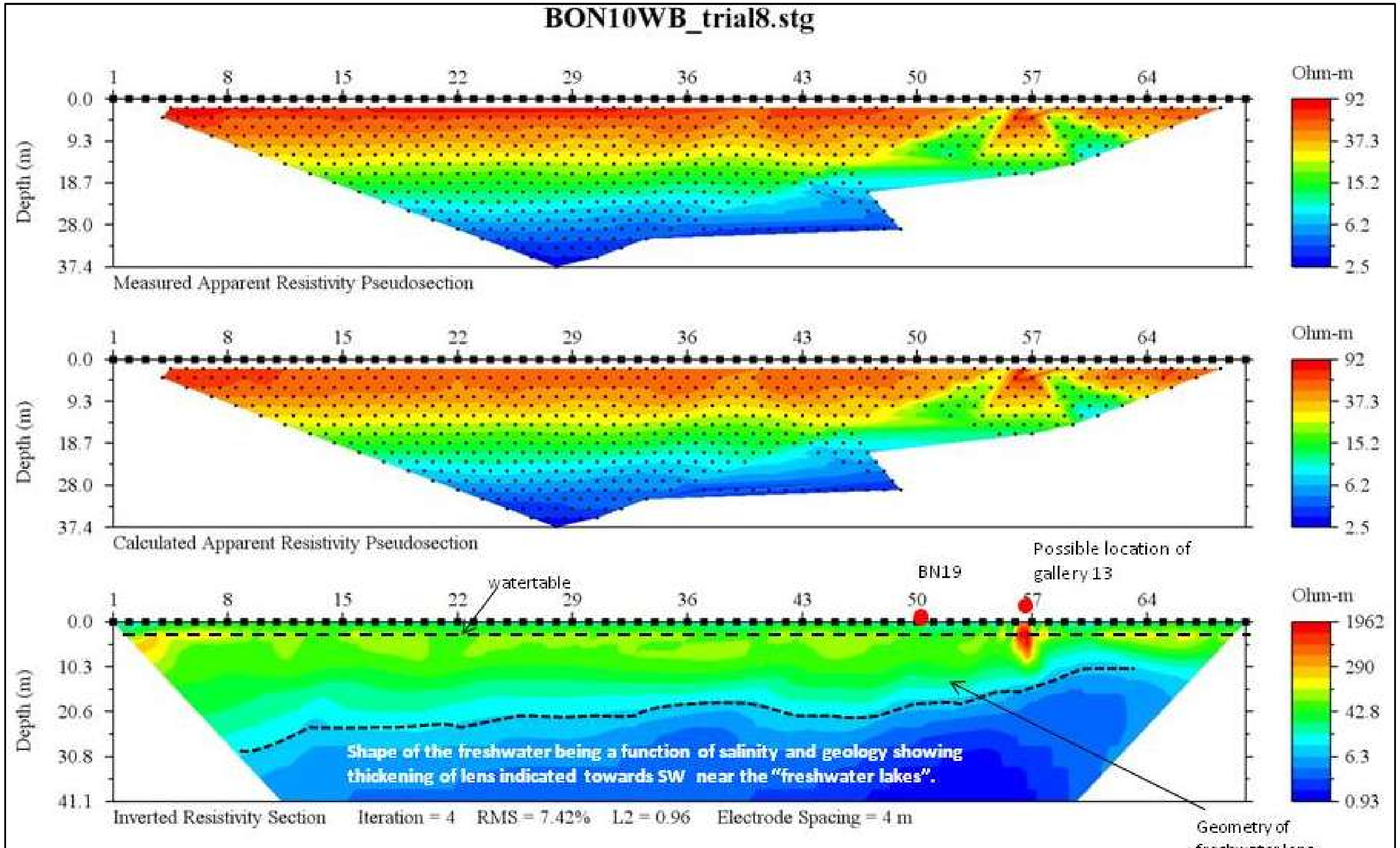
Bonriki Groundwater survey	Survey date: 26 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON08W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 336m rollalong	Wenner array undertaken for same profile as BON08

Figure A8.11: *Survey line BON08W.*



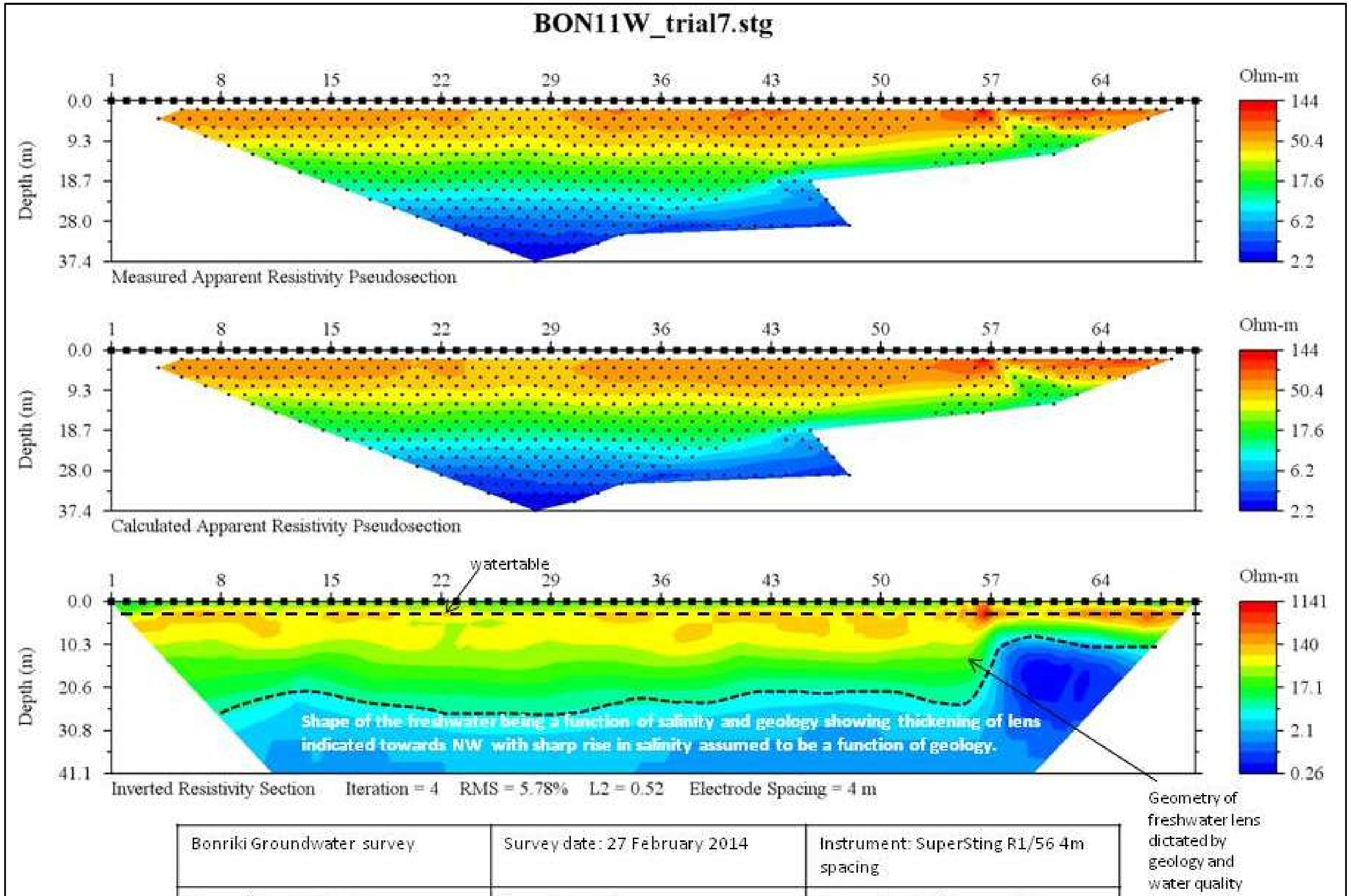
Bonriki Groundwater survey	Survey date: 26 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON09W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 336m rollalong	Roll along survey was attempted

Figure A8.12: *Survey line BON09.*



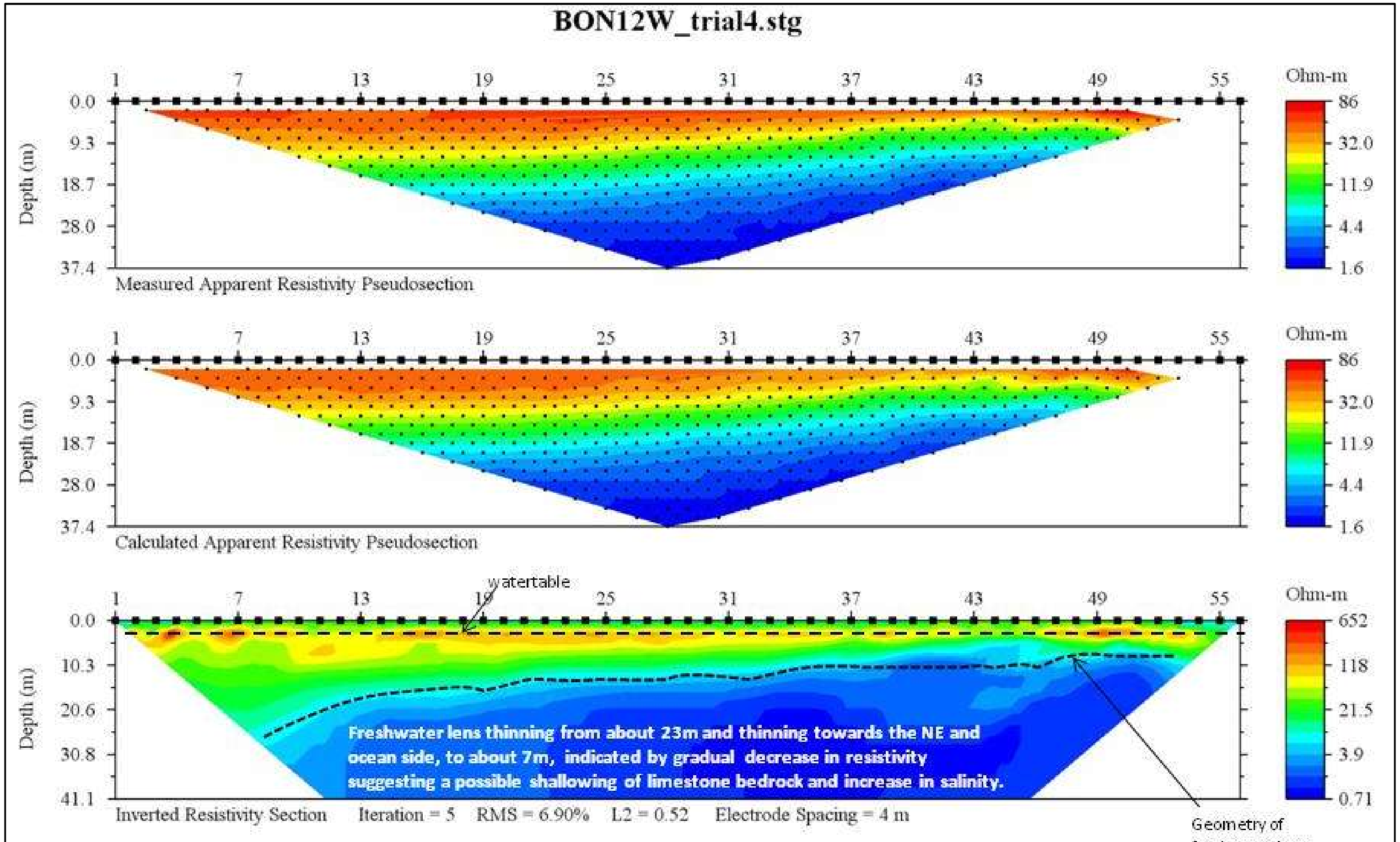
Bonriki Groundwater survey	Survey date: 27 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON10W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 336m rollalong	Roll along survey was attempted

Figure A8.13: *Survey line BON10.*



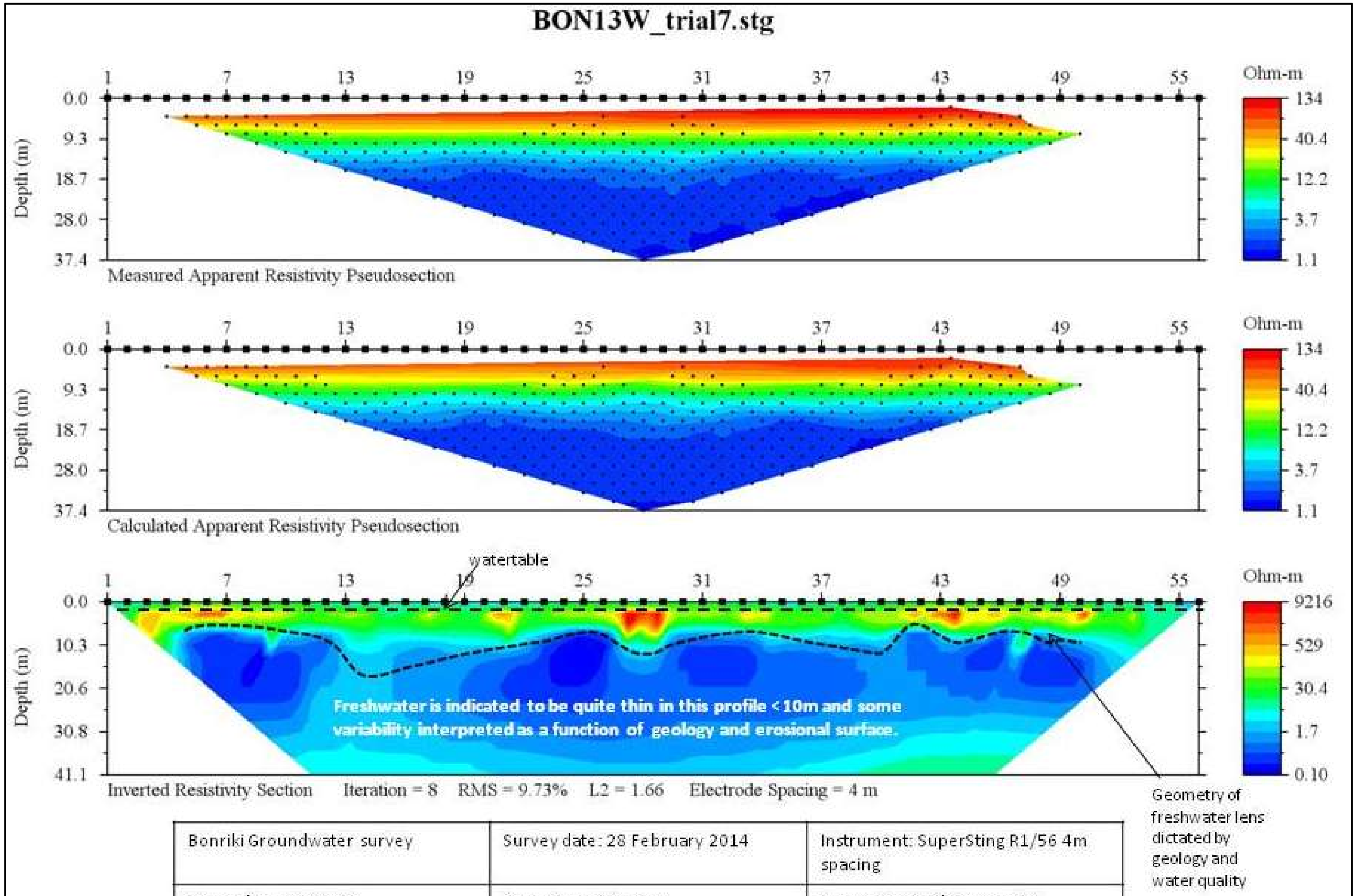
Bonriki Groundwater survey	Survey date: 27 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON11W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 336m rollalong	Roll along survey was attempted, data loss

Figure A8.14: *Survey line BON11.*



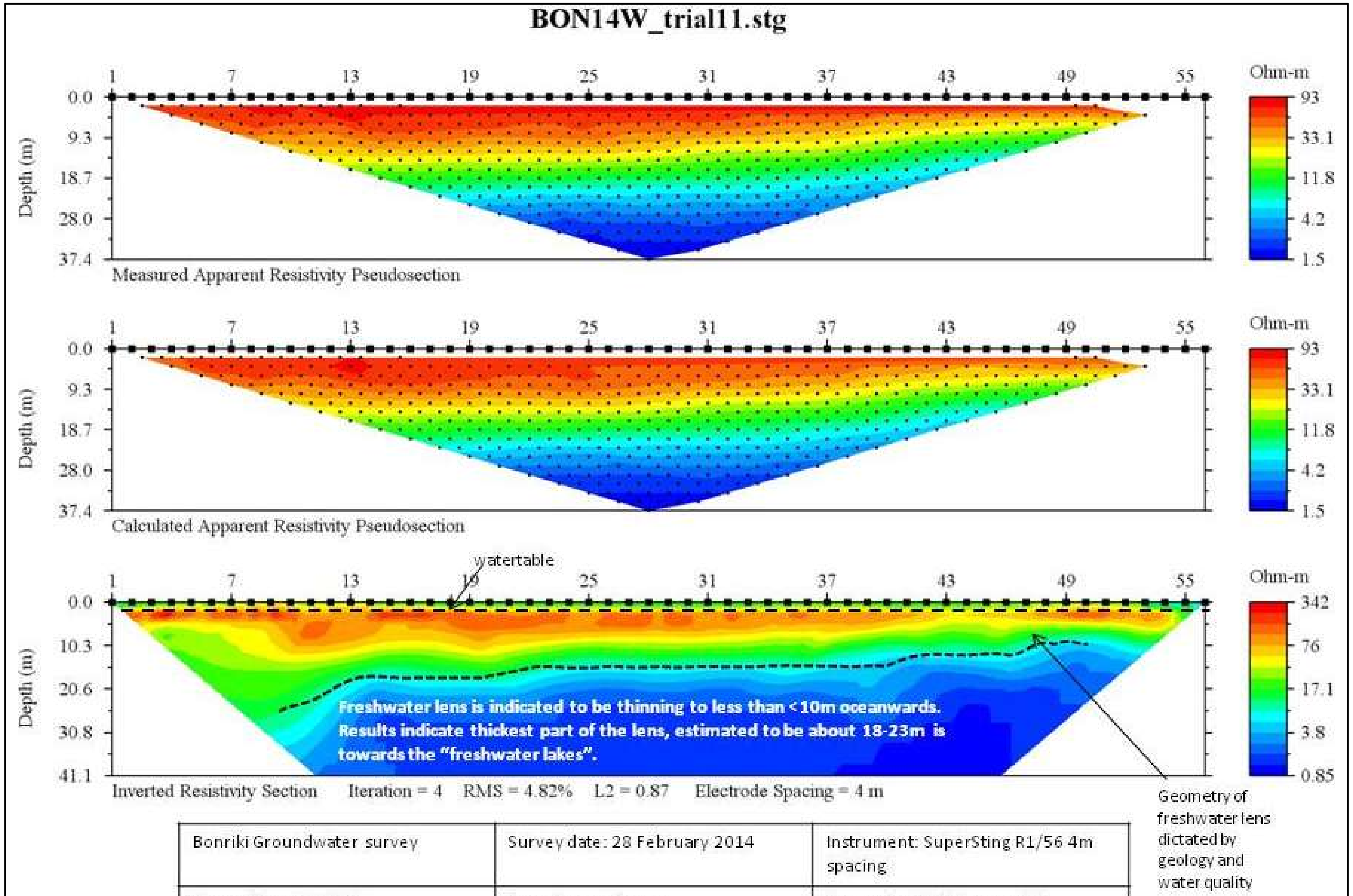
Bonriki Groundwater survey	Survey date: 28 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON12W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	Continuation of BON10

Figure A8.15: *Survey line BON12.*



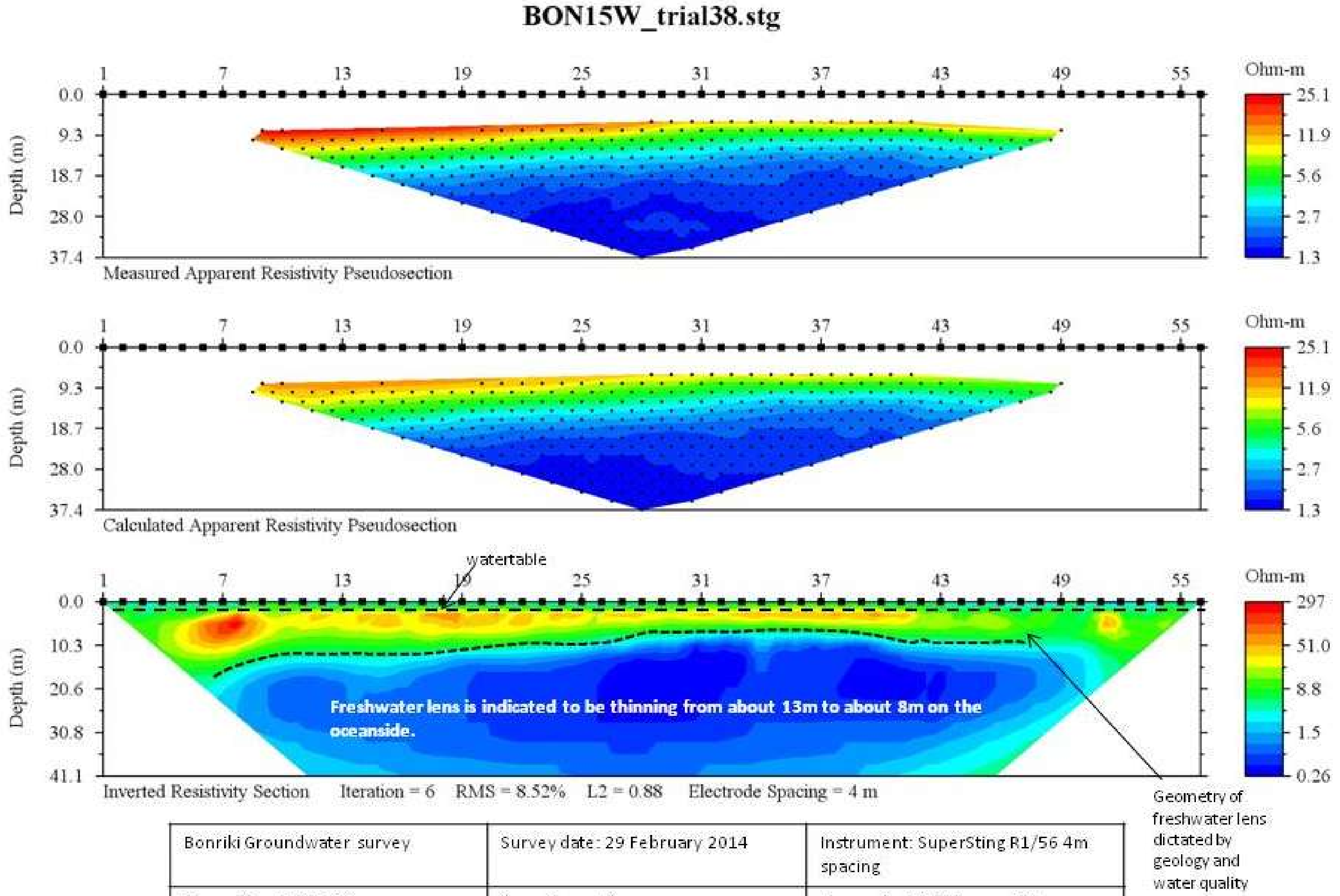
Bonriki Groundwater survey	Survey date: 28 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON13W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	

Figure A8.16: *Survey line BON13.*



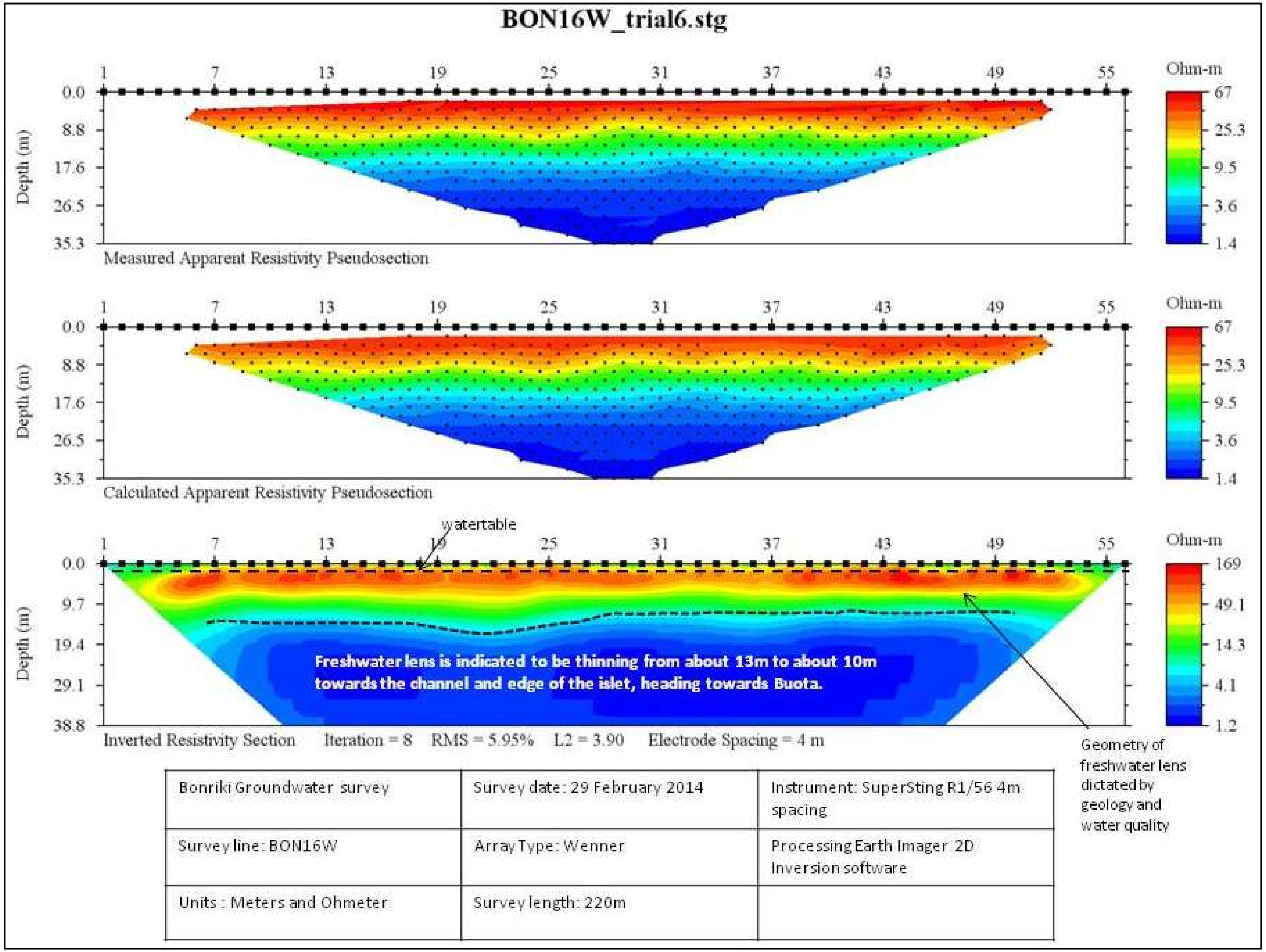
Bonriki Groundwater survey	Survey date: 28 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON14W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	

Figure A8.17: *Survey line BON14.*



Bonriki Groundwater survey	Survey date: 29 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON15W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	

Figure A8.18: *Survey line BON15.*



Bonriki Groundwater survey	Survey date: 29 February 2014	Instrument: SuperSting R1/56 4m spacing
Survey line: BON16W	Array Type: Wenner	Processing Earth Imager 2D Inversion software
Units : Meters and Ohmeter	Survey length: 220m	

Figure A8.19: *Survey line BON16.*

Annex 9. Flow meter testing, Bonriki

Flow meter testing, undertaken at Bonriki water reserve, December2014

This annex contains a description on the methodology and results of the geophysical flow meter testing work that was undertaken by PUB staff, between 17 and 21 December 2014.

Methodology

In consultation with PUB staff and KAPII consultant, Chris Grummitt, the following was provided as a guiding methodology for the testing. The objective was to undertake a review of the main meter at Bonriki and the individual meters on the Bonriki pumping stations using the two new ultrasonic meters provided by Posh and Partners Consulting Engineers under the Leak detection and reduction Program D-2.

Suggested procedure

1. Install an ultrasonic flow meter on the outflow side of the master meter at the treatment plant; record values (photographs) at the start of each day and at the end of each day; leave ultrasonic flow installed on main line for the duration of testing.
2. Record the storage level in the 400 Kl tank at the start of each day and at the end of each day; water level relative to a measuring point at top of tank.
3. Attach a second ultrasonic meter to the individual gallery pumps on the inflow side of the gallery meter for a period of one hour; manually record the power consumption (Ampere), and take a salinity reading of the gallery during the test. Record the flow meter reading and the ultrasonic meter reading at the start and end of the testing period (photographs). This provides information on the accuracy of the meter and the contribution of the gallery pump to the overall flow into the system. Undertake this activity for all 22 gallery pumps; if the pump is not working then this should be recorded, along with: the reason the pump is not working, and estimates for how long it has not been working and how long until it is re-commissioned. Taking a salinity reading would be useful.
4. In addition, attach the second ultrasonic meter to the main line coming from Buota into the treatment plant, just after the meter, for a minimum period of one hour; manually record the power consumption (Ampere), and take a salinity reading where possible. Record the flow meter reading and the ultrasonic meter reading at the start and end of the testing period (photographs).This will provide an estimate of the flow entering the treatment plant from Buota, which can then be subtracted from the master meter at the treatment plant to indicate the contribution from Bonriki and Buota.

__Table A9.1:__ Results of the flow meter testing.

Date	Meter name	Recorded hours fixed flow meters hh:mm	Discharge recorded by fixed flow meter m^3	L/s	Recorded hours ultrasonic meter hh:mm	Discharge recorded by ultrasonic meterm^3	L/s	% difference in discharge between fixed flow meter and ultrasonic meter	Instantaneous flow rate L/s fixed flow meter	EC at gallery uS/cm Dec 2014
21/12/2014	1								0.00	0
17/12/2014	2								0.00	0
17/12/2014	3	1:00	6	1.67	1:04	4.065	1.06	32%	1.89	590
21/12/2014	4	1:00	5	1.39	1:00	4.608	1.28	8%	1.11	960
17/12/2014	5	1:00	5	1.39	1:00	3.704	1.03	26%	1.41	1000
21/12/2014	6								0.00	0
21/12/2014	7								0.00	1040
17/12/2014	8	0:52	5	1.60	1:00	3.688	1.02	26%	1.67	0
20/12/2014	9	1:00	4	1.11	1:00	3.274	0.91	18%	1.01	850
20/12/2014	10	1:00	2	0.56	1:00	2.31	0.64	-16%	0.56	1160
20/12/2014	11	1:00	5	1.39	1:00	4.556	1.27	9%	1.54	710
21/12/2014	12								0.00	0
21/12/2014	13	1:00	2	0.56	1:00	2.403	0.67	-20%	0.68	680
18/12/2014	14	1:00	5	1.39	1:00	4.172	1.16	17%	1.39	760
17/12/2014	15	1:00	1	0.28	1:00	1.638	0.46	-64%	1.61	640
21/12/2014	16	1:00	1	0.28	1:00	2.856	0.79	-186%	0.67	420
18/12/2014	17	1:00	2	0.56	1:00	1.445	0.40	28%	0.54	700
20/12/2014	18	1:00	4	1.11	1:00	2.467	0.69	38%	1.25	1520
17/12/2014	19	1:00	4	1.11	0:59	2.822	0.80	29%	1.11	950
18/12/2014	20	1:00	4	1.11	1:00	2.354	0.65	41%	0.98	460
18/12/2014	21	1:00	2	0.56	1:00	2.149	0.60	-7%	0.76	520
18/12/2014	22	1:00	5	1.39	1:00	3.793	1.05	24%	1.28	1170
17/12/2014	WTP	8:25	720	23.76	8:15	604.588	20.36	16%	NA	
18/12/2014	WTP	8:57	765	23.74	8:53	645.291	20.18	16%	NA	
20/12/2014	WTP	6:10	559	25.18	6:11	445.903	20.03	20%	NA	
21/12/2014	WTP	5:30	46*	2.32	5:30	389.422	19.67		NA	

WTP = Main meter at Bonriki water treatment plant. *Error in recorded meter reading by PUB staff, resulting in erroneous recorded flow.

Comments and recommendations on the methodology, and results from the assessment of flow meters, Bonriki water reserve conducted between 17–21 Dec 2014.

Email correspondence from Tony Falkland 21/1/2015

Regarding ultrasonic flow meter (ufm) measurements v meter readings:

1. The suggested procedure for the flow measurement checks (refer your item 2, *outlined above*) sounds reasonable. It appears that not all of this may have been implemented.

2. The difference in combined flow from Bonriki and Buota galleries between main meter & ufm of 17% may seem high but the magnitude of the difference is really not too bad. However, the fact that the ufm gives lower flows on all 3 days (17, 18 & 20 December) than the main meter indicates it could be under-reading rather than the main meter over-reading. As discussed in previous emails, installed meters (like tend to under-read over time but not over-read). Reasons could be dome air entrainment in the pipe where ufm was installed, incorrect spacing of the sensors (based on wrong pipe dimensions and other parameters) – latter is unlikely if it was checked. Maybe you could get the assumed properties of the pipe (OD and wall thickness). Presumably “PVC” was keyed in as well as water temp, sensor temps. I have not used the type of ufm in Tarawa but have used a GE Panametrics PT878 (in Kiritimati) and O know there are quite a few parameters that need to be keyed in. So if these parameters could be supplied to you by Itienang, I could then check them if you wish.

3. To better assess the difference between the main meter and the ufm measurement, was the 2nd ufm meter used to assess what its flow was compared with the main meter and 1st ufm. If not, I suggest another test over one day between the main meter and both ufms strapped on the pipe in series about 10 m apart.

4. Regarding the main meter flow v ufm measurements, was the 2nd ufm installed for one hour flow test for pipeline from Buota – as per the 4th point of the suggested procedure (shown under item 2 of your email). If so, it does not seem to appear in the spreadsheet. Instead an “Estd Buota contribution” of 260 m3/day is shown in row 34 of sheet Summary. If the Buota pipe flow measurement was done, what was the result? If not done, I suggest it be redone, preferably over one day and with both ufms in series.

5. For the individual gallery meter flows compared with ufm measurements, you mention that the range of % differences is from +25% to -58% (+ve indicating meter flow is higher than ufm flow). The spreadsheet (Col J of sheet Summary) from Itienang seems to show an even greater range of +41% (gallery 20) to -186% (gallery 16). The comparisons would be slightly different is the instantaneous flows are used (i.e. time taken for 100 L to pass through meter as shown in sheet AmpsVolts). For gallery 16, the average flow over 1 hour is shown as 0.28 L/s (Col E) while the instantaneous flow is shown as 0.67 L/s (Col J). If the latter flow is used, the % difference between the meter and ufm flow (Col H) reduces significantly to -18%

6. Regarding point 3 above, the flow volumes shown in Col D for the gallery meters are only shown to the nearest 1 m3 (1,000L). This causes problems when the differences between the gallery meter flow and the ufm flows are small. Take the example of gallery 16 again. The recorded flow in one hour for the gallery meter is 1m3 while the ufm recorded 2.856m3. The 1m3 could be anywhere between 0.51 m3 and 1.49m3. Were these readings actually recorded to nearest litre or only to nearest m3? If to nearest m3, does the meter enable more accurate readings to be taken (i.e. to nearest litre). On this note, the meters on the gallery pumps should all be able to read to nearest litre. What type of meters are they. For future reference, I strongly recommend that Kent PSM or KSM meters (or Elster equivalents) be installed at the gallery pumps. These meters are robust, can be read to nearest litre and all numbers are on a single numeric barrel (unlike some meters with dials for the litres, 10 x litres and 100 x litres). The latter are much harder to read accurately – and may be the cause of the current readings to nearest m3 only.

7. No point showing % differences in Col J to 2 decimal places when the data in Col D is so inaccurate.

8. Based on the above, the accuracy of all the current differences and %differences in readings (Cols I and J) comes into question. I would recommend repeating this comparative exercise and this time:
   a. Read all gallery meters to nearest 1 litre

   b. Measure instantaneous flows (i.e. timing of 100 litres through the meter) at least twice – one at start of the hour long comparative test and one at the end).

   c. As well as comparing the average flows between gallery meters and ufm readings, also look at the ratios of the metered flows to see how well the one hour average flow rates compare with the instantaneous flow rates through the gallery meters.

9. Once the additional flow measurements are done (including (a) main meter v 2 x ufms over one day, Buota pipeline measurement – again with two ufms) and at the galleries, the new data should be checked and analysed and then compared with the current data.

10. If flow measurements still show major differences between the main meter and the ufms, then I strongly recommend that a new main meter be purchased and installed. The current one (I think) has been there since the AusAID funded Tarawa Water Supply project installed it in the mid 1980s. 30 years of service is enough. Time to retire it in any case. If possible the new main meter should be installed temporarily in a new part of the pipe downstream of the current main meter to check the flow in both meters against each other (as well as the two ufms). Then the new main meter can be installed in its permanent location (probably where the current main meter is located) and the temporary "cut-in" repaired with a short length of PVC pipe and two repair couplings. However, before deciding on the exact location of the new main meter, the piping arrangement should be checked. There should be a length of straight pipe equivalent to 10 x pipe diameters upstream of the meter to the nearest fitting (e.g. elbow) and 5 x pipe diameters downstream. I have forgotten what the diameter of the outlet pipe is but I think it is nominal 225mm PVC pipe. Hence the straight length upstream should be about 2.3m and the straight pipe downstream should be about 1.2m. This may mean installing the new meter in a different location.

11. As mentioned above (item A5), I would not be assuming that that the lower flow measurements from the ufm are necessarily more accurate than the main meter for total Bonriki and Buota outflow. I think items B9 and B10 above should proceed before any final decisions are made about which is the most accurate At this stage, I would continue to use the main meter flows as correct.

    I hope the above is useful.

Annex 10. Diver loggers, Bonriki

Summary of the survey data from 'diver' loggers installed in piezometers in Bonriki water reserve

This annex contains the plots of the 'diver' loggers that were installed for periods ranging from three to six months in piezometers within the Bonriki water reserve.

The survey was undertaken by surveying staff of the Geoscience Division of the Secretariat of the Pacific Community, and staff from the Ministry of Fisheries and Mineral Resources Development, between Nov 2013 and June 2014.

Figure A10.1: *Location of the 10 CTD divers (divers denoted in green installed Nov 2013–March 2014; divers denoted in red installed Nov 2013–June 2014). The barometer diver was located in BN26.*

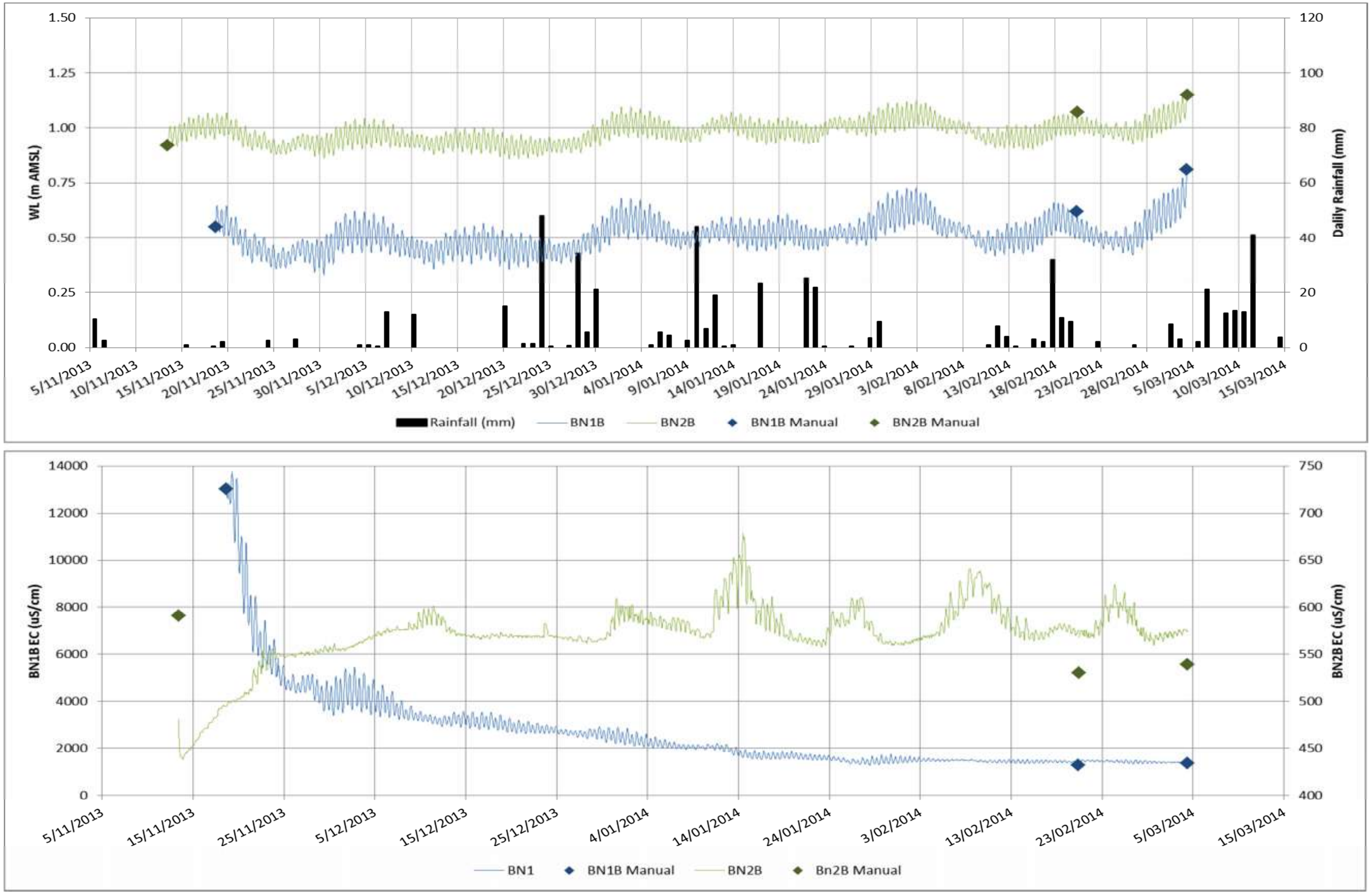


Figure A10.2: *CTD divers data and manual recorded data in monitoring locations BN1B and BN2B (Nov 2013–March 2014).*

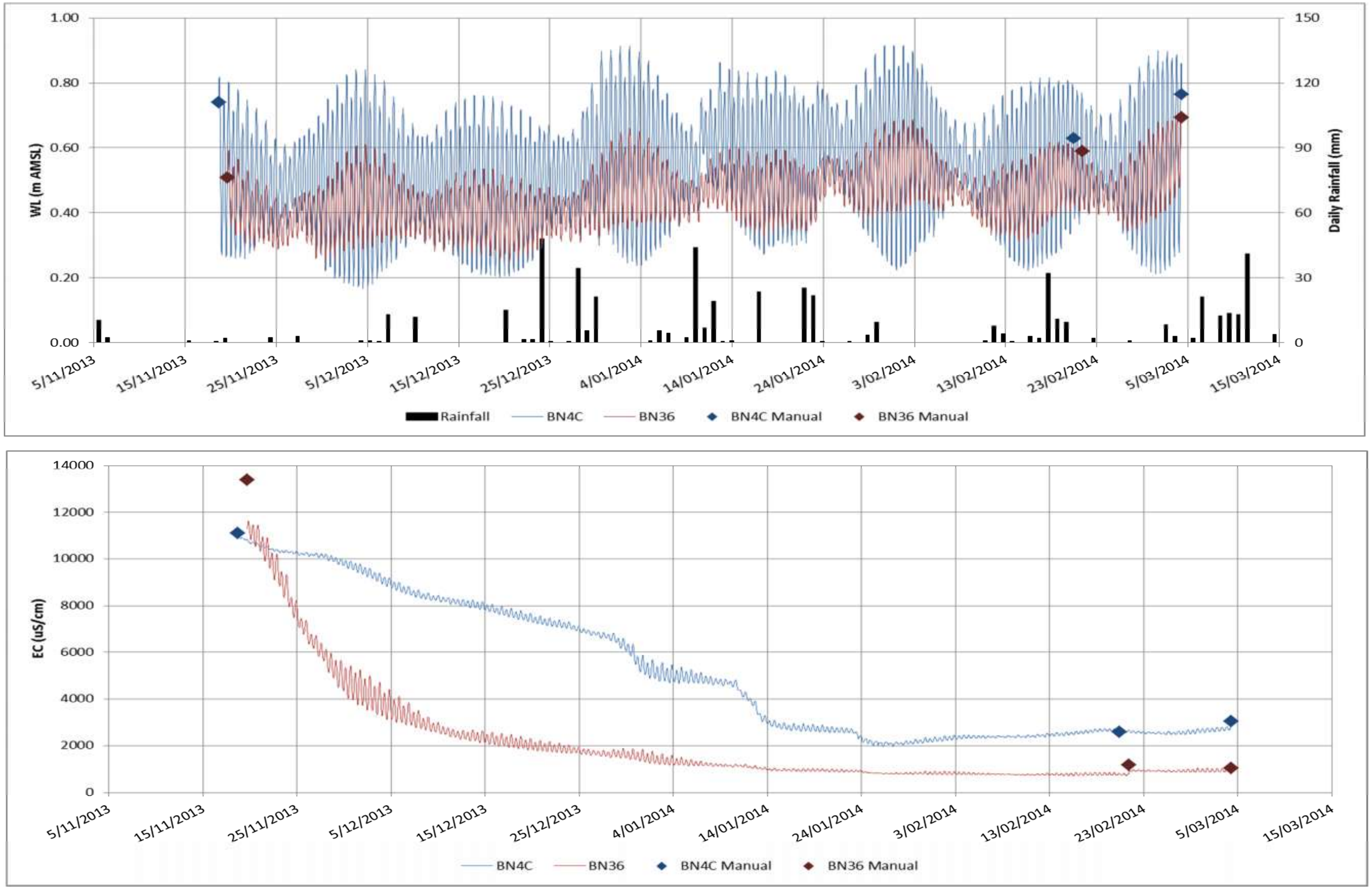


Figure A10.3: *CTD divers data and manual recorded data in monitoring locations BN4C and BN36 (Nov 2013–March 2014).*

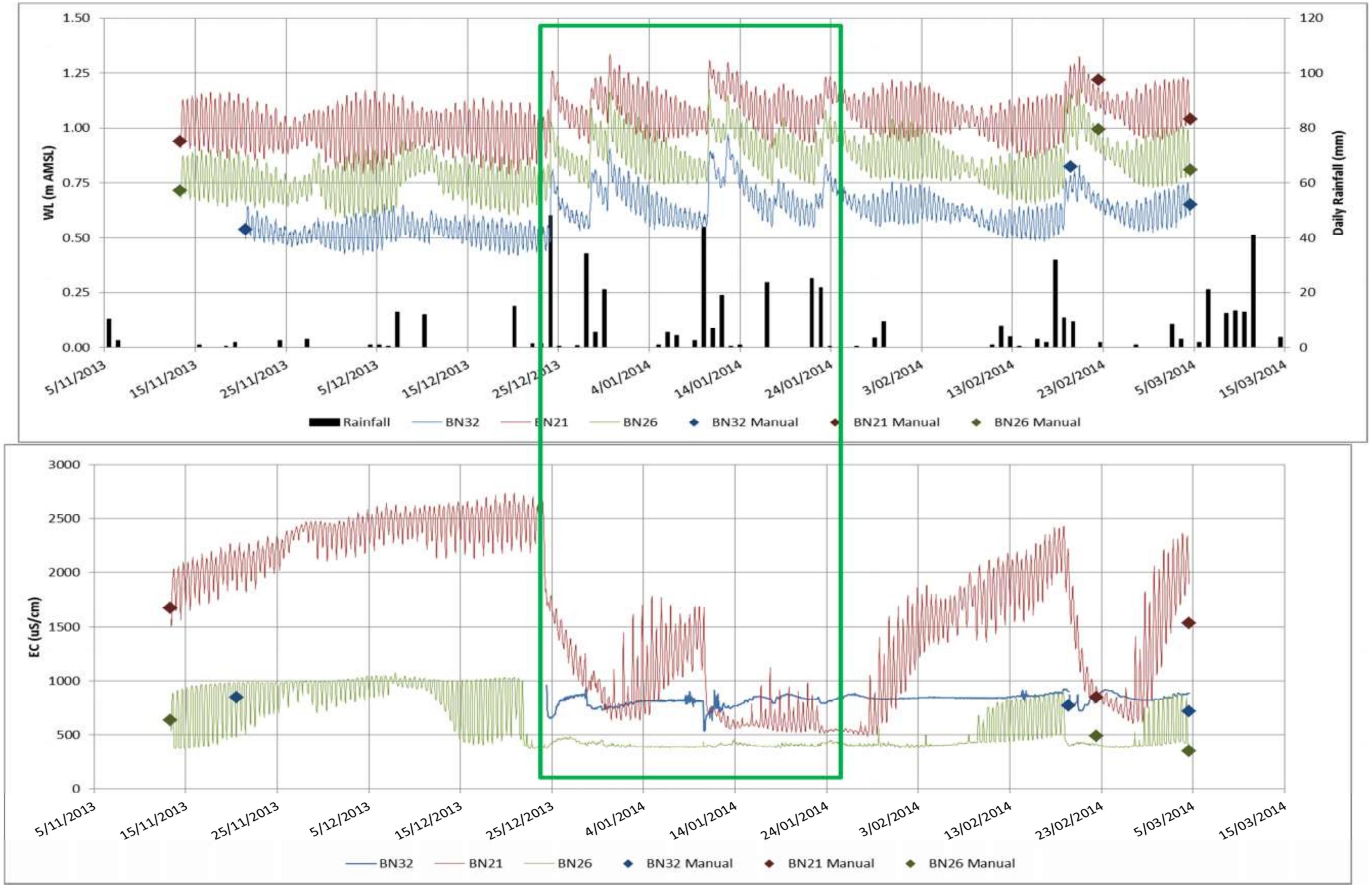


Figure A10.4: *CTD divers data and manual recorded data in monitoring locations BN32 and BN26 (Nov 2013–March 2014).*

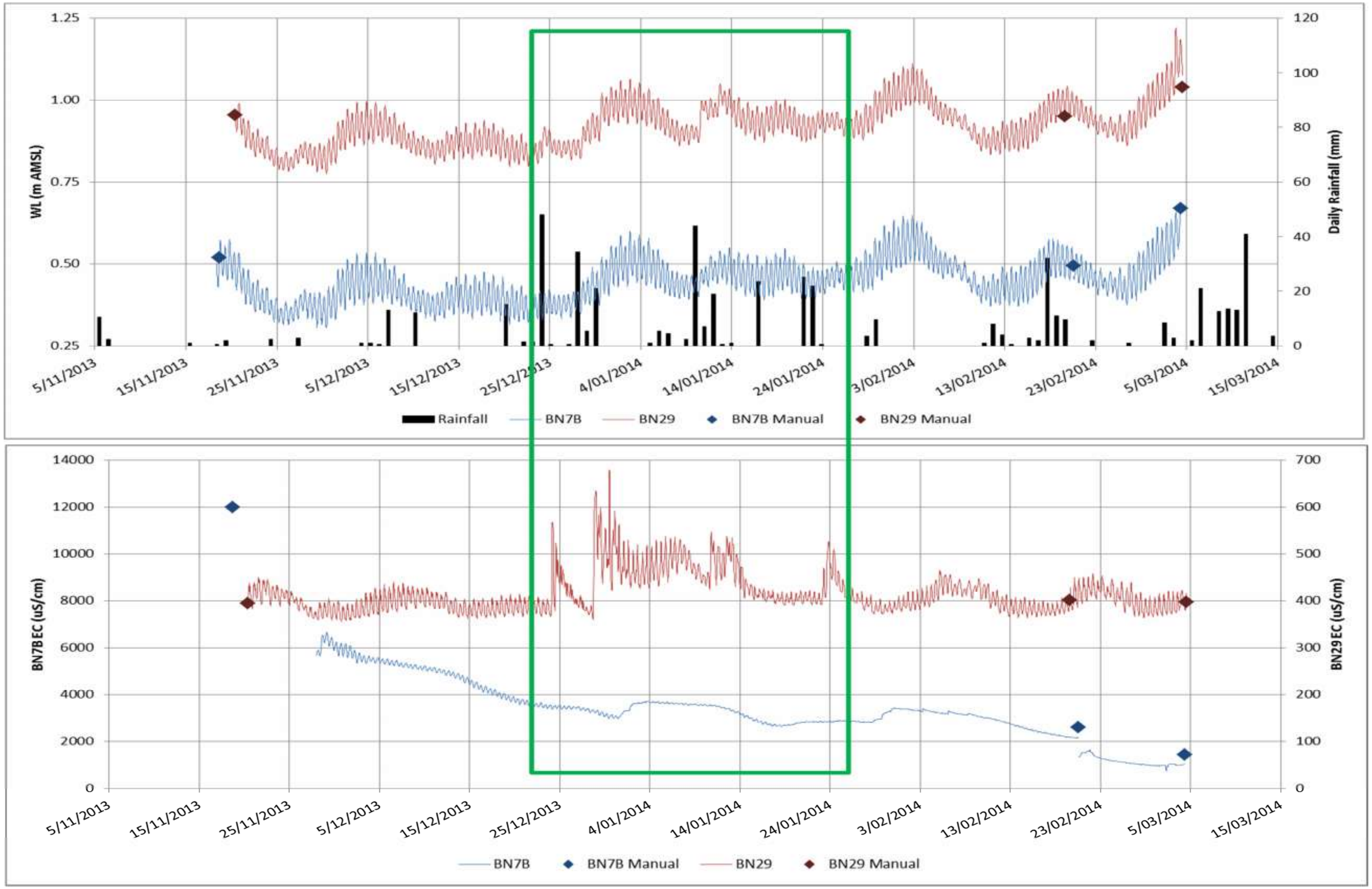


Figure A10.5: *CTD divers data and manual recorded data in monitoring locations BN7B and BN29 (Nov 2013–March 2014).*

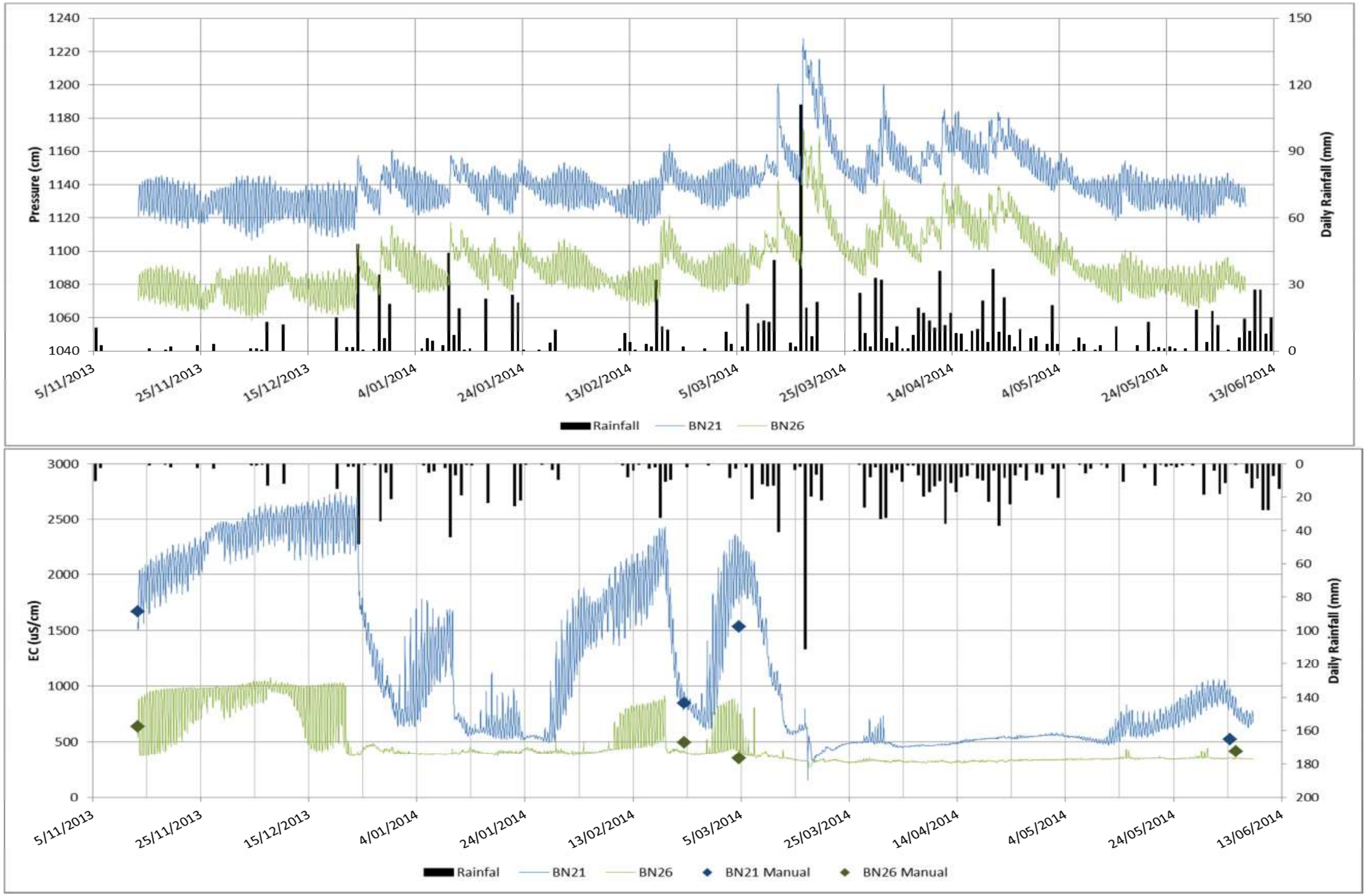


Figure A10.6: *CTD divers data and manual recorded data in monitoring locations BN21 and BN26 (Nov 2013–June 2014).*

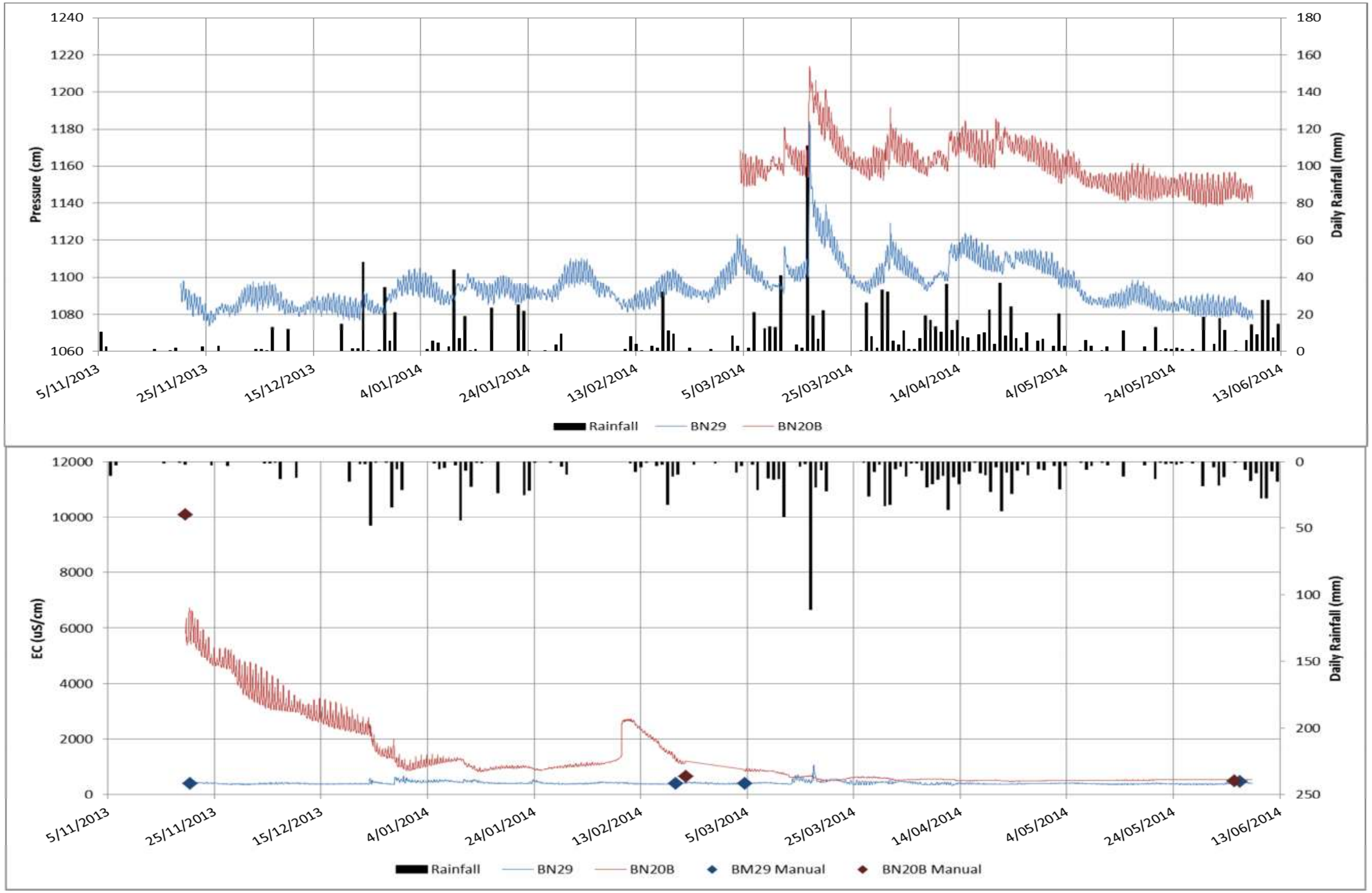


Figure A10.7: *CTD divers data and manual recorded data in monitoring locations BN29 and BN20B (Nov 2013–June 2014).*

Annex 11. EC-compact plate sampling procedures

This annex contains the results of the bacteriological sampling undertaken at Bonriki water reserve, from November 2013 to February 2014.

The monitoring bore sampling was undertaken by Water and Sanitation Programme staff of the Geoscience Division of the Secretariat of the Pacific Community, and staff from the Ministry of Public Works and Utilities, throughout the duration of the project on a quarterly basis, commencing in April 2013.

Standard membrane filtration method

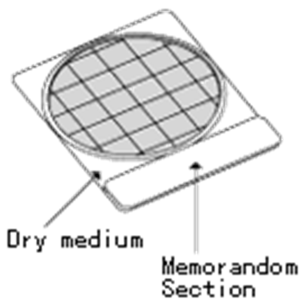
(Adapted from the US Environmental Protection Agency [EPA] and American Public Health Association methods [APHA] [EPA, 2000; APHA, 1995]).

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 at a temperature that is as cool as possible, and in the dark, but not in a freezer; for example, in a chilly bin or a bag with cool elements. Samples need to be processed within 12 hours of collection; ensure no melted water comes into contact with the sample.

Equipment:
The following are required for each 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 is necessary to filter; never more than 100 ml. If the water is heavily contaminated and more than 200 colonies is put on a 1 ml plate, the sample must be diluted, e.g. 1 in 10 ml, and then 1 ml of this needs to be filtered (or even 1 in 100 ml). The dilution must be added into the final calculation.

Procedure

1. **Field sampling procedure**

a. Rinse sample bailer three times with sample water before rinsing sample bottles.
b. Fill bottle with sampled water.
c. Label sample with water source details (e.g. W001 for well 1 and T001 for rainwater tank 1). Make sure that other relevant details, such as sample collection time, village name and well or tank owner's name, are also recorded.
d. Place sample bottle carefully in a cooler box and close the lid properly.
e. Samples should be analysed within 12 hours after 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. Rinse bottles thoroughly again in boiled water to clean and remove residual bleach.
d. Sanitise hands with soap before taking the bottles out and drying them using tissue paper.
e. Clean the storage container with bleach and boiled water prior to placing the sample bottles inside prior to the field visit.

3. **Lab sampling preparation**

<u>Set-up procedures</u>

a. Ensure there is enough boiled water, sterile water and bleach to conduct the entire 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 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 paper for drying/cleaning any sample water on the table.
h. Prepare a bucket or container for storing all unused sample water and wastewater.

<u>1 ml sample preparation</u>

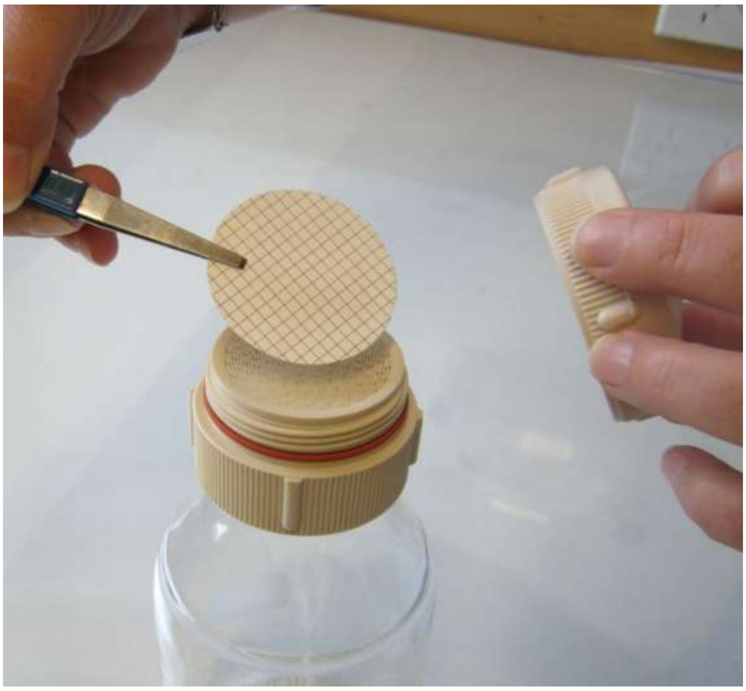
a. Label all 1 ml dry compact plates with sample details (e.g. sample number, team number, etc,).
b. Purge a 1 ml syringe with boiled water before filling and pouring 1 ml of sterile water onto the first plate for the 1 ml control.
c. Rinse the 1 ml syringe thoroughly with boiled water (three times) to clean it before filling it up with sterile water to cool it down.
d. Fill the 1 ml syringe with sample water and the 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 of the rehydrated 1 ml plates in a cooler box and record the incubation start time.

<u>50 ml sample preparation</u>

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 of sterile water prior to the placement of sample-rinsed filter papers (see below).

c. Purge a 1 ml syringe with boiled water before filling and pouring 1 ml of sterile water onto all labelled dry plates to rehydrate the agar.
d. Fill and rinse the 50 ml syringe with boiled water three 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 with sterile water and push water through the filter housing to cool both the syringe and the filter housing, and at the same time keep the filter housing sanitised.
f. Rinse the 50 ml syringe with the sampled water three times. These should be dumped in the wastewater bucket.
g. Sanitise the tweezers with 5% bleach and then sterile water. The latter is aimed at removing any residual bleach.
h. Take a filter paper using the sanitised tweezers, and place it on the filter housing. Place filter (grid side up) on the filter support and carefully close the housing tightly, ensuring 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 (two or three times) to remove any residual water from the filter housing.

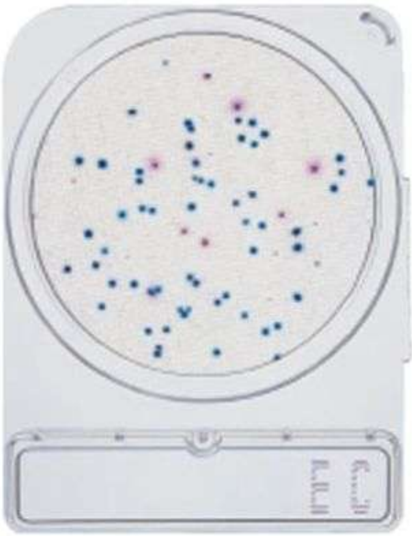
k. Use the sanitised tweezers to transfer the filter paper from the housing to the re-hydrated plate.
l. Repeat steps **d.** to **e.** until all samples have been prepared for 50 ml analysis.
m. For the control sample, use sterile water instead of sample water. Subsequently rinse the syringe and filter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

4. Post-sampling procedure

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

5. Counting Procedure

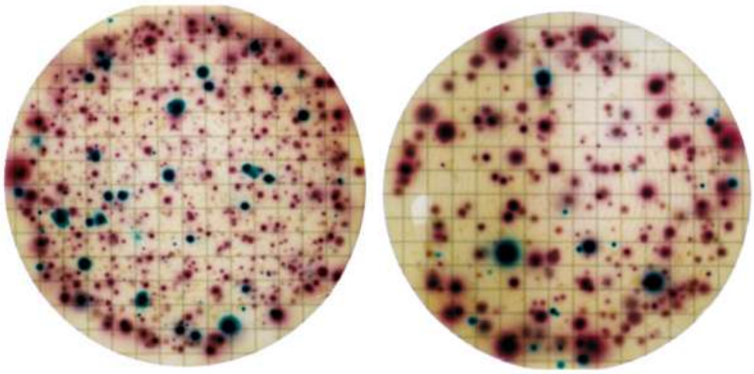
Compact Dry plates: Count the number of red and blue colonies.



The number of red and blue colonies = Total Coliforms

The number of blue colonies = *E. coli*

The filters on Compact Dry may look like the above photographs. As specified, 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 the plates that have between 20 to 200 colonies on them. If the count is too high to count, count 10 squares randomly on the filter, work out the average per square and multiply by 100 to obtain a count per filter. This is not an ideal way of counting but it will give an estimate from which you can decide what volume you should have filtered. Calculate all final numbers as bacteria per 100 ml. If you get no growth on 50 ml the result is <1 per 50 ml, and you will need to repeat the procedure 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 times with boiled water to remove any residual bleach. Then boil a large pot of water. Boil this for 10 minutes to kill any pathogens. Then place the syringes and filter housings in the pot and boil for a further 10 minutes. Turn off the heat 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 enough to burn skin, and place them in a clean plastic container or zip lock bag.

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; while still hot pour into a glass bottle that has been previously cleaned with 5% bleach and rinsed three times with boiling water. Let the water cool overnight and use the next day for the sample analysis.

6. Results

Table 1, below, illustrates the results of bacteriological sampling undertaken at Bonriki water reserve.

Table A101.1: *Bacteriological sampling results – Bonriki water reserve.*

EC compact dry sample			Coliform calculation					
Date: 12-20 / 11/2013								
Sample	**Village**	**Tank/Well owner**	**1 ml E.Coli**	**1ml T.Coliform**	**50ml E.Coli**	**50ml T.Coliform**	**E.coli count**	**Total Coliform count**
Bacteriological sampling – November 2013								
MPWU1	Betio	Rain water	0	200	8	TNTC	4	TNTC
MPWU2	Betio	Well water	0	5200	14	TNTC	7	TNTC
NO STANDARD			0	0	0	0	0	0
BN2B	Bonriki WR	PVC pipe	1400	2300	TNTC	TNTC	999	TNTC
BN11B	Bonriki WR	PVC pipe	0	TNTC	0	TNTC	0	TNTC
BN19 (1)	Bonriki WR	PVC pipe	0	6500	46	TNTC	23	TNTC
BN19 (2)	Bonriki WR	Tube 1 (6m)	0	100	0	18	0	59
BN19 (3)	Bonriki WR	Tube 4 (14.4m)	0	100	0	32	0	66
BN21 (1)	Bonriki WR	PVC pipe	3000	TNTC	TNTC	TNTC	999	TNTC
BN21 (2)	Bonriki WR	Tube 1 (6m)	0	1400	0	360	0	880
BN26	Bonriki WR	PVC pipe	0	200	0	408	0	304
BN27 (1)	Bonriki WR	PVC pipe	0	0	4	24	2	12
BN27 (2)	Bonriki WR	Tube 1 (6m)	0	1100	0	416	0	758
BN34	Bonriki WR	PVC pipe	0	1400	0	TNTC	0	TNTC
STANDARD			0	0	0	0	0	0
BN1	Bonriki WR	Tube 1 (6.4m)	0	TNTC	0	TNTC	0	TNTC
Tad's guest house water	Tad's	Rain water	0	0	0	14	0	7
Tad's guest house water	Tad's	Boiled water	0	200	0	TNTC	0	TNTC
STANDARD			0	0	0	0	0	0
BN7 (1)	Bonriki WR	Tube 1 (5.8m)	0	0	0	22	0	11
BN7 (2)	Bonriki WR	Tube 2 (8.8m)	0	0	2	52	1	26

EC compact dry sample			Coliform calculation					
Date: 12-20 / 11/2013								
Sample	**Village**	**Tank/Well owner**	**1 ml E.Coli**	**1ml T.Coliform**	**50ml E.Coli**	**50ml T.Coliform**	**E.coli count**	**Total Coliform count**
BN4C	Bonriki WR	PVC pipe	200	TNTC	360	TNTC	280	TNTC
STANDARD			0	0	0	0	0	0
BN13	Bonriki WR	Tube 1 (6.2m)	0	0	0	20	0	10
BN23B	Bonriki WR	PVC pipe	900	TNTC	TNTC	TNTC	999	TNTC
BN23 (1)	Bonriki WR	Tube 1 (6m)	0	0	0	22	0	11
BN23 (2)	Bonriki WR	Tube 2 (9m)	0	0	0	124	0	62
BN20B	Bonriki WR	PVC pipe	1400	TNTC	TNTC	TNTC	999	TNTC
BN20 (1)	Bonriki WR	Tube 1 (6m)	0	0	0	118	0	59
BN20 (1)	Bonriki WR	Tube 4 (15.2m)	0	0	0	14	0	7
BN24	Bonriki WR	PVC pipe	1100	TNTC	TNTC	TNTC	999	TNTC
BN28 (1)	Bonriki WR	PVC pipe	0	7000	54	TNTC	27	TNTC
BN28 (2)	Bonriki WR	Tube 1 (6m)	0	0	0	78	0	39
STANDARD			0	0	0	0	0	0
Bacteriological sampling – February 2014								
BN29 (1)	Bonriki WR	PVC pipe	0	1000	0	TNTC	0	TNTC
BN29 (2)	Bonriki WR	Tube 1 (6m)	0	0	0	TNTC	0	TNTC
BN25 (1)	Bonriki WR	PVC pipe	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC
BN25 (2)	Bonriki WR	Tube 1 (6m)	0	0	0	TNTC	0	TNTC
BN25 (3)	Bonriki WR	Tube 2 (9m)	0	0	0	TNTC	0	TNTC
BN32 (1)	Bonriki WR	PVC Pipe	800	TNTC	0	TNTC	400	TNTC
BN32 (2)	Bonriki WR	Tube 2 (9m)	0	0	0	TNTC	0	TNTC
BN32 (3)	Bonriki WR	Tube 3 (12m)	0	100	TNTC	TNTC	TNTC	TNTC
BN23 (1)	Bonriki WR	Tube 1 (6m)	0	800	0	TNTC	999	TNTC

EC compact dry sample			Coliform calculation					
Date: 12-20 / 11/2013								
Sample	Village	Tank/Well owner	1 ml E.Coli	1ml T.Coliform	50ml E.Coli	50ml T.Coliform	E.coli count	Total Coliform count
Tad's guest house water	Tad's	Rain water	0	0	0	TNTC	0	TNTC
STD			0	0	34	TNTC	17	TNTC
BN1 (1)	Bonriki WR	T1 (6m)	0	300	0	100	0	200
BN2B (1)	Bonriki WR	PVC pipe	0	1000	0	TNTC	0	TNTC
BN4C (1)	Bonriki WR	PVC pipe	0	5000	0	TNTC	0	TNTC
BN7B (1)	Bonriki WR	PVC pipe	0	1900	0	TNTC	0	TNTC
BN7 (1)	Bonriki WR	Tube 1 (5.8m)	0	0	0	34	0	17
BN7 (2)	Bonriki WR	Tube 2 (8.8m)	0	1500	0	TNTC	0	TNTC
BN13B (1)	Bonriki WR	PVC pipe	0	0	0	46	0	23
STD			0	0	0	0	0	0
BN11B (1)	Bonriki WR	PVC pipe	0	700	0	TNTC	0	TNTC
BN15B (1)	Bonriki WR	PVC pipe	0	600	0	0	0	300
BN19 (1)	Bonriki WR	PVC pipe	0	0	0	0	0	0
BN19 (2)	Bonriki WR	Tube 1 (6m)	0	0	0	2	0	1
BN19 (3)	Bonriki WR	Tube 3 (11m)	0	800	0	TNTC	0	TNTC
BN20B (1)	Bonriki WR	PVC pipe	0	0	0	28	999	14
BN20 (1)	Bonriki WR	Tube 1 (6m)	0	0	0	0	0	0
BN20 (2)	Bonriki WR	Tube 2 (8m)	0	0	0	2	0	1
BN24 (1)	Bonriki WR	PVC pipe	0	TNTC	0	TNTC	999	TNTC
BN34 (1)	Bonriki WR	PVC pipe	0	0	0	114	0	57
BN35 (1)	Bonriki WR	PVC pipe	0	0	0	48	0	24
BN36 (1)	Bonriki WR	PVC pipe	0	100	0	64	999	82

EC compact dry sample Date: 12-20 / 11/2013			Coliform calculation					
Sample	Village	Tank/Well owner	1 ml E.Coli	1ml T.Coliform	50ml E.Coli	50ml T.Coliform	E.coli count	Total Coliform count
STD			0	0	0	0	0	0
BN21 (1)	Bonriki WR	PVC pipe	0	400	0	TNTC	0	TNTC
BN21 (2)	Bonriki WR	Tube 1 (6m)	0	0	0	14	0	7
BN21 (3)	Bonriki WR	Tube2 (9m)	0	0	0	2	0	1
BN26 (1)	Bonriki WR	PVC pipe	0	100	0	44	0	72
BN27 (1)	Bonriki WR	PVC pipe	0	0	16	22	8	11
BN28 (1)	Bonriki WR	PVC pipe	0	1700	0	TNTC	0	TNTC
BN28 (2)	Bonriki WR	Tube 1 (6m)	0	1000	0	18	0	509
STD			0	0	2	2	1	1

Annex 12. Monitoring borehole salinity, Bonriki

Bonriki water reserve monitoring bore location

This annex contains the details and bore salinity results at Bonriki monitoring bores.

The survey was undertaken by Water and Sanitation Programme staff of the Geoscience Division of the Secretariat of the Pacific Community, and staff from the Ministry of Public Works and Utilities, during February 2014.

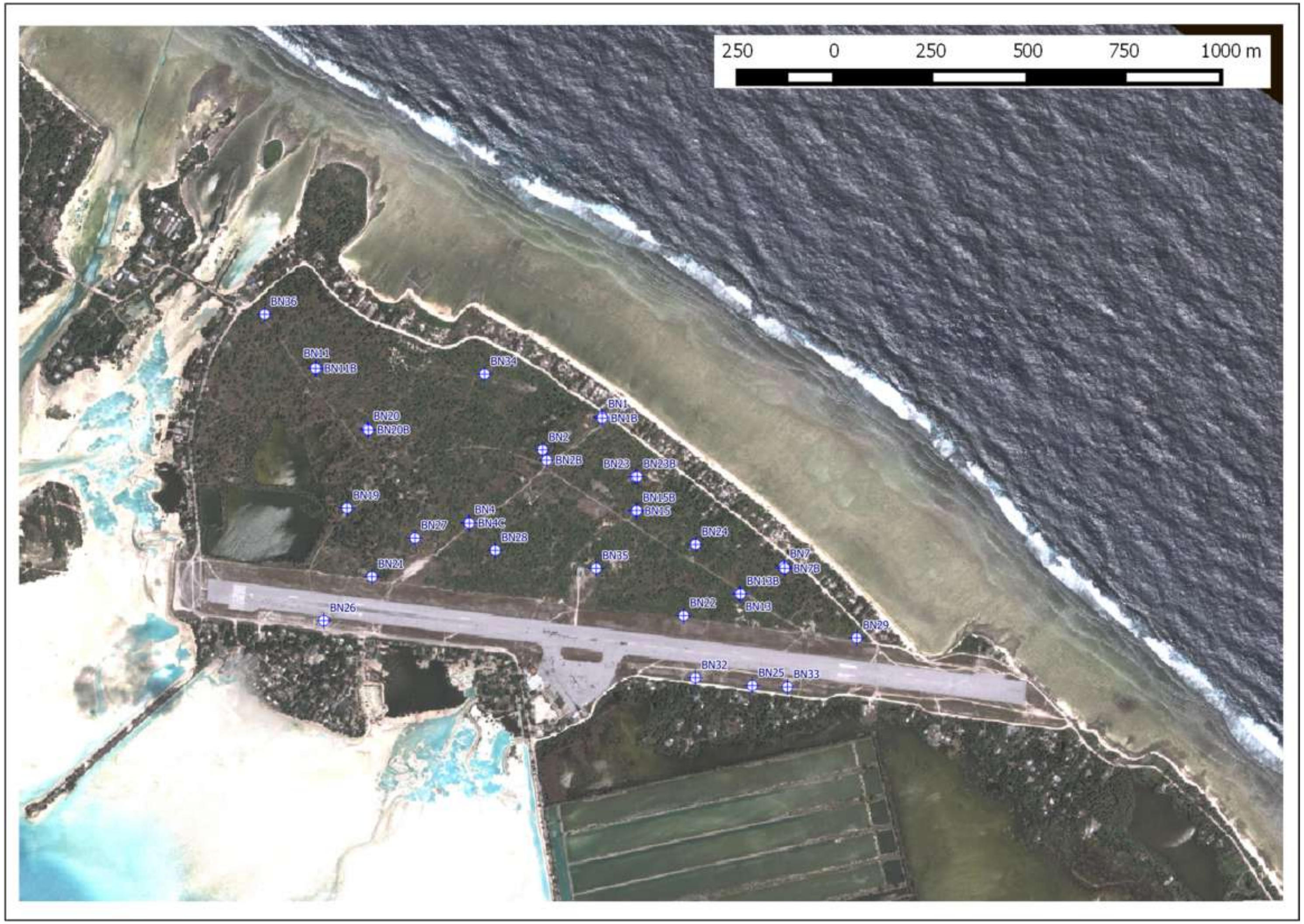


Figure A12.1: *Monitoring boreholes at Bonriki, Tarawa, Kiribati.*

BN1

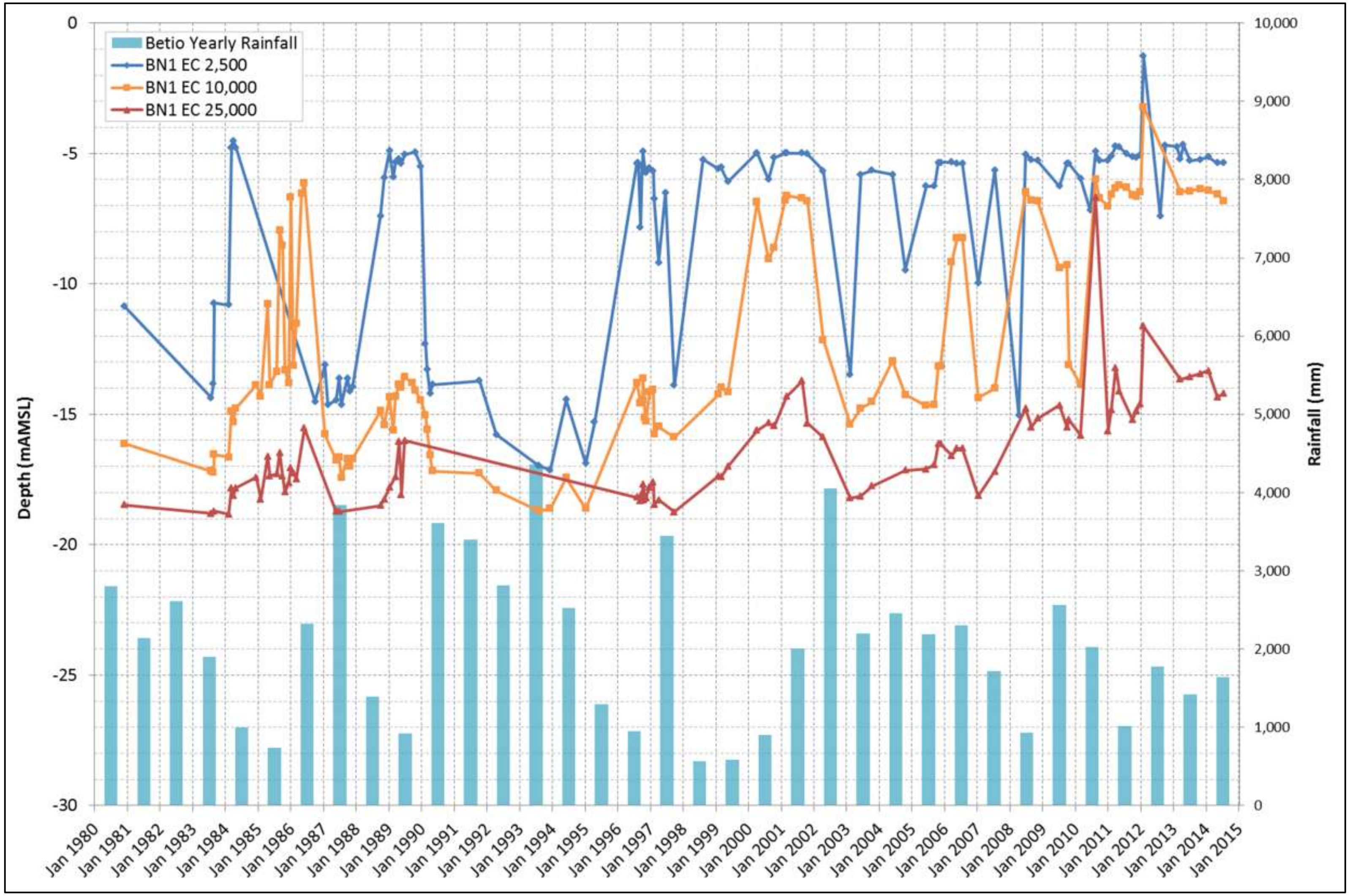


Figure A12.2: *Historical salinity variations at monitoring location BN1.*

BN2

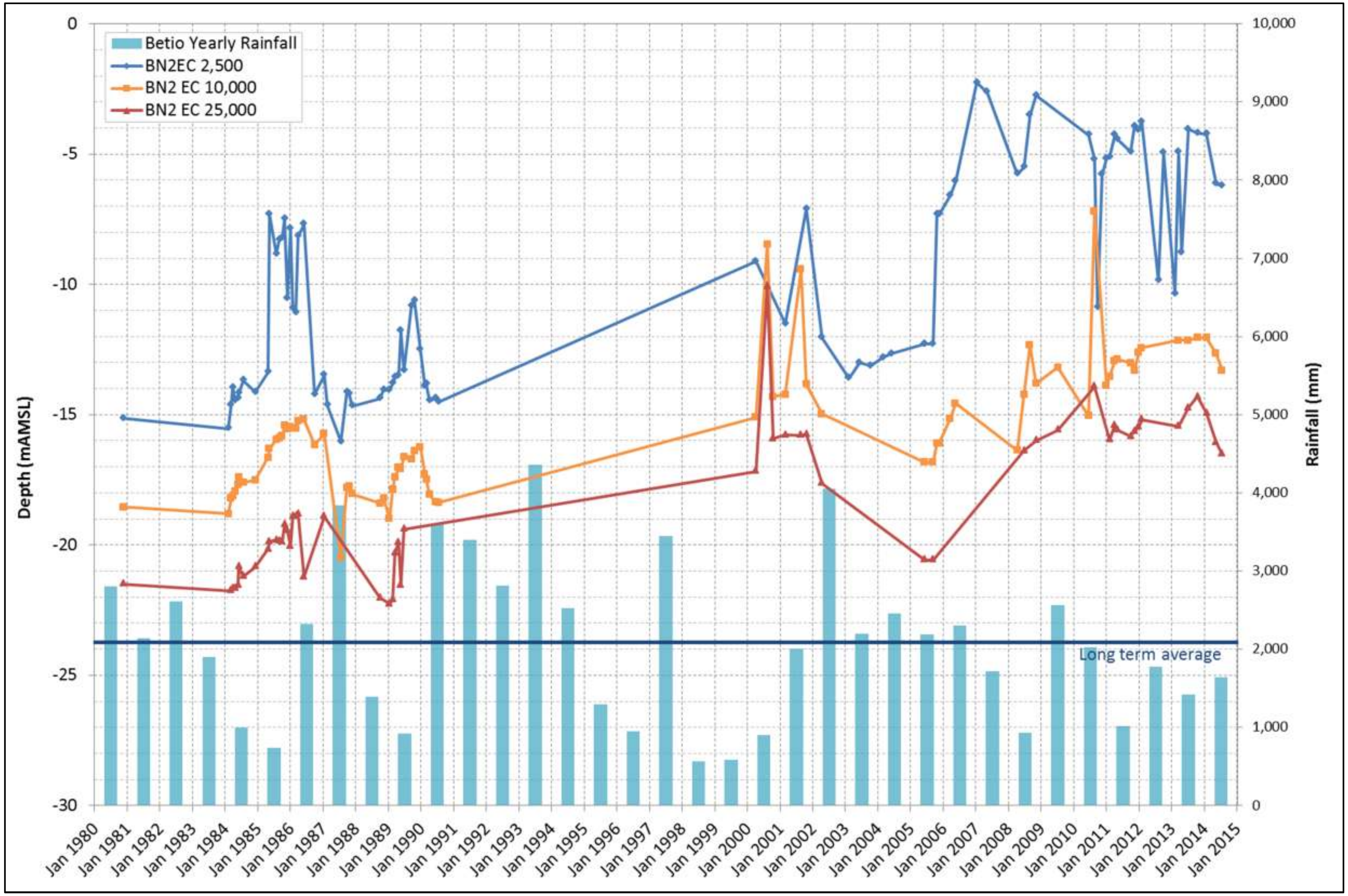


Figure A12.3: *Historical salinity variations at monitoring location BN2.*

BN4

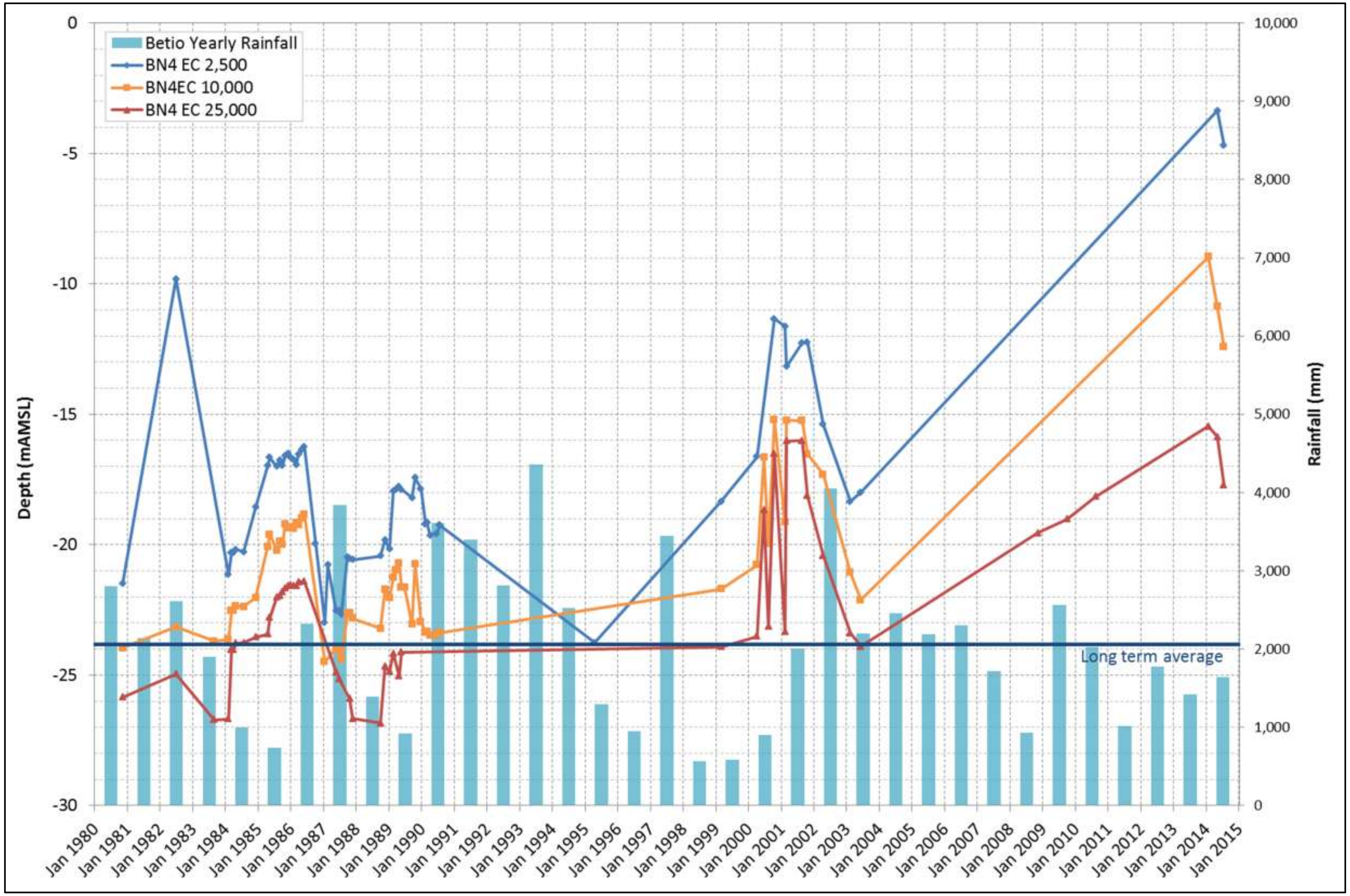


Figure A12.4: *Historical salinity variations at monitoring location BN4.*

BN11

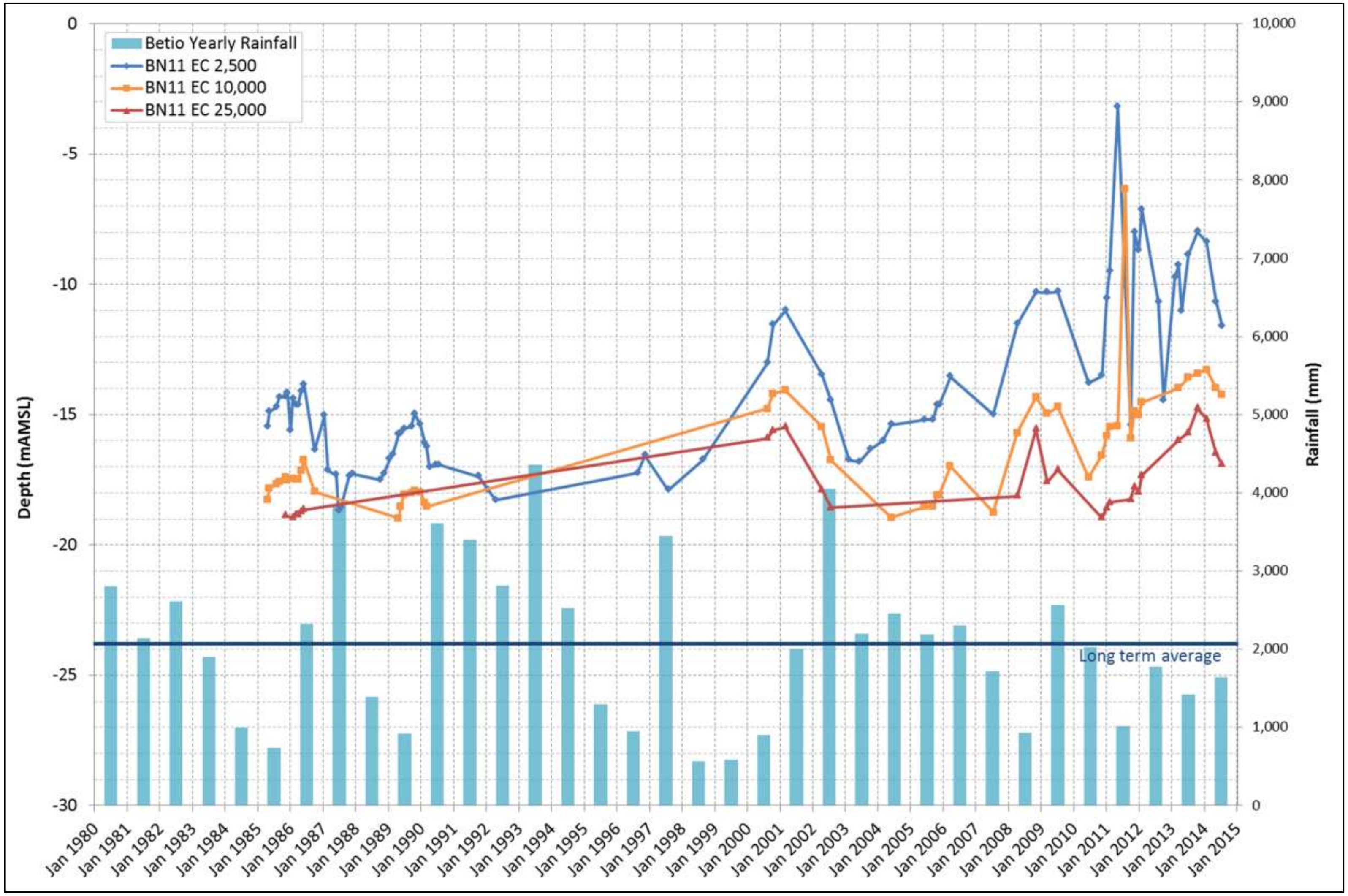


Figure A12.5: *Historical salinity variations at monitoring location BN11.*

BN7

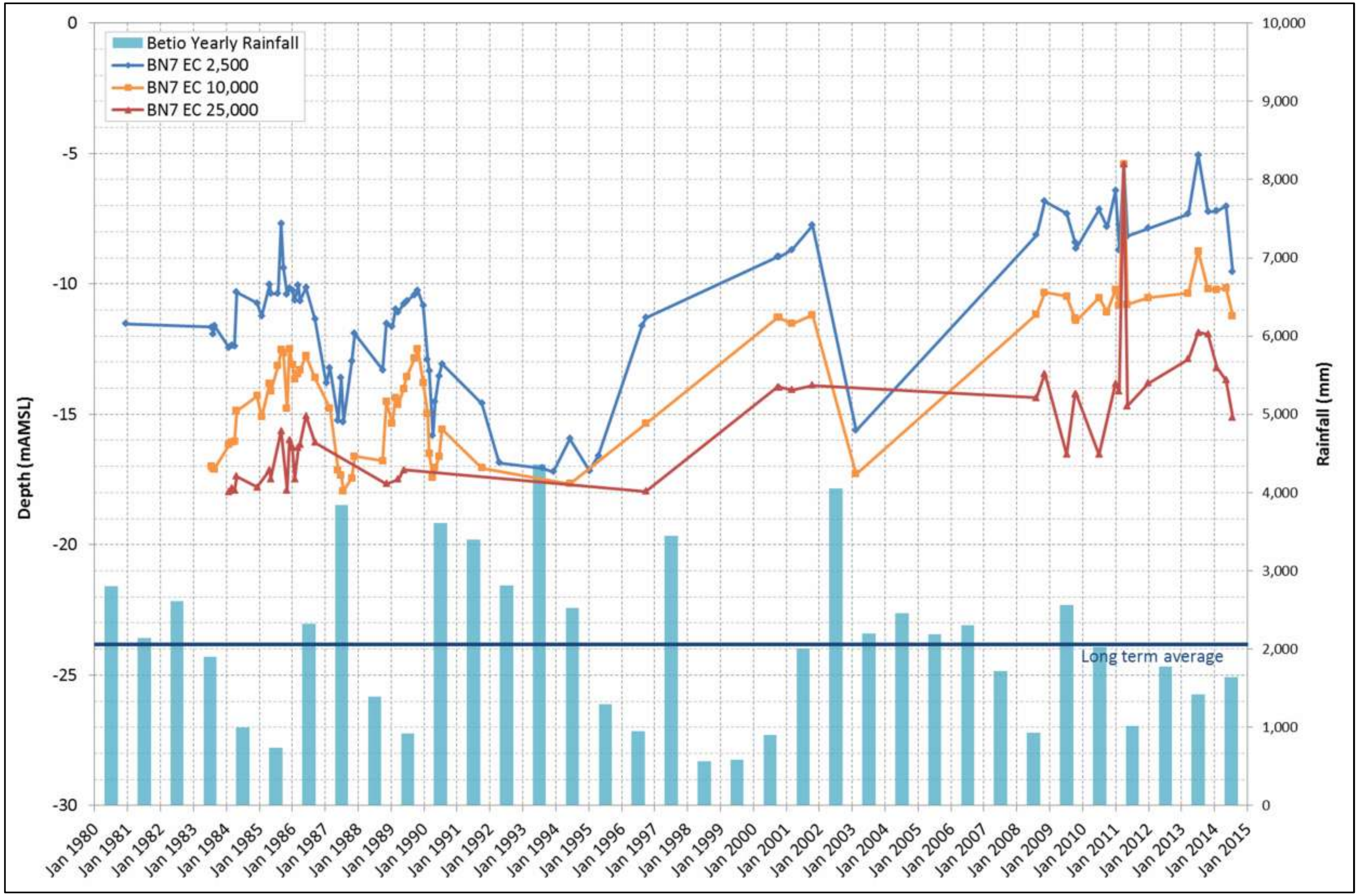


Figure A12.6: *Historical salinity variations at monitoring location BN7.*

BN15

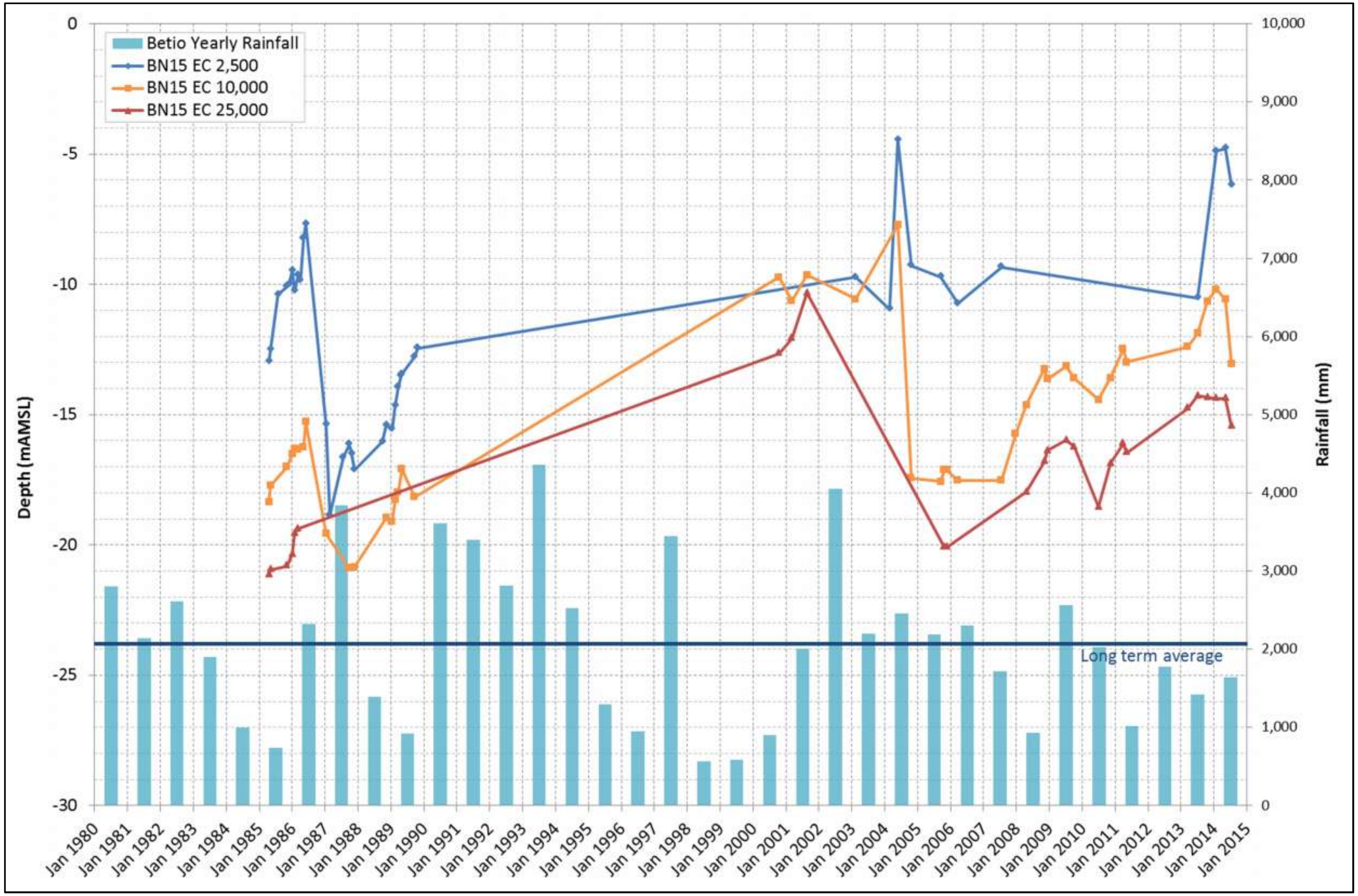


Figure A12.7: *Historical salinity variations at monitoring location BN15.*

BN13

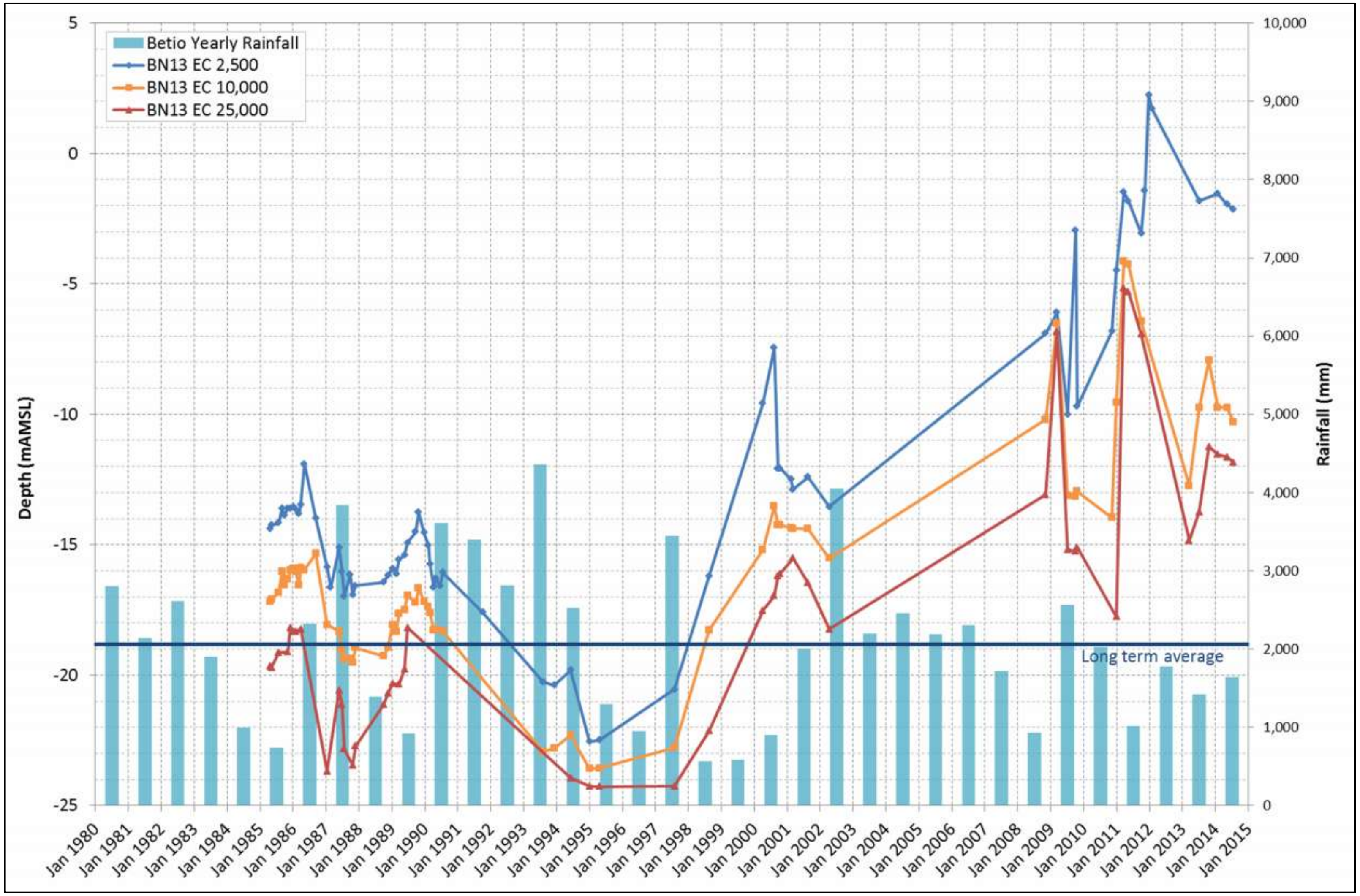


Figure A12.8: *Historical salinity variations at monitoring location BN13.*

BN1

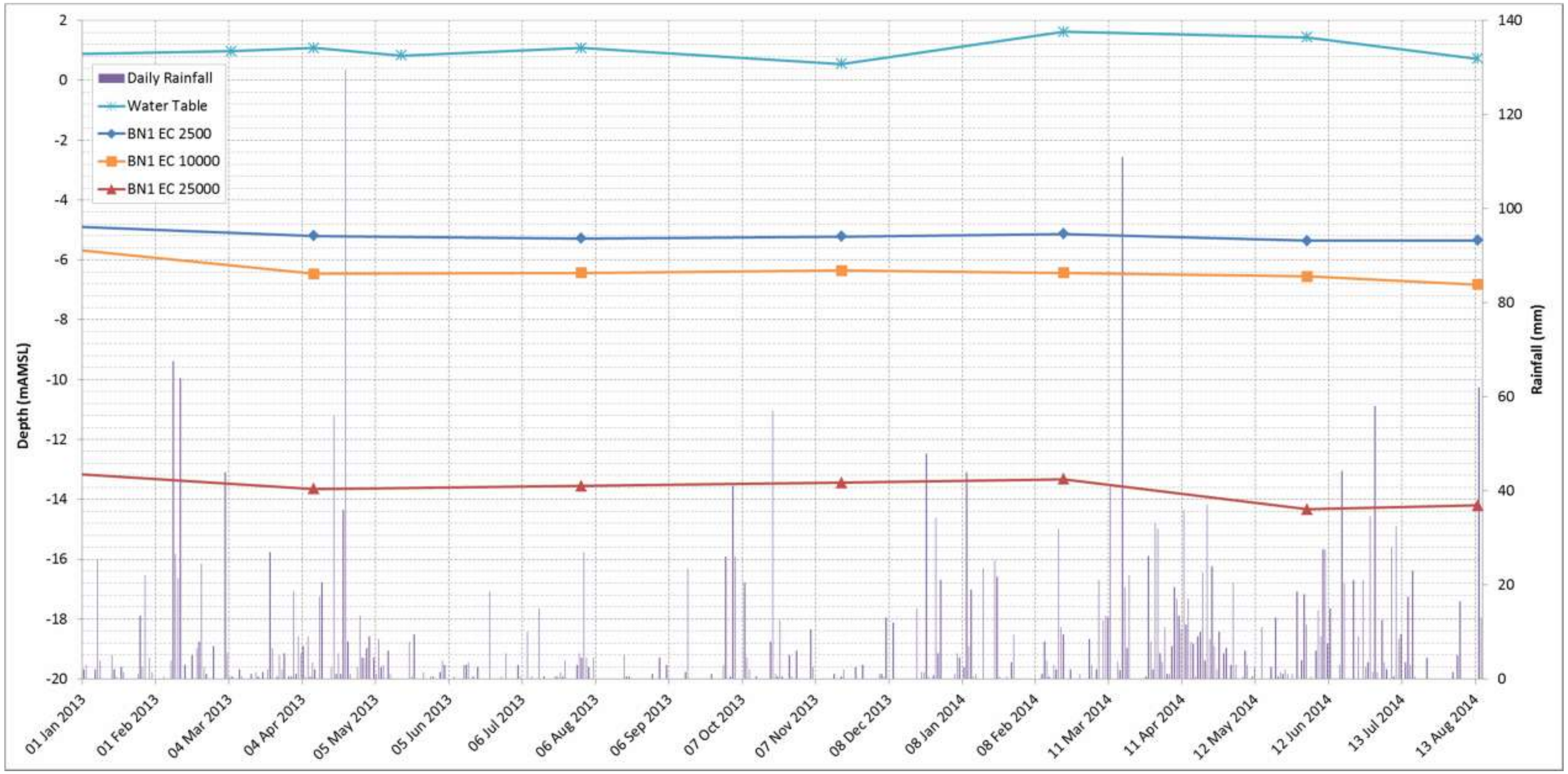


Figure A12.9: *Recent salinity variations at monitoring location BN1.*

BN11

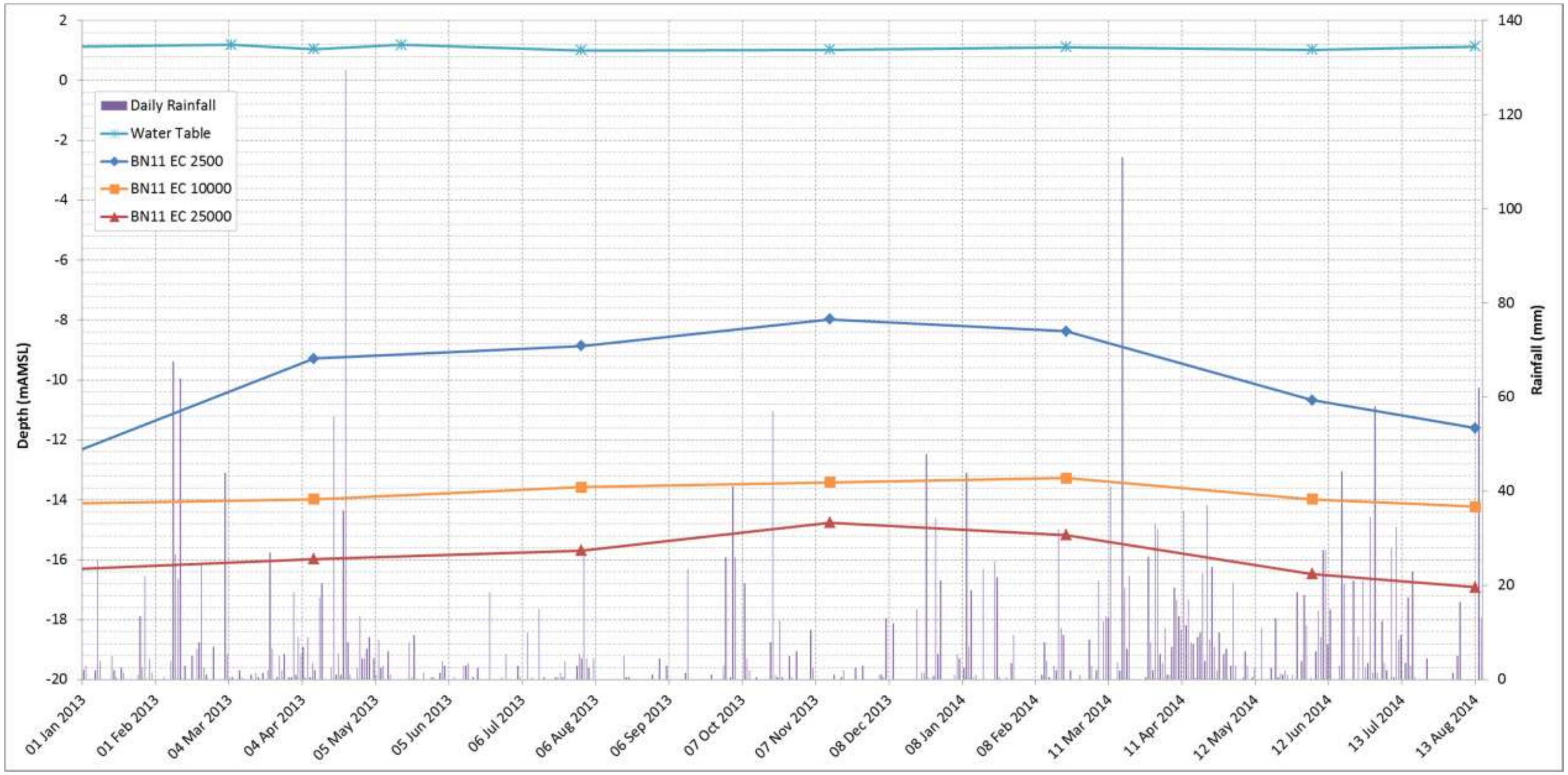


Figure A12.10: *Recent salinity variations at monitoring location BN11.*

BN13

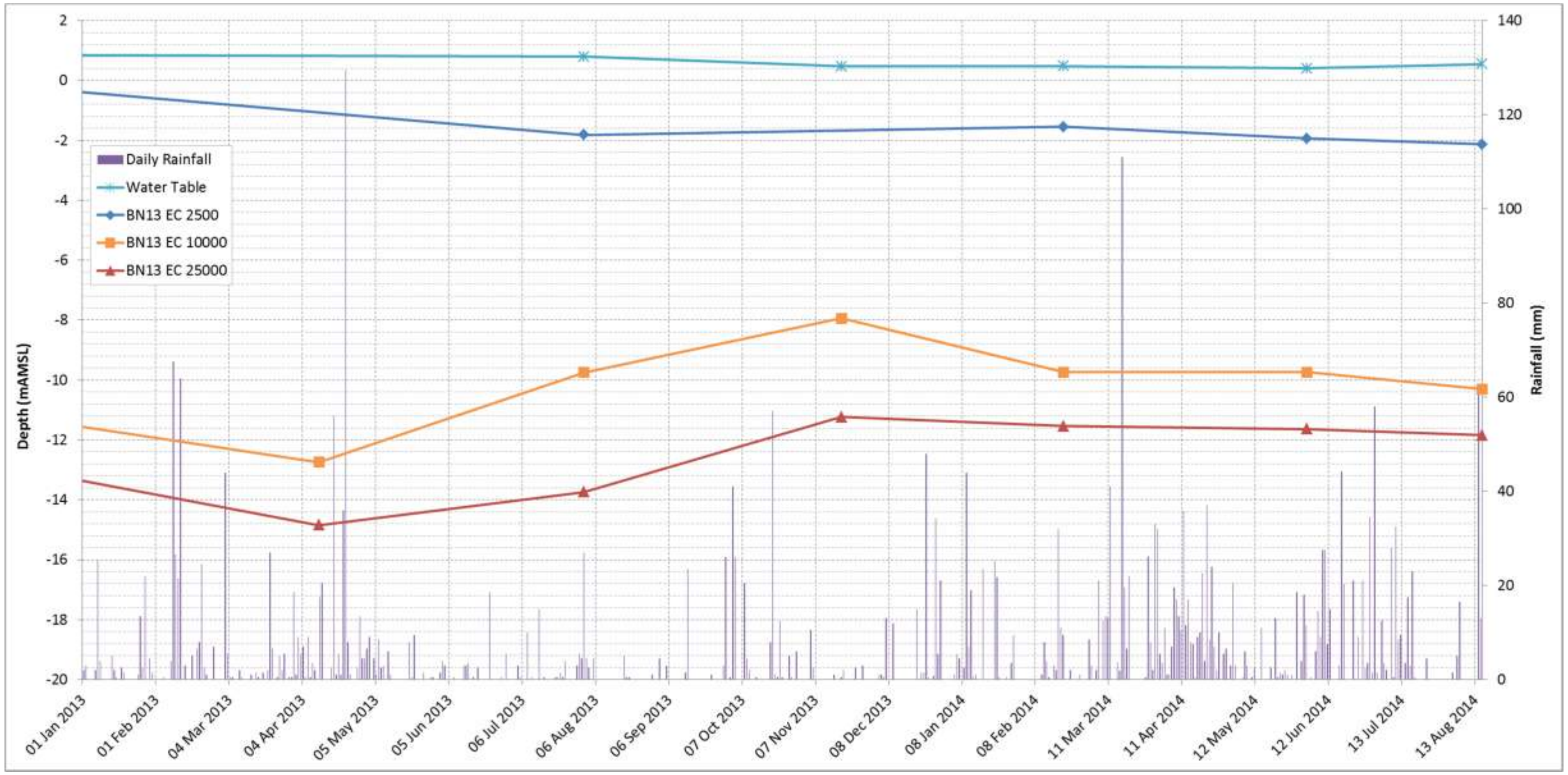


Figure A12.11: *Recent salinity variations at monitoring location BN13.*

BN15

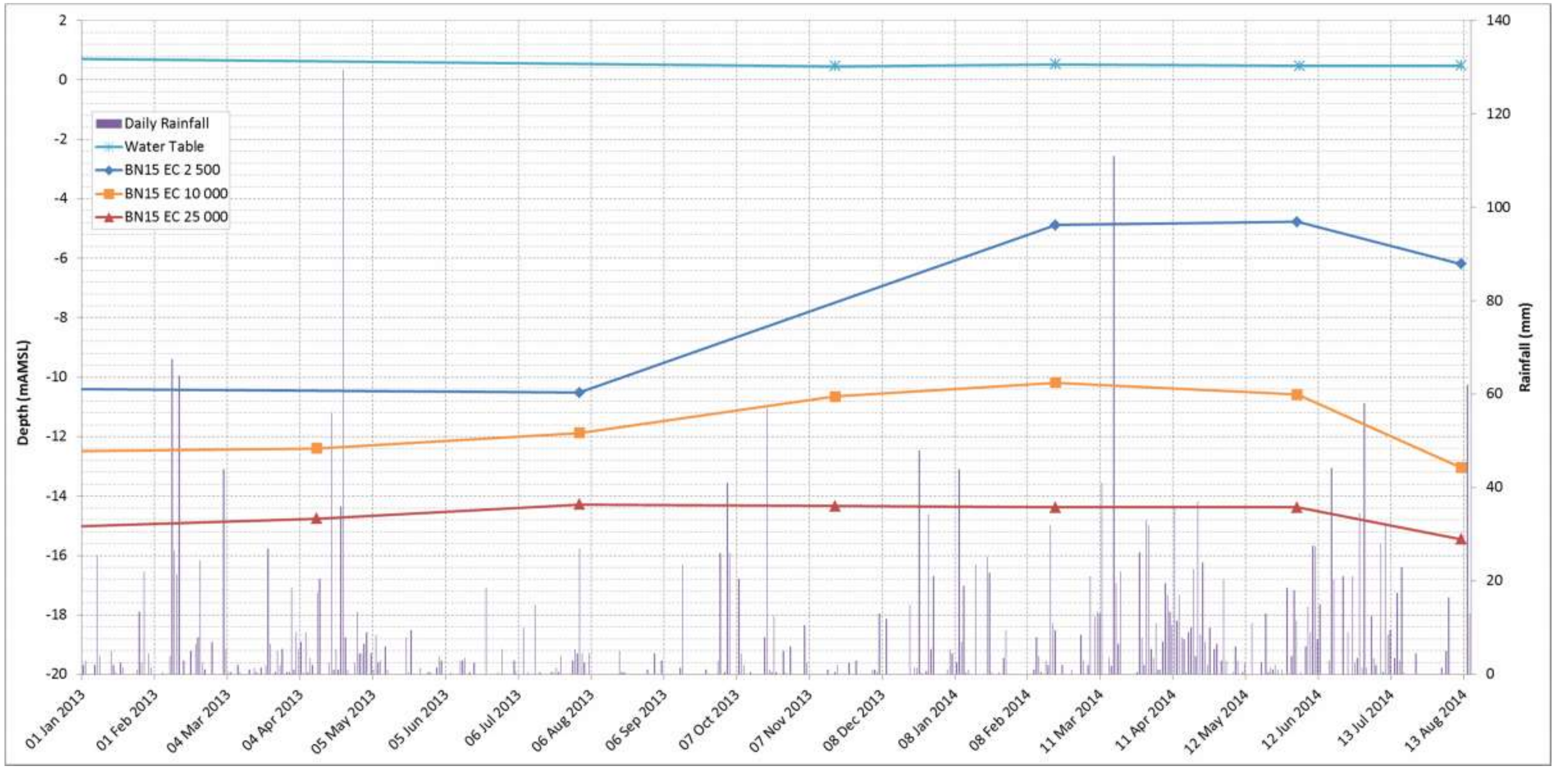


Figure A12.12: *Recent salinity variations at monitoring location BN15.*

BN27

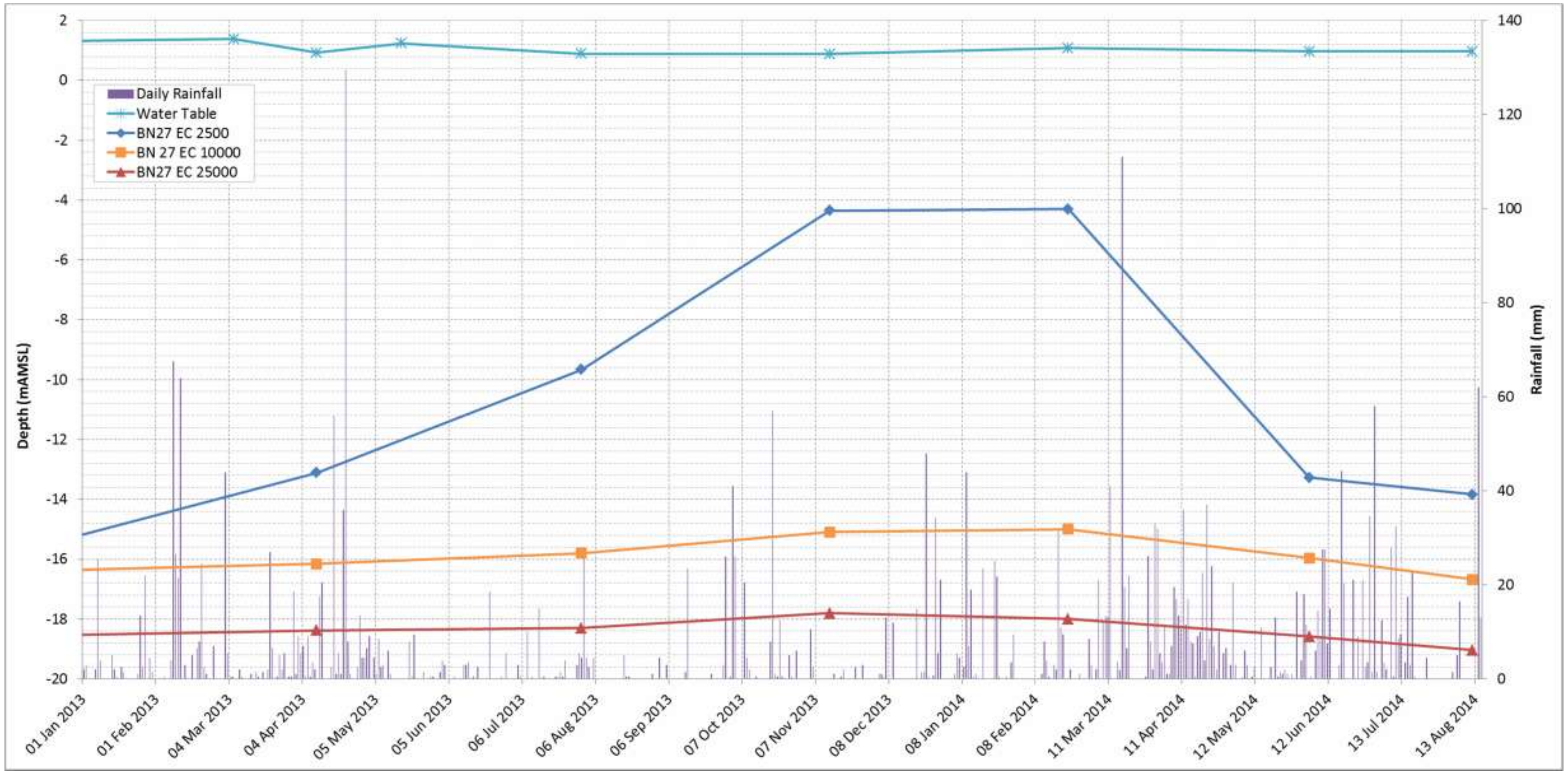


Figure A12.13: *Recent salinity variations at monitoring location BN27.*

BN2

Figure A12.14: *Recent salinity variations at monitoring location BN2.*

BN21

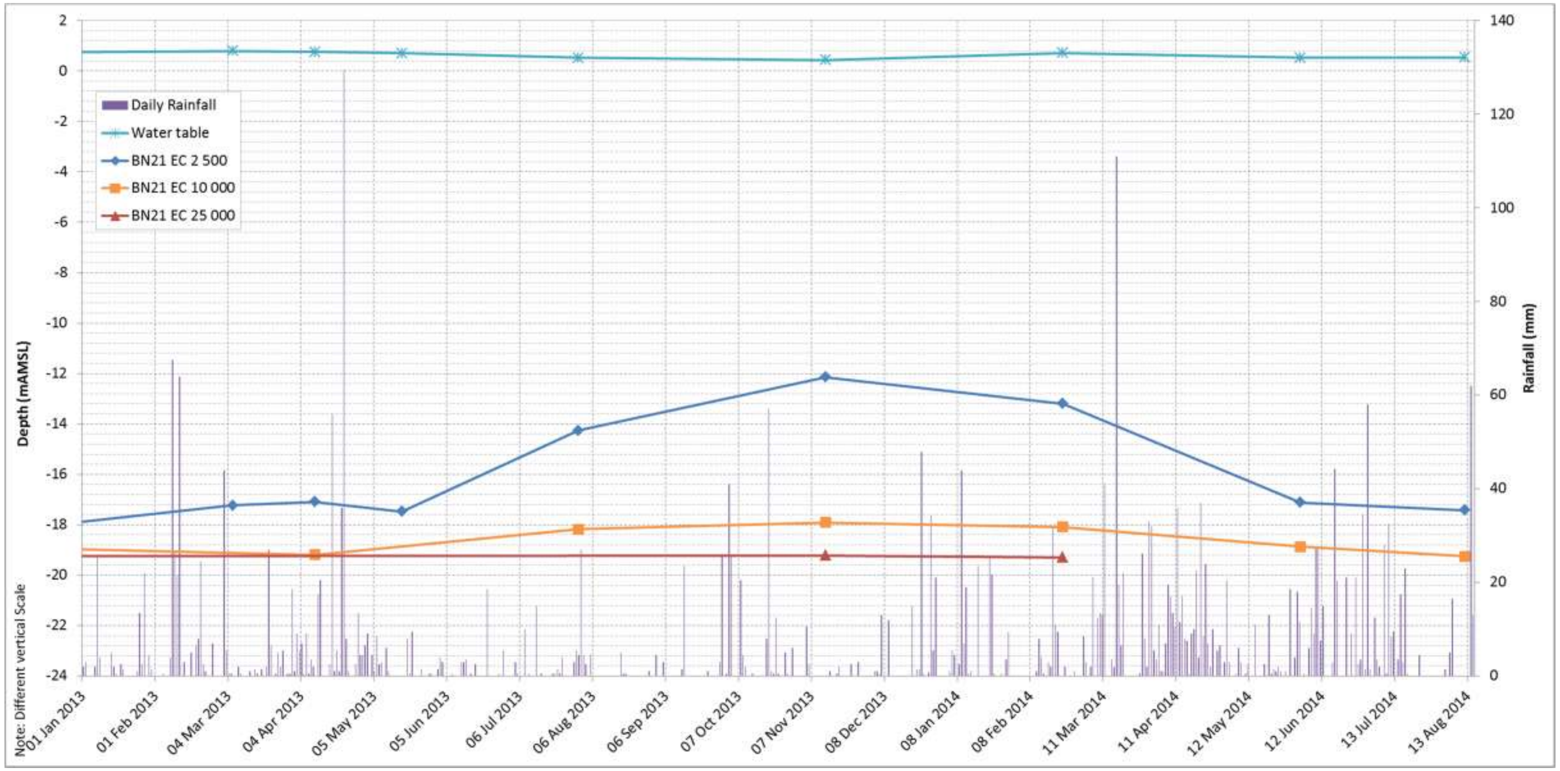


Figure A12.15: *Recent salinity variations at monitoring location BN21.*

BN22

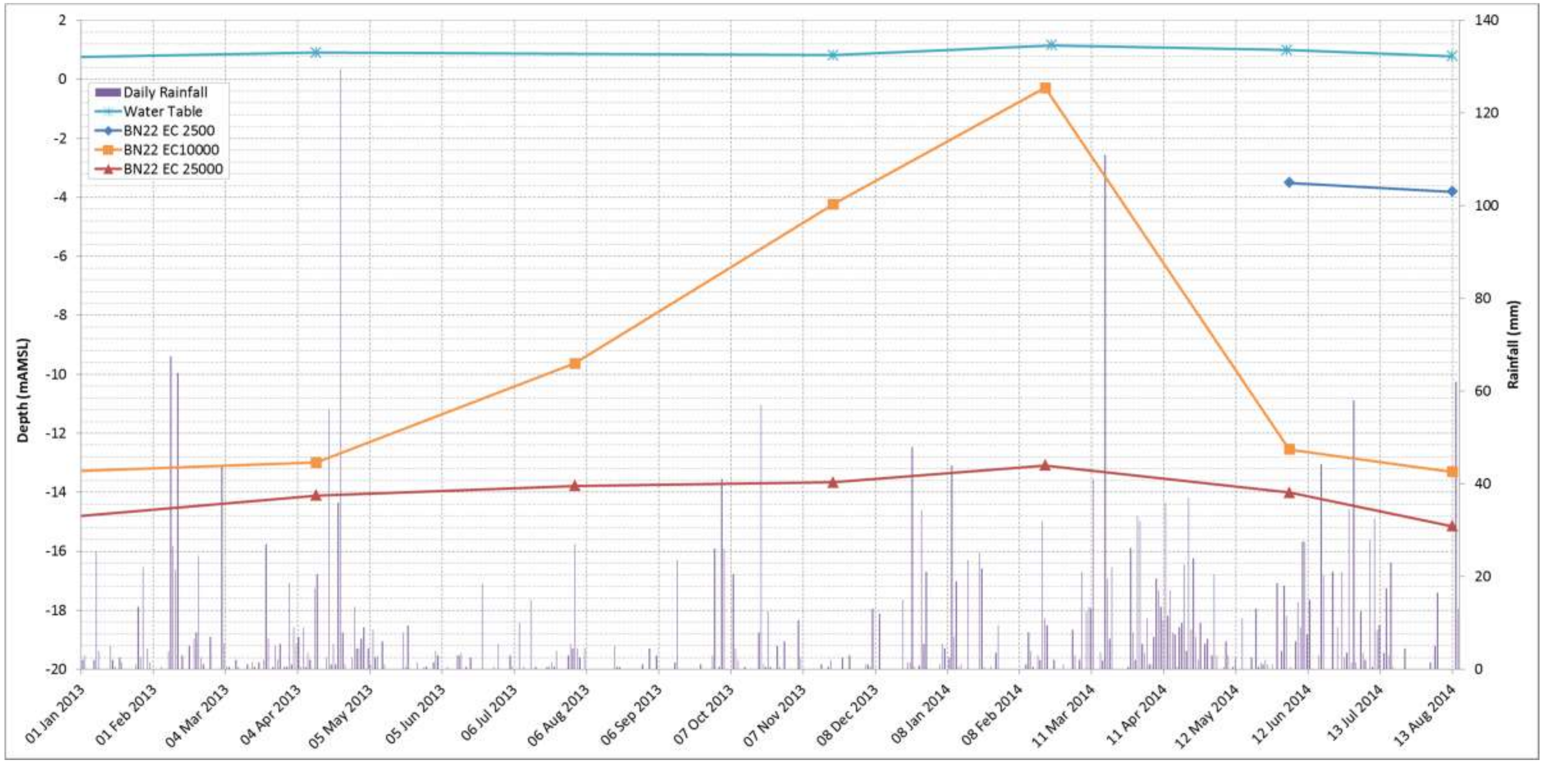


Figure A12.16: *Recent salinity variations at monitoring location BN22.*

BN23

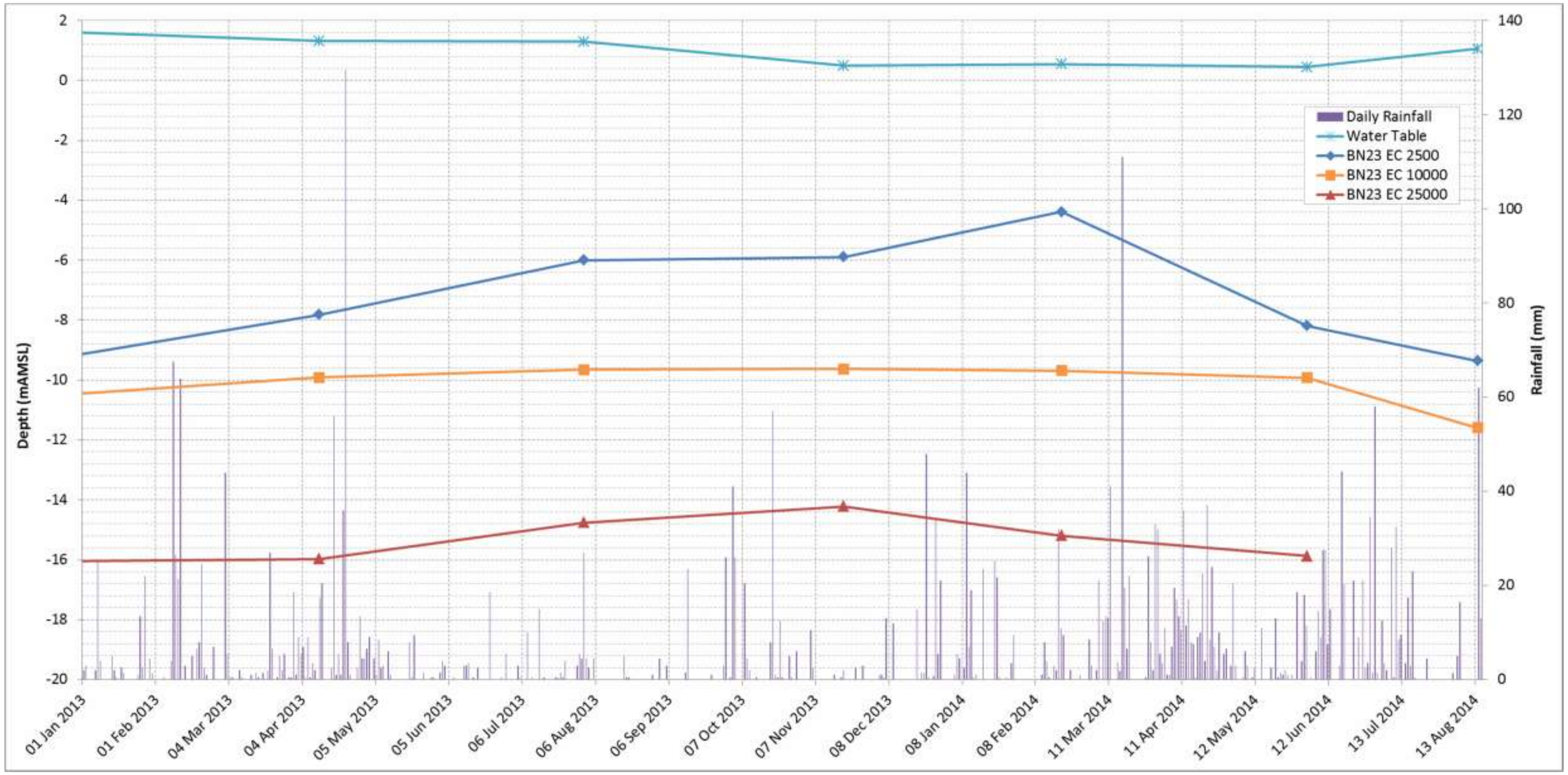


Figure A12.17: *Recent salinity variations at monitoring location BN23.*

BN24

Figure A12.18: *Recent salinity variations at monitoring location BN24.*

BN26

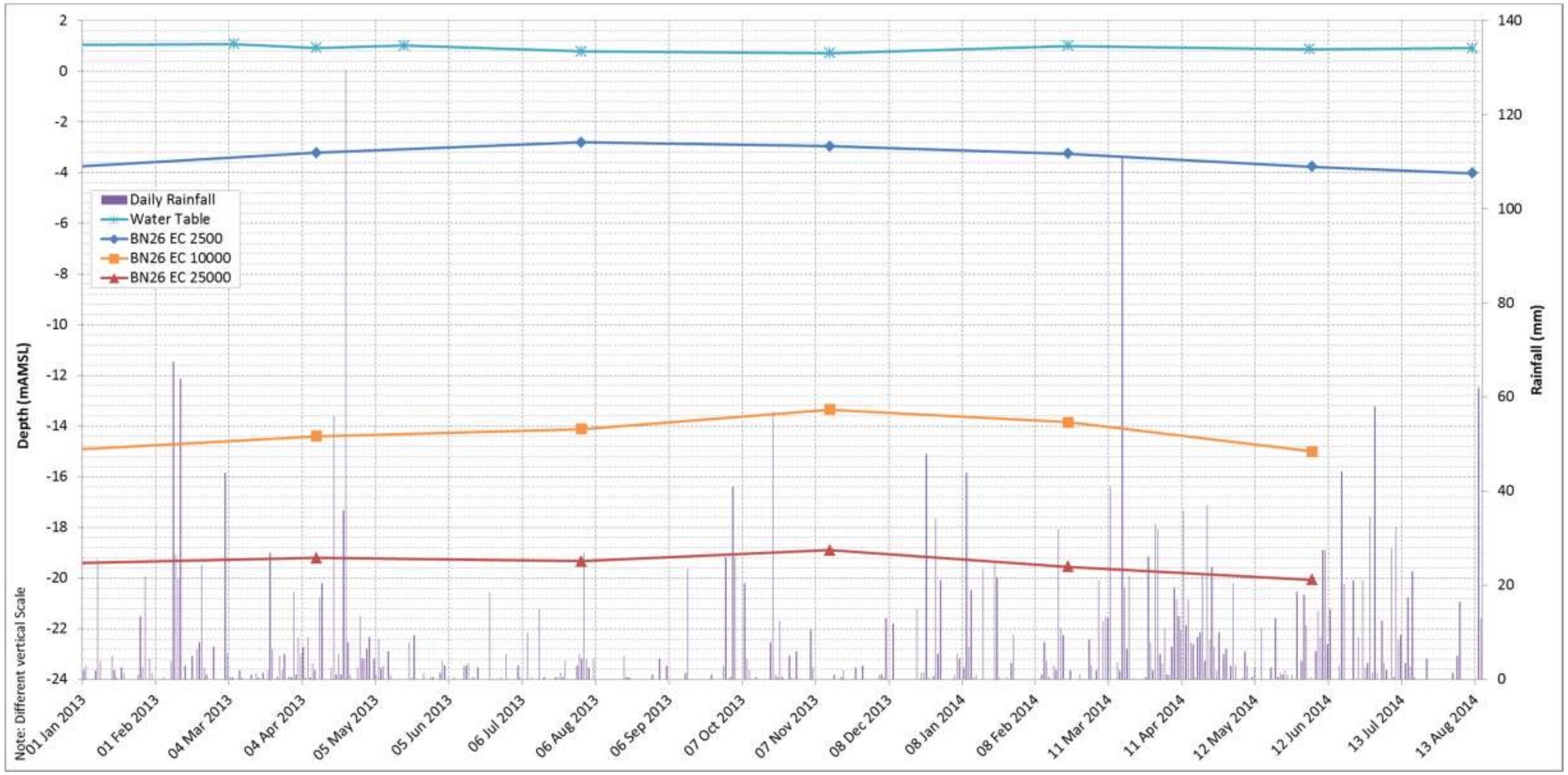


Figure A12.19: *Recent salinity variations at monitoring location BN26.*

BN28

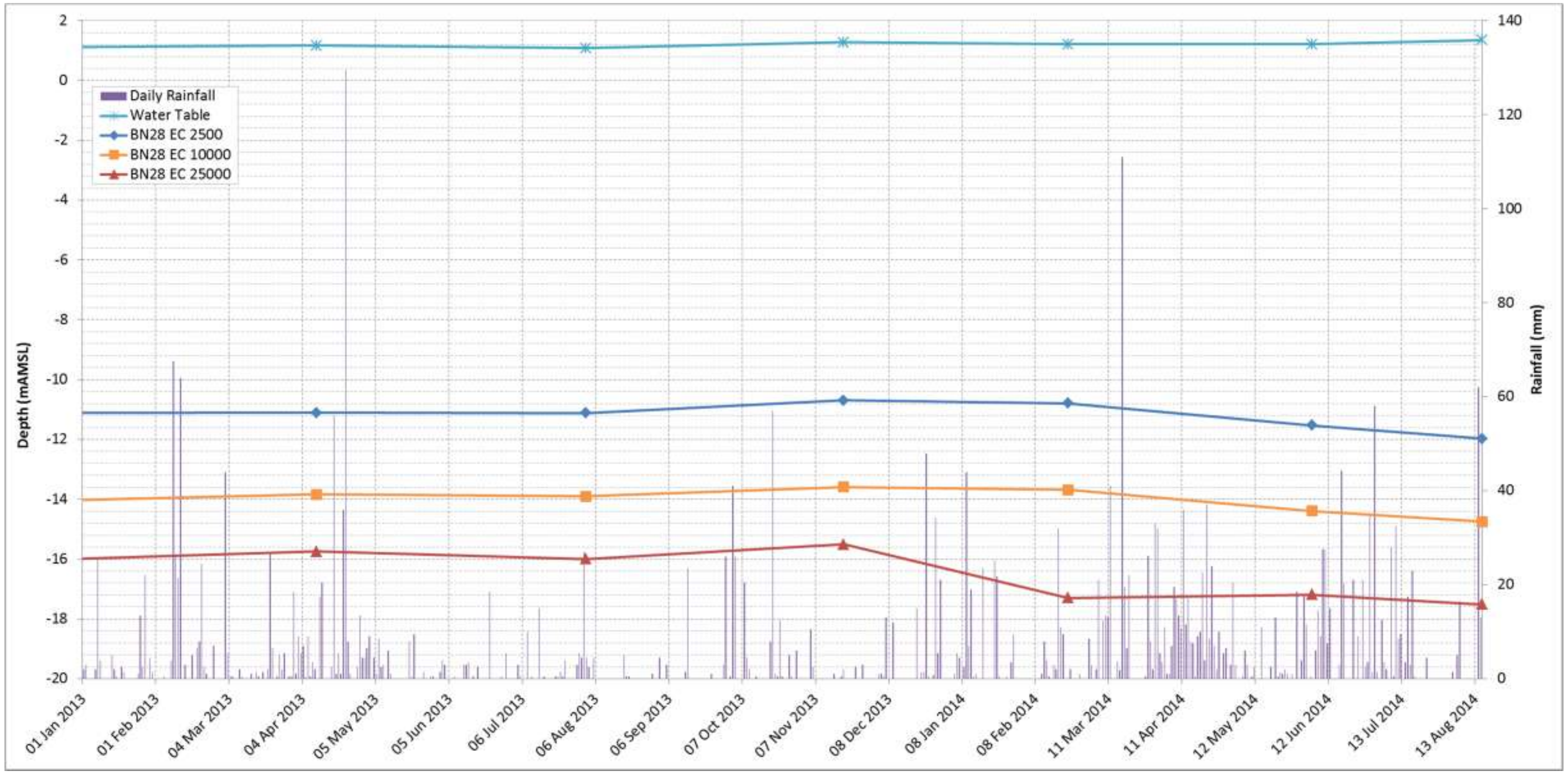


Figure A12.20: *Recent salinity variations at monitoring location BN28.*

BN29

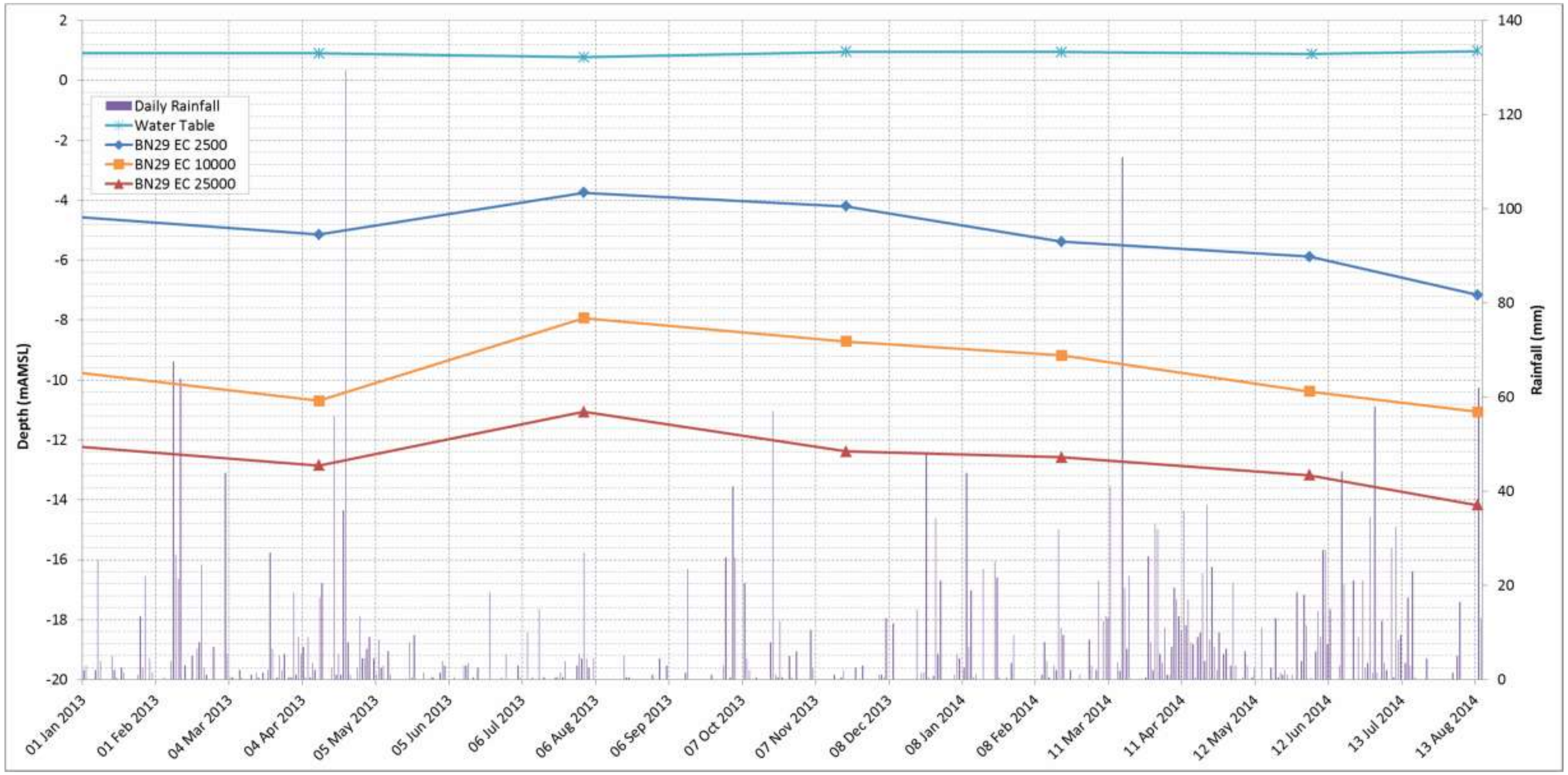


Figure A12.21: *Recent salinity variations at monitoring location BN29.*

BN32

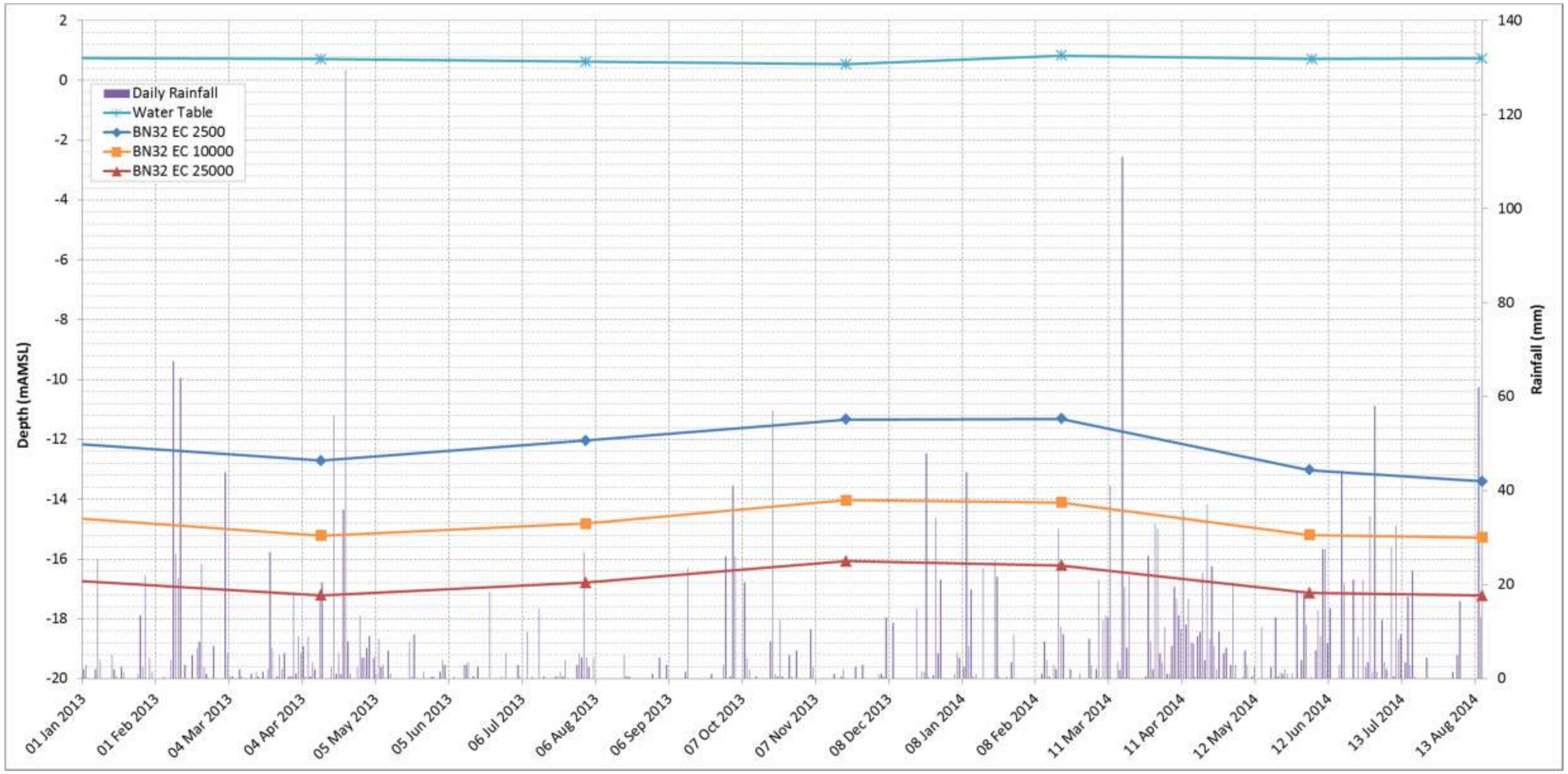


Figure A12.22: *Recent salinity variations at monitoring location BN32.*

BN33

***Figure A12.23:** Recent salinity variations at monitoring location BN33.*

BN34

Figure A12.24: *Recent salinity variations at monitoring location BN34.*

BN7

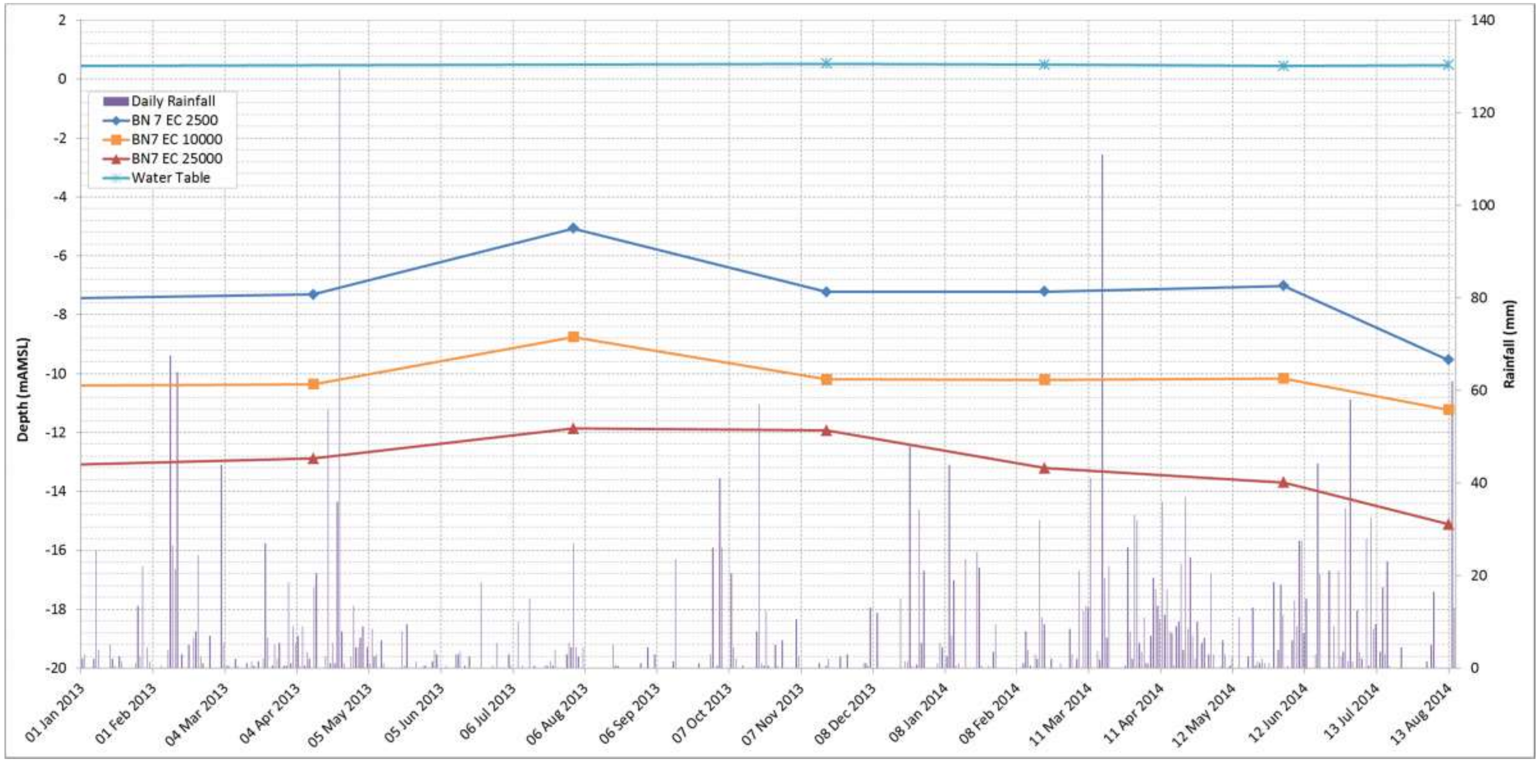


Figure A12.25: *Recent salinity variations at monitoring location BN7.*

BN4

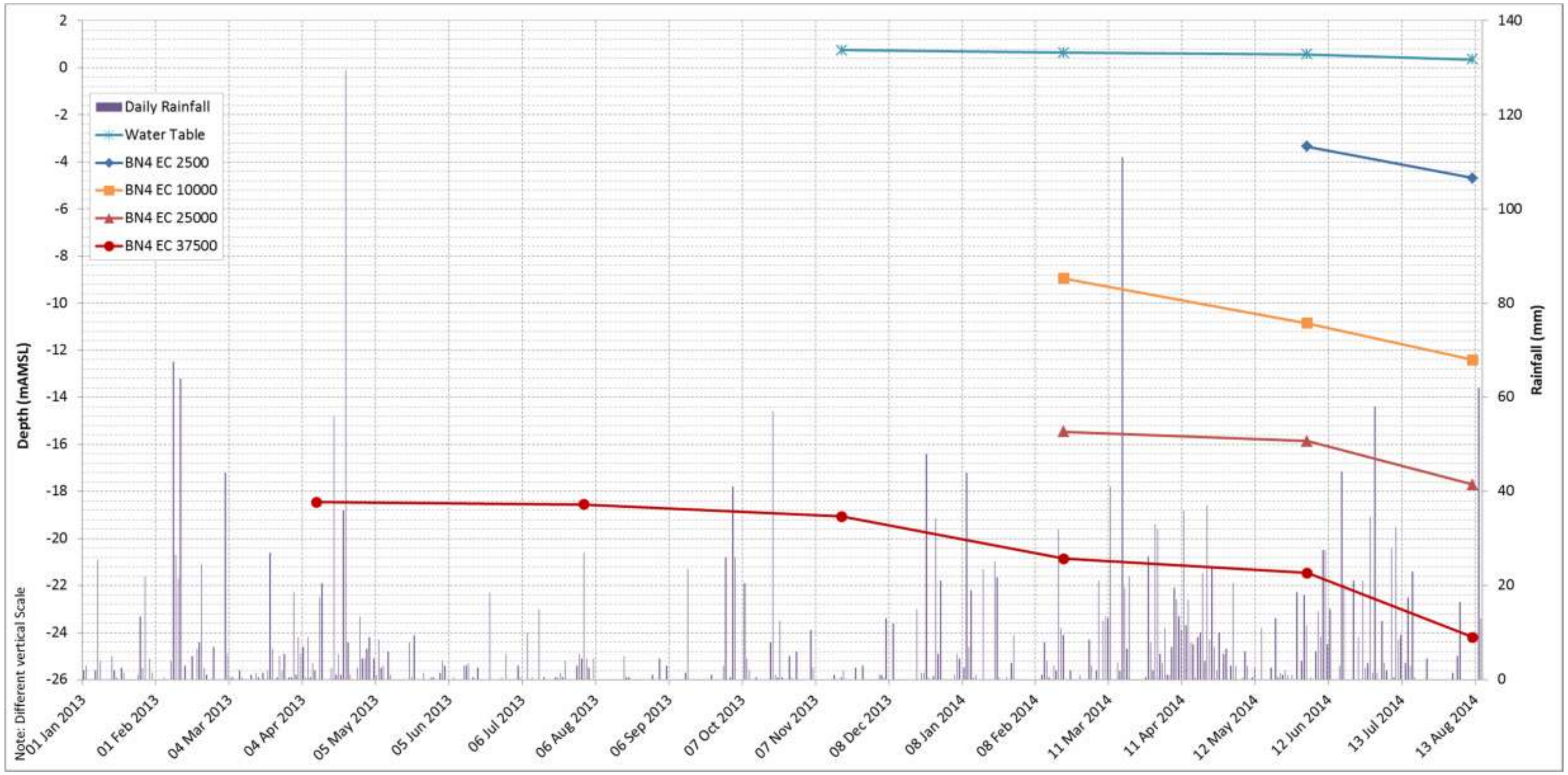


Figure A12.26: *Recent salinity variations at monitoring location BN4.*

BN19

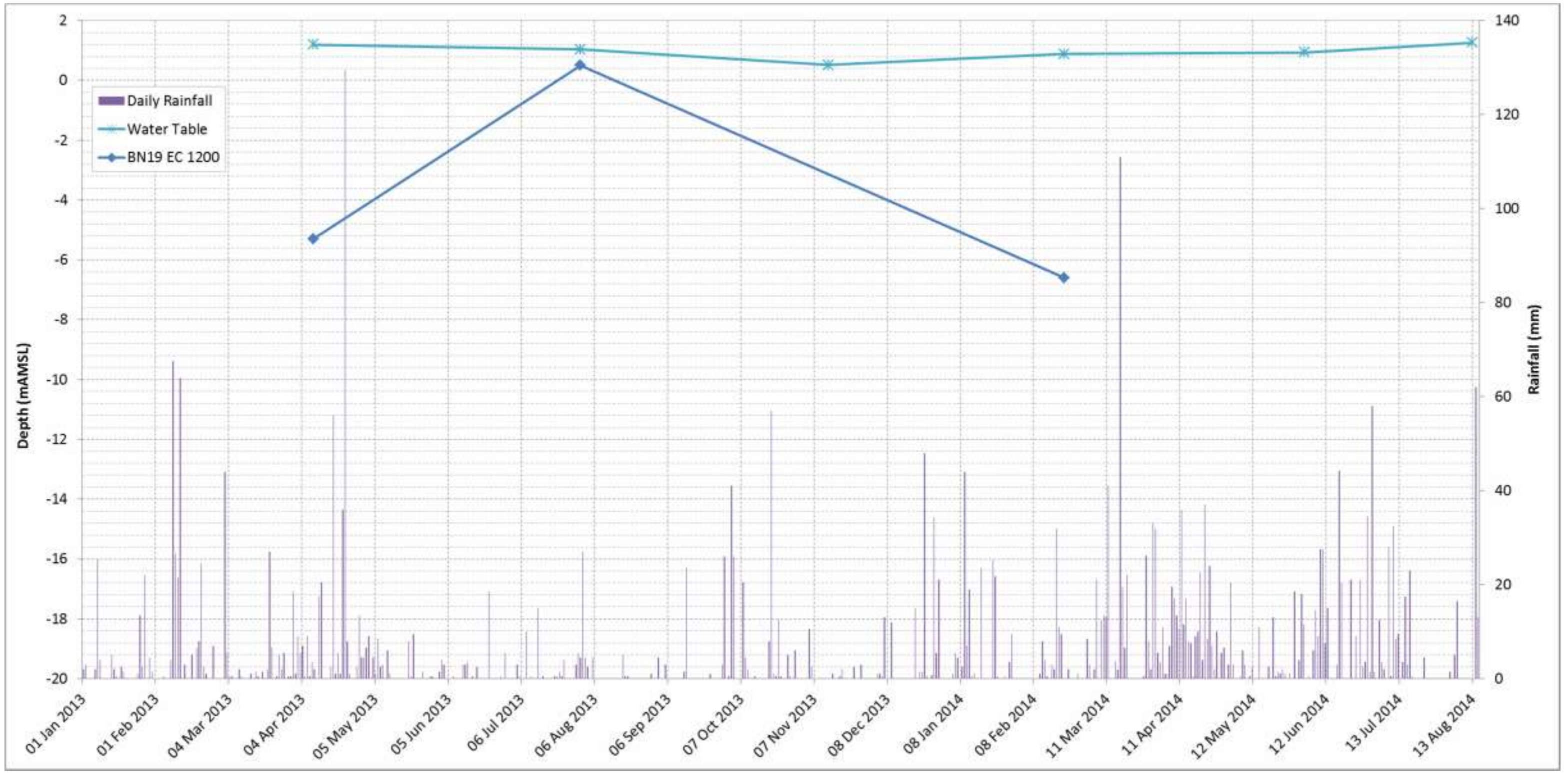


Figure A12.27: *Recent salinity variations at monitoring location BN19.*

BN20

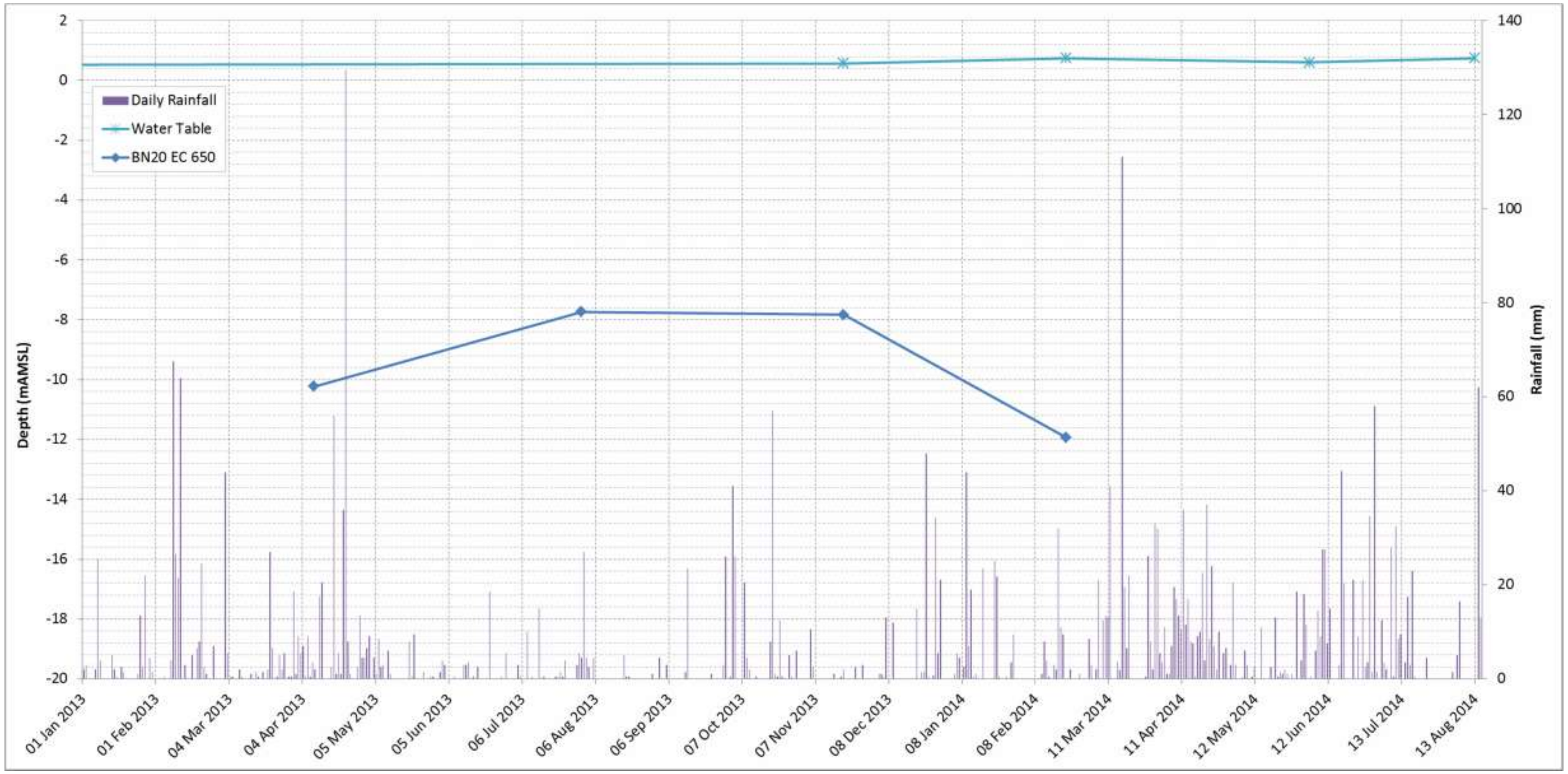


Figure A12.28: *Recent salinity variations at monitoring location BN20.*

BN25

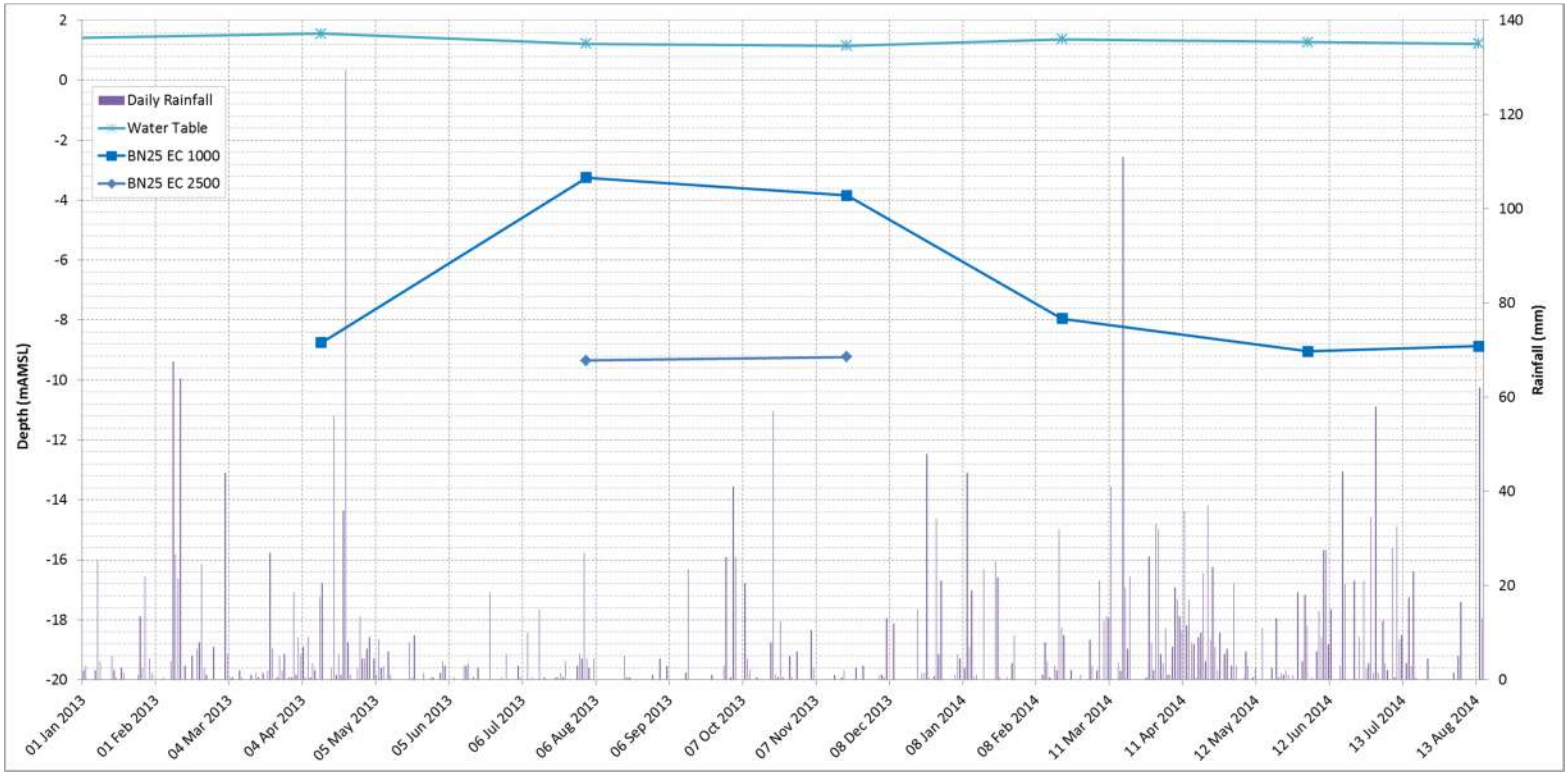


Figure A12.29: *Recent salinity variations at monitoring location BN25.*

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