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

KIRIWATSAN

GROUNDWATER AND RAINWATER MONITORING GUIDELINES FOR THE OUTER ISLANDS OF KIRIBATI

Secretariat of the Pacific Community, Suva

July 2015

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IMPORTANT NOTICE
This report has been produced with the financial assistance of the European Community; however, the views expressed herein must never be taken to reflect the official opinion of the European Community.

SPC Technical Report SPC00025

Original text: English

Prepared for publication at SPC, Suva, Fiji

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TABLE OF CONTENTS

1. INTRODUCTION TO WATER RESOURCES MONITORING GUIDELINES IN THE OUTER ISLANDS OF KIRIBATI 6
2. PURPOSE OF THE DOCUMENT 7
   2.1 Why Do We Need Monitoring 7
   2.2 Structure of the Guidelines 10
3. RAINFALL FOR WATER RESOURCES MONITORING 11
   3.1 Purpose 12
   3.2 Current Practice 12
   3.2 Recommendations for Improvements 13
4. MONITORING OF RAINWATER HARVESTING INFRASTRUCTURE 15
   4.1 Purpose 15
   4.2 Current Practice 15
   4.3 Recommendations for Improvements 16
5. MONITORING OF GROUNDWATER 17
   5.1 Purpose 17
   5.2 Current Practice 18
   5.3 Recommendations for Improvements 18
6. MONITORING OF WATER QUALITY 20
   6.1 Purpose 20
   6.2 Major Parameters 20
   6.3 Current Practice 21
      i. Salinity 21
      ii. Microbiology 21
   6.4 Recommendations for Improvements 22
      i. Salinity monitoring 22
      ii. Bacteriological monitoring 23
   6.5 Reading List 23
7. WATER SUPPLY INFRASTRUCTURE INSPECTION 25
   7.1 Purpose 25
   7.2 Current Practice 25
   7.3 Recommendations for Improvements 27
   7.4 Reading List 29
8. DATA ANALYSIS AND MANAGEMENT 29
   8.1 Purpose 29
   8.2 Current Practice 29
   8.3 Recommendations for Improvements 30
9. LOGISTICAL CONSIDERATION AND FUNDING 36
   9.1 Purpose 36
   9.2 Current Practice 36
   9.3 Recommendations for Improvements 37
10. LINKAGE TO EXISTING POLICIES FOR OUTER ISLANDS 39
   10.1 Purpose 39
   10.2 Current Practice 39
   10.3 Recommendations for Improvements 40
   10.4 Reading List 41
11. AWARENESS AND TRAINING PROGRAMME 41
   11.1 Purpose 41
   11.2 Current Status 41
   11.3 Recommendations for Improvements 42
   11.4 Reading List 44
12. CONCLUSIONS AND RECOMMENDATIONS 45
13. BIBLIOGRAPHY 48
14. ANNEXES 50

List of Tables

Table 1. Main freshwater demand and uses in Kiribati (National Statistics Office, 2012). 8
Table 2. Key water-related issues (White, 2010). 9
Table 3. Current rainfall measurement practice and its limitations. 13
Table 4. Advantages and disadvantages of rainwater harvesting in the atoll islands 16
Table 5. Water supply infrastructure inspection report on four KIRIWATSAN target villages 26
Table 6. Suggested water supply infrastructural improvements. 28
Table 7. Suggested procedures and basic steps to follow to ensure high quality data is collected 31
Table 8. Suggested approach to data handling, analysis and reporting 34
Table 9. Major costs involved in conducting groundwater level and salinity measurements 36
Table 10. Various water quality field-testing methods and associated estimated costs. 47

List of Figures

Figure 1. Annual rainfall variability around the Gilbert Islands Group 11
Figure 2. CV variability around the Gilbert Islands Group 12

List of Annexes

Annex

1 Conventional rainfall measurement and recording techniques
2 Rainwater harvesting field survey sheet
3 Groundwater level field sheet
4 Detailed instructions for groundwater level and salinity measurements
5 TPS WP84 Conductivity meter operation and calibration
6 Sampling procedures for drinking water
7 Bacteriological contamination field procedures for presence of *E.coli*/Total Coliform

Abbreviations and symbols

ADB	Asian Development Bank
AUSAID	Australian Agency from International Development
CV	Coefficient of variation
EM	Electro-Magnetic
ENSO	El Niño – Southern Oscillation
EU	European Union
GoK	Government of Kiribati
HYCOS	Hydrological Cycle Observing System
KIRIWATSAN	European Union Kiribati Water and Sanitation for Outer Islands
KMS	Kiribati Meteorological Services
MA	Medical Assistant
MFED	Ministry of Finance and Economic Development
MFMRD	Ministry of Fisheries and Mineral Resources Development
MIA	Ministry of Internal Affairs
MELAD	Ministry of Environment, Land, and Agricultural Development
MoHMS	Ministry of Health and Medical Services
MPWU	Ministry of Public Works and Utilities
NDO	National Disaster Office
NO	Nitrogen oxide
NWRIP	National Water Resources Implementation Plan
NWRP	National Water Resources Policy
NZAID	New Zealand Agency for International Development
OIC	Officer in Charge
OIWT	Outer Island Water Technician
PUB	Public Utilities Board
PWD	Public Works Department
QA/QC	Quality assurance/quality control
RWH	Rainwater harvesting
SOI	Southern Oscillation Index
SOPAC	South Pacific Applied Geoscience Commission/Pacific Islands Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SST	Sea-surface temperature
UNCDF	United Nations Capital Development Fund
UNICEF	United Nations Children and Education Fund
uv	ultra violet
WASH	Water, sanitation and hygiene
WEU	Water Engineering Unit
WHO	World Health Organization

1. INTRODUCTION TO WATER RESOURCES MONITORING GUIDELINES IN THE OUTER ISLANDS OF KIRIBATI

The Government of Kiribati (GoK), faced with severe climatic challenges and having limited and vulnerable fresh groundwater, has made numerous approaches to advance the development, protection and management of freshwater resources. This included the establishment of the outer island water technicians (OIWT) position in all the atoll islands outside South Tarawa within the Gilbert Islands Group. The position formerly created as a sanitarian aide[1], in the late 1990s by the then Public Works Department (PWD), now the Ministry of Public Works and Utilities (MPWU), was established for the maintenance and monitoring of its outer island communities' water systems. This initiative is in line with the GoK's long-term national and social obligation to oversee and improve the operation and maintenance of water systems in outer island communities. The inclusion of the OIWT position into the GoK structure was considered the best model for Kiribati to keep water supply system breakdowns to a minimal and provide support for improved water supplies to the outer islands.

Duties of OIWTs include, but are not limited to, the following:

1. Measurement and recording of daily rainfall at installed rain gauges.
2. Carrying out periodical groundwater level and salinity monitoring of selected wells around the island.
3. Conduct water supply infrastructure inspection and maintenance.
4. Installation and support for maintenance of solar pumps and *Tamana* pumps.
5. Supervising all Government plumbing and rainwater harvesting (RWH) works on the islands.

Records of these collected observations by OIWT should be sighted by the Island Council Clerk, although this is not always the case, before being sent to the Water Engineering Unit Officer in Charge (WEU-IOC) at the MPWU. MPWU is responsible for archiving all records of water monitoring observations from all of the outer islands where water technicians are assigned.

The 2012-2013 water resources assessment field trips to eight of the outer Gilbert islands of Kiribati by a team from the Secretariat of the Pacific Community (SPC), together with the lessons from previous projects, identified a need to support and provide guidance to the OIWT and relevant personnel/authorities for improved monitoring of the water resources in the atoll islands.

[1] Sanitarian Aide was a position previously created for a person on the island who received some salary from the Public Works Department and undertook some training for the construction and maintenance of various component of the UNCDF Project (Mourits, 1995). The position is now absorbed into GoK and now known as the Outer Island Water Technician (Martin Mataio, Water Engineering Unit, pers. comm., April 2015).

2. PURPOSE OF THE DOCUMENT

These monitoring guidelines (Guidelines) are intended to provide guidance on water resources monitoring in the outer islands of Kiribati, and to improve and strengthen the existing monitoring practices carried out by these Government officials and community representatives.

The Guidelines have been prepared through the European Union-funded Water and Sanitation in Outer Islands (KIRIWATSAN I) Project in consultation with the Ministry of Works and Public Utilities (MPWU), and the United Nations Children and Education Fund (UNICEF).

This compilation supports the National Water Resources Policy (NWRP) and its accompanying National Water Resources Implementation Plan (NWRIP). Specifically, the guidelines will be linked to the NWRIP goal of improving the understanding and monitoring of water resources and their use (White, 2010) through:

- improving knowledge of the quality and quantity of the nation's freshwater resources;
- improving understanding of water demand in rural and outer islands and the capacity to pay for water;
- improving knowledge and management of water resources under climatic extremes and impacts of climate change; and
- improving monitoring, data collection, storage, analysis and reporting of information on water resources for improved understanding, development and management of water resources.

2.1 Why Do We Need Monitoring

Management of any resource is best achieved where it is supported by long-term, quality-controlled measurements of known constants or variable parameters, together with the consistent and proper collection protocols, archiving and analysis of observations and information, about different aspects of the resource. This particularly applies to managing the **limited freshwater resources** in the outer islands of Kiribati with the quality and quantity of freshwater resources having a direct influence on the health issues of the communities in the outer islands. The freshwater resources in atoll environments are known to be limited and vulnerable to degradation, a robust monitoring programme is important to allow managers and operators of the water supply systems an opportunity to detect early the onset of emerging issues and develop with the community appropriate solutions and a course of actions.

Previous studies (Falkland 2003 and White 2010) document the linkage between the scarcity of freshwater resources in Kiribati and ENSO-driven rainfall variability, coupled with limited and poorly maintained rainwater harvesting infrastructure and rapidly responsive shallow groundwater systems. Table 1 presents the 2010 census record of the main water sources for drinking and washing highlighting the reliance by households on different water sources for different needs.

Table 1. Main freshwater demand and uses in Kiribati (National Statistics Office, 2012).

Water usage	Water Source	Percentage of households
Drinking	Pipe-water system (PUB)	32%
	Well water	61%
	Rainwater Tanks	6%
	Bottled water	1%
Washing	Pipe-water system (PUB)	12%
	Well water	85%
	Rainwater Tanks	2%
	Other sources	1%

The key authorities in Kiribati responsible for water supply management and quality, include Ministry of Public Works and Utilities (MPWU), Public Utilities Board (PUB), Ministry of Health and Medical Services (MoHMS), Kiribati Meteorological Services (KMS), and Ministry of Internal Affairs (MIA), have identified major issues threatening the water resources of the Republic of Kiribati in relation to its burgeoning population and economic aspirations. Table 2 provides a summary of the key priority areas identified by White (2010) and generally observed by the KIRIWATSAN 1 assessment teams in the Gilbert Islands. Systematic and consistent monitoring is expected to strengthen the protection and management of fresh water resources into the future.

Table 1 identifies that groundwater has an important role in providing long-term water security in outer islands now and into the future. Given the issues identified in Table 2 the long-term security, livelihood and sustainability of water resources in atoll communities will be improved with the establishment of a monitoring programme which includes review and analysis of the monitoring data. This will enhance the GoK's understanding of the behaviour and response of freshwater resources to climatic and human-induced stresses; which will affect the provision, protection and conservation of sustainable water supplies to the outer island communities (White, Tarawa Water Master Plan: 2010 - 2030, 2010).

While the monotony and cost of taking daily measurements (for example of rainfall collected at the rain gauge) might seem unnecessary and is not called upon under normal conditions; during drought this actual data will form the basis for better quantification of the impact of regional extreme events specific to a location and assist in determining appropriate and specific actions.

OIWTs should be supported and regularly reminded of the fundamental and important contribution their routine measurements make to the overall management of water resources; and the importance of their role and data in the remote islands of Kiribati.

Furthermore, while data may be faithfully collected, it is also vitally important that it be provided and archived in a usable format. These Guidelines will also provide procedures that can be followed to undertake preliminary processing of data to ensure it is provided in useful formats according to international or industry standards.

The KIRIWATSAN Project has prepared these Guidelines to help strengthen existing procedures of water resources monitoring as practised by outer islands water technicians and other relevant personnel.

Table 2. Key water-related issues highlighted by different government authorities; previous studies; and KIRIWATSAN I observations (White, 2010).

Priority water resources area(s)	Main identified issues
Health	• The unacceptably high rate of preventable deaths, particularly of infants, due to water-borne diseases • The unacceptably high rate of preventable illnesses due to water-borne diseases • Contamination of fresh groundwater and rainwater tanks by human settlements, improper land-use activities, sanitation systems, livestock and waste • Limited access to safe drinking water
Climate and geography	• Frequent La Niña related severe droughts • Vulnerability of shallow groundwater to sea water intrusion • Vulnerability of groundwater lens to storm surges • Vulnerability of rainwater storage to failures during drought events
Water supply	• Inadequate groundwater and rainwater supply infrastructure • Vandalism of water supply infrastructure • Reliance on highly-contaminated and poorly-equipped household wells in villages • Inadequate use of rainwater harvesting and storage in communal buildings • Poor maintenance and management of water supply systems • Limited access to spare parts for water supply systems
Demand	• Continuing population growth in many of the villages • Conflict between land-use activities (livestock, sanitation and *bwabwai*) and groundwater sources protection • Conflicting water demand and use for water
Economic and financial	• High cost of replacing damaged water supply • High treatment cost of preventable water-borne illnesses • Cash-poor communities • Financially unsustainable water supply system
Institutional arrangement	• Absence of National Water Resources legislation • No drought contingency plans • Conflict between traditional and public ownership of groundwater • Fragmented and ineffective control, management and protection of freshwater resources • Poor communication between agencies with responsibilities in the water sector • Inadequate knowledge, monitoring, analysis and reporting on status of freshwater resources • Lack of trained water specialists and technicians • Limited training schemes
Community	• Limited community participation in freshwater management and protection • Limited community understanding of responsible water use, conservation and protection of water sources and water supply infrastructure • Lack of ownership and commitment on water resources management due to over-reliance on Government machinery • A need for enhanced water education in schools
Knowledge gaps	• Limited information on the quantity and quality of groundwater resources in the islands • Limited information on the household use of water from various sources • Very limited information on rainwater harvesting systems • Sparse and inadequate groundwater monitoring data

2.2 Structure of the Guidelines

The Guidelines describes current practice and advises on improvements in the following areas of interest in the KIRIWATSAN Project:

1. Monitoring or measurement of rainfall for water resources monitoring (Section 3)
2. Monitoring of rainwater harvesting infrastructure (Section 4)
3. Monitoring of groundwater including water levels, and conductivity in selected wells in each village (Section 5)
4. Monitoring of water quality (Section 6)
5. Water supply infrastructure inspection (Section 7)
6. Data analysis and management (Section 8)
7. Logistical consideration and funding (Section 9)
8. Linkage to existing policies or TOR for outer islands (Section 10)
9. Awareness and training programme (Section 11)

Under each of these sections, a summary of current practice and recommendations for improvements are provided; followed by a reading list.

3. RAINFALL FOR WATER RESOURCES MONITORING

Rainfall or precipitation is the fundamental meteorological process that allows the establishment of fresh groundwater lenses and the collection of rainwater, the main sources of potable water in Kiribati (White & Falkland, 2010). Rainfall throughout the Pacific, including Kiribati, has been documented to be highly variable (Figure 1). This variability has been recently assessed through the historical annual mean and the coefficient of variation (CV) (Figure 2), across the Gilbert Islands in Kiribati indicating there is significant variation in the occurrence, availability and usability of fresh groundwater from recorded rainfall events in the Gilbert Islands Group (Figure 2).

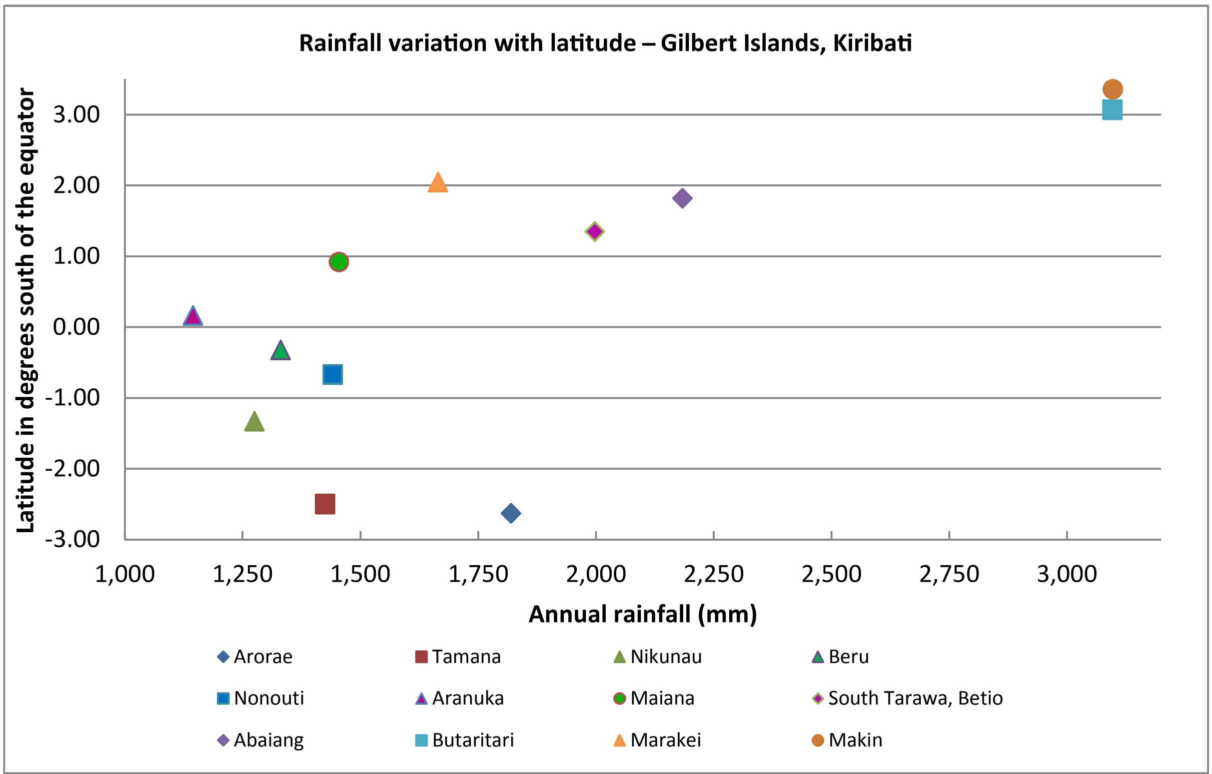

Figure 1. Annual rainfall variability around the Gilbert Islands Group.

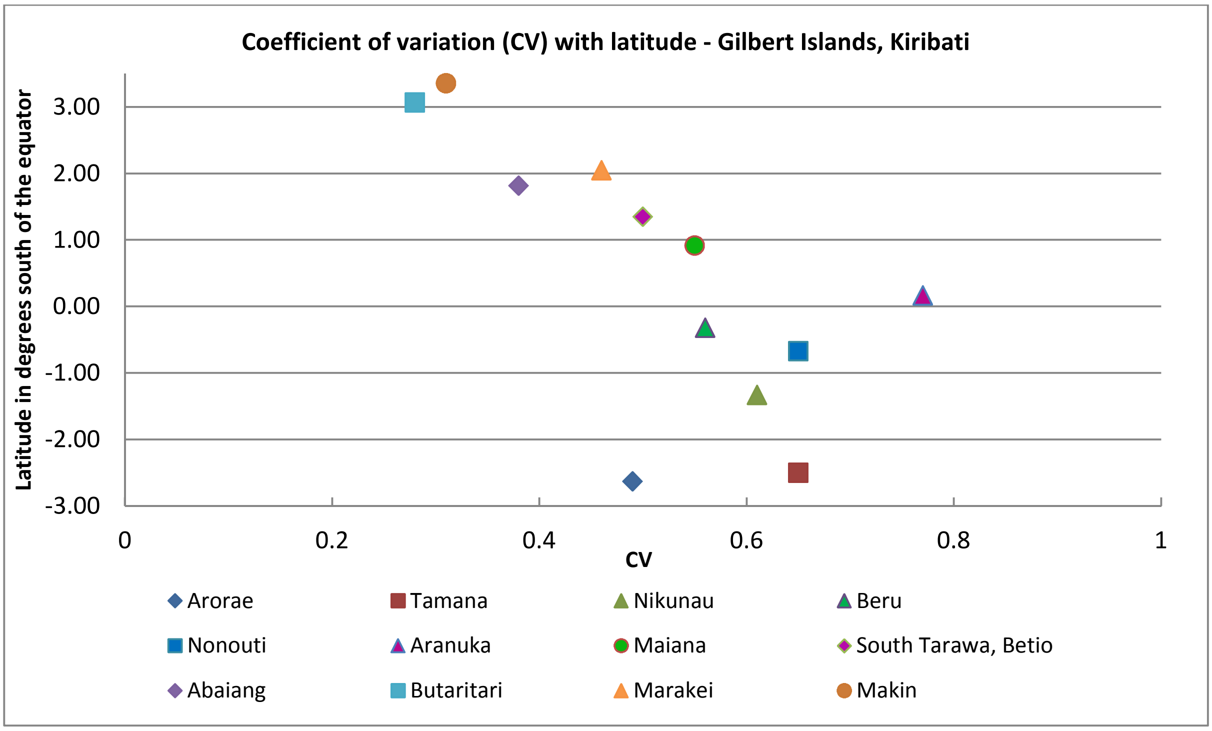

Figure 2. CV variability around the Gilbert Islands Group.

Figure 2 indicates the considerable variability in rainfall received across the outer islands that are fundamental to the availability of freshwater resources. Accurate and reliable measurement of rainfall is therefore critical for water resources management; and to assist in promoting water security in each of the atoll islands.

3.1 Purpose

To ensure that proper rainfall measurement procedures are available to GoK officials and to enhance the accuracy and reliability of all rainfall records for further analysis.

3.2 Current Practice

The summary of the current practice is presented in Table 3, together with associated challenges as highlighted in previous studies.

Table 3. Current rainfall measurement practice and its limitations.

Current practice	Major limitations (after Falkland, 2003)
• Water technicians manually read rainfall measurements as and when they remember – training instructions were given such that measurement are taken every morning between 9 and 10 am • Readings are manually recorded in the Pacific HYCOS rainfall book, which are kept and accessed by the water technicians ONLY • Daily rainfall readings are then tallied and sent to the WEU-MPWU office by post on a monthly basis • WEU staff responsible to do data entry then transfer these manual readings to an excel spreadsheet that is electronically archived in the WEU server • Upon request from KMS and approval by the WEU-OIC can the rainfall data be shared	• Most rainfall records have missing daily and monthly records suggesting poor awareness, carelessness and negligence • Some months showing all days with zero rainfall when this probably means missing data • Daily rainfall data recorded to 0.01 mm when the gauge can only be read to 0.1 mm • Data in the book does not always match the data on the original sheets • Double handling of the data (from sheet to book to spreadsheet) can potentially lead to errors • Over-grown vegetation around rainfall station • Fence around the rainfall station either broken or in very poor condition • Rain gauge poorly maintained • Children and animals able to access instrument site resulting in damage to equipment

3.3 Recommendations for Improvements

Improvements to rainfall measurements should include training on routine standardised daily measurements, data quality checks and other key areas of improvements:

1. A refresher training programme should be organised and conducted on a regular basis by both WEU-MPWU and KMS for all WEU staff and water technicians to:
    a. reinforce conventional rainfall measurement and recording techniques (Annex 1) – this will allow KMS to share and provide standardised protocols for quality assured rainfall measurements essential for meaningful analysis; and
    b. to understand the importance of conducting rainfall measurements on a daily basis at both local and national scale.
2. Rain gauge should be well protected with fencing and surroundings should be cleared at all times to avoid any potential interference to gauges.
3. The Island Council Clerk should be authorised and encouraged to conduct routine random checks on the rainfall field book or on the water technicians when conducting rainfall measurements. This is aimed at fostering accountability, due diligence and data quality assurance at a local level by all parties and to ensure that data records are in acceptable format and status.
4. All rainfall data should be seen and verified by the Island Council Clerk or Mayor before data are sent to the MPWU.
5. A three carbon-copy format field book (such as provided under Pacific HYCOS Project), should be used to ensure that a copies are forwarded to the WEU OIC in Tarawa and KMS whilst the OIWT island water technician will retain a copy. This approach is useful for data archiving, future reference, analysis and data sharing.
6. The WEU-OIC should assign a staff member, with capacity and skills in data verification and analysis to conduct data entry and perform basic data analysis.

7. The outer islands monthly rainfall spreadsheet designed by Falkland in 2003 (Annex 1 – the Abaiang Island example) and updated by SPC during KIRIWATSAN I, should be retained and updated by WEU on a monthly basis and provided to OIWT and KMS.
8. KMS shall be responsible for the archiving of the rainfall data in the National Climate database
9. Data recording and sharing protocols are agreed to and maintained, highlighted in Section 8.

3.4 Reading List

1. Yuen, L., 2009. Automatic rain gauge installation manual. Pacific Hydrological Climate Observing System (Pacific HYCOS) Project. SOPAC Miscellaneous Report 708, 140 p.
2. Kiribati Meteorological Services on http://www.climate.gov.ki/met/
3. KIRIWATSAN database – http://ict.sopac.org/kiriwatsan/. Note that plans are on-going to improve the database's functionality to include the island's updated monthly rainfall.

4. MONITORING OF RAINWATER HARVESTING INFRASTRUCTURE

Collecting and storing rainwater, if designed, built and managed properly can offer safe and reliable water source for drinking and cooking requirements (GWP, 2011). This is generally referred to as 'rainwater harvesting' (RWH) and is used across the whole Pacific area. Rainwater harvesting requires a collection, transmission and storage system. Permanent roofing such as metal roofs to collect rainwater, PVC gutters and downpipes to transfer the collected water, and plastic or concrete tanks or cisterns to store the water are found in churches and some *maneaba* and households in Kiribati outer islands.

RWH is the primary water supply in areas where negligible groundwater potential is observed, whilst the conjunctive use of both rainwater and groundwater is successfully practised in areas of adequate groundwater resources. In view of the increasing vulnerability of freshwater lenses to human-induced *E.coli* contamination, RWH is a suitable solution for water safety and security for Kiribati's outer island communities (University of Technology, 2011).

4.1 Purpose

To promote improvements in the practice of rainwater harvesting – including installation and maintenance of rainwater harvesting systems in use in the Gilbert Islands for improved water safety and security.

4.2 Current Practice

Very little coordinated effort is undertaken by GoK authorities regarding rainwater harvesting assessment and management. It is clear that previous projects have attempted to improve and strengthen the potential for rainwater harvesting, with efforts concentrated on communal buildings, namely churches, *maneaba* and schools. In general there is limited capacity for rainwater to provide the freshwater supply needs of villages due to the limited permanent roofing materials used on private households. Those RWH systems that are in place, are often inadequately equipped to ensure maximum rainwater collection and to prevent physical and bacteriological contamination. These infrastructure inadequacies include but are not limited to the following:

- poor roofing materials,
- lack of proper guttering,
- no fascia board,
- absence of downpipes,
- lack of appropriately-sized storage tanks,
- absence of screens on tank inlets to prevent the entry of organic litter or insects into the storage tanks and,
- accessing rainwater from the top of the tank with the use of bailers that are found to be lying on the ground when unused.

The Tarawa Water Master Plan released in 2010 indicates that in Tarawa rainwater tanks have capacity to supply only 5L/person/day based on average household size and average roof catchment area without risk of excessive tank failures (White, 2010). In the outer islands, the reliability and high variability of rainfall and heterogeneity of groundwater systems mean that some outer islands, namely Butaritari, Abaiang and Maiana have substantial fresh groundwater lens thickness for use as a public water supply. The conjunctive use of rainwater and groundwater has been successfully used in these islands to meet potable and non-potable needs of the population (White, 2009). Poor groundwater potential areas, such as Kiebu and Nonouti, consider RWH as the primary water source and require coordinated intervention from governing authorities to ensure freshwater safety and security for the atoll population.

Summarised in Table 4 are the advantages and disadvantages of rainwater harvesting in the atoll islands.

Table 4. Advantages and disadvantages of rainwater harvesting in the atoll islands (SOPAC, 2004).

Advantages of RWH	Disadvantages of RWH
• Provides a source of water at the point where it is needed, being owner-operated and managed • Provides an essential reserve during emergency and/or breakdown of the public water supply system • Generally considered to have superior physical and chemical properties to those of groundwater • Operational costs are low • The construction, operation and maintenance does not have to be labour-intensive	• Depends on frequency and amount of rainfall, hence, not a dependable water source in times of prolonged drought • Stored water can become contaminated by animal waste (birds, insects), poorly stored and maintained bailers and organic matter (rotten leaves and fruit) • Health risk may arise as rainwater is seldom treated or boiled prior to drinking • Cisterns and storage tanks can be breeding grounds for mosquitoes • Purchase of storage tanks, proper guttering and roofing materials can be expensive for households

4.3 Recommendations for Improvements

1. Standardised training should be provided to WEU staff, water technicians and village representatives on:
   - conducting RWH assessment and providing advice on infrastructure elements (SOPAC, 2004) and construction design (Sinclair et al., 2015);
   - conducting periodical sanitary inspection around communal and household systems to determine the cleanliness of the system and its surrounding environment as well as identify the presence of potential contamination risks that may trigger water quality testing (Kohlitz & Smith, 2015); and
   - conducting regular inspection of catchment materials, tanks, guttering and all system components to determine the need to clean, repair or replace them (Gould, 1999).

2. The attached (Annex 2) rainwater harvesting survey form may be useful to assess permanently-roofed buildings whilst the suggested method of estimating appropriately-sized tanks as presented in SOPAC (2004) is recommended.

3. Community awareness on potential contamination sources of rainwater, transmission routes of diseases, and the general perception that rainwater is always clean and pure in nature (Kohlitz & Smith, 2015).

4. Standardised training on checking water level and cleaning tanks should be provided to all OIWTs and community representatives.

5. The responsibility of management and maintenance of RWH systems, be it a communal or domestic setting, should be clarified to ensure agreed ongoing accessibility and suitability for potable use.

4.4 Reading List

1. SOPAC. (2004). Harvesting the Heavens – Guidelines for Rainwater harvesting in Pacific Island Countries. South Pacific Applied Geoscience Commission for the United Nations Environment Program, Suva.
2. GWP, 2011. Rainwater harvesting guidelines: design, construction and specifications: Government of Kiribati, Tarawa.
3. Sinclair, P., Loco, A., & Mataio, M. (2015). KIRIWATSAN Technical notes on water supply design principles. Geoscience Division, SPC, Suva, 81p.

5. MONITORING OF GROUNDWATER

Groundwater is among the most precious natural resources found in atoll environments and heavily relied upon by more than 90% of the households in the outer islands of Kiribati. It is the primary source of freshwater for daily household activities such as cooking and drinking.

Groundwater in atolls generally is found as a thin freshwater lens in a shallow unconfined aquifer. Freshwater lenses and are extremely vulnerable to natural processes such as storm surges, prolonged dry periods (or droughts) and human-induced anthropogenic influences. Groundwater on outer islands is most often abstracted through private wells sited in close proximity to the house or through a communal village well.

Measurement of water levels and salinity in existing wells, provides the most direct indicator of the occurrence, fluctuation and suitability of this resource: thereby providing a first point of reference about the stresses on the resource. Stresses on the resource can be due to over-abstraction, prolonged drought affecting groundwater recharge, storage and discharge.

5.1 Purpose

To ensure that the measurement of groundwater level is appropriately conducted and data is systematically recorded and communicated among relevant stakeholders.

5.2 Current Practice

Measurement of groundwater level together with the measurement of groundwater salinity are considered the two most easily obtained and useful groundwater parameters for assessing the variation in shallow groundwater systems found in atoll environments. The current measurement practice includes the following:

1. Selection and measurement of existing monitoring wells around the villages and island.
2. Groundwater level is measured from the top of water surface to the ground level. If there is a well parapet present measurement is taken from the surface of water to the top of the parapet. Parapet height is then subtracted to deduce water level in the well, relative to ground level.
3. Measurements are conducted through the use of simple equipment such as a builder's steel measuring tape and in some instance a dip meter. Measurements are recorded in the OIWT's field books.
4. Periodical measurements of groundwater level in selected villages wells by OIWTs.
5. All groundwater level data should be sighted and endorsed by Island Council officials, namely the Clerk or Mayor, before data is transferred to the WEU-OIC in Tarawa, who in turn, assigns staff who transfer and update this data into an existing Microsoft spread sheet for each island.

5.3 Recommendations for Improvements

1. Schedule of monitoring periods and selection of monitoring wells around the islands should be reviewed by both WEU and Island Council representatives, as per the following considerations:
    a. All communal or shared groundwater wells, and several household wells should be on a monitoring schedule to ensure that adequate spatial coverage around the village is periodically captured. It is recommended that monitoring be taken on a quarterly basis and on a more frequent basis as required, such as during droughts.
    b. The selected wells should be accessible during the agreed monitoring schedule to permit the groundwater level measurement.
    c. Adequate logistical support, namely transport, measuring tape, field stationery, are available to the OIWT to conduct proper water level monitoring in a timely manner according to the schedule.

2. Water level (WL) in the wells and total well depth (TD) should be measured from the same known point of reference near ground level to the water surface in the well each time. The field sheet for recording the results of groundwater level measurements is attached in Annex 3.

3. All newly excavated groundwater wells, be it for household or communal water supply, should be assessed using the field survey sheet attached (Annex 3) with the water levels and salinity monitored and registered into the KIRIWATSAN database.

4. During times of drought, the frequency of groundwater monitoring should increase to once every month with measurements restricted to communal or public groundwater supply sources only.

5. During times of wave overtopping, groundwater monitoring should be urgently conducted after a reported event. These should be focussed on affected areas with measurements restricted to communal or public groundwater supply sources.

6. Routine checks should be undertaken by a village representative during every monitoring event to ensure that work has been completed around selected wells in the villages in accordance with agreed practice.

7. Routine data checks should be conducted and verified by the Island Council Clerk or Mayor before data is transferred to the WEU-OIC in Tarawa.

8. Records received at the MPWU without the endorsement of either the village or Island Council representative should be communicated back to the OIWT and request necessary checks and clarification with continued adherence to the suggested routine. Repeated failure to maintain agreed monitoring scheduling or procedures may demonstrate negligence and require appropriate action or penalties in accordance with existing government labour laws.

9. All groundwater level data should be updated, archived and stored into the KIRIWATSAN database.

10. Periodical groundwater level reports should be provided to each Island Council, providing analysis in conjunction with rainfall measurements on the observed fluctuation in water levels and salinity and possible causes. Routine Island Council meeting agenda should require the tabling of this reporting.

11. Annual groundwater awareness should be conducted around all the villages regarding:
    a. water level and salinity fluctuation trends;
    b. implications on the resource of the observed trends; and
    c. recommendations on proposed actions, e.g. regulated abstraction, to safeguard groundwater resources.

Refer to Annex 4 for detailed instructions on groundwater measurements.

5.4 Reading List

1. Sinclair, P., Loco, A., & Mataio, M. (2015). KIRIWATSAN Technical notes on water supply design principles. Geoscience Division, SPC, Suva, 81p.

2. Hasan, T., & Aalbersberg, W. (2008). Designing a drinking water quality monitoring programme – a practical guide for Pacific Island countries. SOPAC, Suva, 44p.

3. Mudaliar, M.M., Bergin, C., MacLeod, K. (2008). Drinking water safety planning – a practical guide for Pacific Island Countries. World Health Organisation and Pacific Islands Applied Geoscience Commission, Suva, 104p.

6. MONITORING OF WATER QUALITY

Water quality is important in determining the suitability of a water source for potable use. Water quality in Kiribati is generally expressed through the salinity and bacteriological readings, being parameters which can be readily undertaken.

Salinity is measured in the field using electrical conductivity (EC) units of micro-Siemens per centimetre (µS/cm) or milli-Siemens per cm (mS/cm). In Kiribati, a threshold of 2.5 mS/cm is used as an upper limit of usable freshwater resources. This threshold limit for freshwater is useful to identify potential water supplies or determine the usability of an existing source, although it is reported people in Kiribati often have to drink water of higher salinity in case of prolonged droughts.

Escherichia coli (or *E.coli*) is an indicator organism for faecal contamination that is found in warm-blooded animals. Both groundwater and rainwater in outer islands communities are vulnerable to *E.coli* contamination. Groundwater sources can be contaminated through surface ingress due to poor well construction and protection; seepage from nearby and poorly-designed toilets; and improper land-use practices such as inappropriately-located *bwabwai* pits and piggeries. Rainwater can be contaminated by organic litter attracting animals onto roofs, and poorly stored or maintained bailers which can come into contact with faecal material.

In view of the prevalence of WASH-related diseases and the high infant mortality rate in Kiribati, it is suggested that rapid bacteriological sample procedures, such as the Collilert-18 or compact dry plate filtration membrane procedures, are useful to determine either the absence/presence; or to quantify the level of *E.coli* bacteria in drinking water sources.

As currently practised, brackish water may not be suitable for drinking, but may be suitable for other household activities such as washing and cleaning. Similarly, bacteriological contamination can render water sources unfit for human consumption. Water contaminated by *E.coli* should be treated chemically, chlorination or other disinfectants, or physically by boiling, before being used for drinking.

6.1 Purpose

To ensure that water quality tests are conducted in accordance with recommended procedures to improve confidence in results.

6.2 Major Parameters

Water quality monitoring is important to provide confidence that water safety measures are being effective and to promote the practice and use of safe drinking water approaches in communities. It is therefore useful to monitor basic water quality parameters. Basic water quality parameters which could be monitored include:

- temperature,
- salinity (Electrical Conductivity),
- microbiology (i.e. faecal coliform organisms, enterococci organisms).

Other physical water quality features that may trigger water quality assessments in Kiribati include:

1. presence of rubbish and leaves in the wells;
2. algal growth potentially because of nutrients;
3. potential contamination sources such as animal enclosures and rubbish pits;
4. poorly constructed wells with likely surface water ingress;
5. presence of dead leaves or insects in the rainwater tanks; and
6. poorly-drained areas under rainwater tank outlet taps.

Groundwater monitoring can be conducted for many purposes; however, in atoll environments it is important to monitor resources to:

- characterize groundwater and identify changes or trends in groundwater quality over time;
- identify specific existing or emerging water quality problems; and
- respond to emergencies, such as wave over topping etc.

6.3 Current Practice

Current practice of groundwater quality monitoring in outer islands of Kiribati is for salinity only. This should be carried out quarterly by OIWT at selected village wells. A TPS WP84 conductivity meter can be used to measure the conductivity and temperature of water in the well and has been provided to all OIWT under the KAPII Project.

i) Salinity

Conductivity is a measure of the capacity of an aqueous solution to carry an electrical current, which depends on the presence of ions; their total concentration, mobility and valence. Conductivity is commonly used to determine salinity and is mostly reported in micro Siemens per centimetre (µS/cm) or milliSiemens per metre (mS/m) at a standard reference temperature of 25 $^{\circ}$C.

For Kiribati, water conductivity less than 2500 µS/cm or 2.5 mS/cm is considered an upper limit of freshwater resources.

A TPS WP84 conductivity meter is recommended to measure the conductivity and temperature of water in the well. Please refer to Annex 5 for the operation and calibration of the TPS. Once the measurement is done the results should be recorded in a field sheet.

ii) Microbiology

There is no *E.coli* sampling and analysis conducted in the outer islands by water technicians (Martin Mataio, pers. comm., 21st May 2015). It is only during diarrhoea outbreaks in outer islands when medical assistants are urgently requested to collect and send water samples to Tarawa for *E.coli* tests. Delays between sampling and analysis can yield unreliable results.

6.4 Recommendations for Improvements

i) Salinity monitoring

1. It is recommended that current groundwater salinity monitoring practice be further strengthened through the following;

    a. Appropriate and regular training of outer island water technicians, Island Council representatives and village representatives on field techniques (site selection, sampling and equipment maintenance and calibration).

    b. Update inventory of groundwater monitoring equipment in outer islands and replace old or defunct equipment, and ensure calibration solutions are available.

    c. The selection of wells for periodical and long-term monitoring. Adequate logistical support, including transport, technical equipment (salinity meters and calibration solutions), and appropriate data storage facilities will be required.

    d. Recording the impact of drought and extreme wave or tidal events on the monitoring bores will further assist with understanding the impact to the groundwater resources from these extreme events.

2. Establish schedules to monitor groundwater salinity at all communal wells and selected household wells in each village on a three monthly basis.

3. TPS salinity meter should be calibrated using appropriate EC standard solutions before measurements on any day.

4. Continue with current groundwater salinity monitoring on very months (quarterly) basis, recommending approximately seven (7) sites in total per village.

5. For groundwater wells, salinity should be measured surface (**top salinity**) and base (**bottom salinity**).

6. All newly excavated groundwater wells, be it for household or communal water supply, should be assessed using the field survey sheet attached (Annex 3) with the water levels and salinity readings recorded registered into the KIRIWATSAN database by MPWU staff in Tarawa

7. During times of drought, the frequency of groundwater salinity monitoring may be increased to monthly with measurements restricted to communal or public groundwater supply sources.

8. During times of wave overtopping, groundwater salinity monitoring should be conducted as soon as possible after a reported event to determine its impact and usability. Measurements should target affected areas with measurements restricted to communal or public groundwater supply sources.

9. All monitoring data to be checked and signed off by Island Council representative before being transferred to the WEU-OIC in South Tarawa who will then assign staff to conduct database update and verify sign-off.

10. Periodical groundwater salinity reports should be provided as updates to each Island Council, regarding the fluctuation in water levels and what it means.

11. Annual water quality awareness should be conducted around all the villages regarding:

    a. water salinity fluctuation trends over time;
    b. the implication of the observed trend to the status of the resource; and
    c. the proposed actions, such as regulated abstraction, to safeguard groundwater resources.

ii) Bacteriological monitoring

1. Standardised training should be provided to OIWTs, island nurses and WEU staff on the *E.coli* sampling and analysis techniques, utilising a standardised procedure such as the Collilert or the compact dry plate procedures.
2. Government of Kiribati will be required to provide adequate logistic support including sampling and analysis equipment to OIWT and island clinics to ensure that sampling can be conducted as and when required. It is suggested that the costs for this could be shared between a number of government agencies with the relevant mandates
3. It is suggested that bacteriological sampling be carried out on an annual basis with support from MPWU.
4. In times of disease outbreaks, coordinated *E.coli* sampling could be conducted by both the MPWU and MoHMS on all public water supply sources and storage facilities, i.e. selected wells, storage tanks, rainwater tanks or concrete cisterns.
5. Other water quality parameters (nitrates, ammonia, phosphorous and heavy metals) could be sampled as required when potential contamination threat is suspected.
6. Periodical contamination reports should be provided to each Island Council, in conjunction with water safety plans to assess the potential threat to water sources to assist in assessing the risk and identifying appropriate options for management.
7. Annual water resources contamination awareness raising should be conducted around all the villages regarding:
    - the status of *E.coli* contamination based on the previous bacteriological tests around the village; and
    - proposed actions, such as water safety planning, and the need for maintain clean and secure areas around water sources and options for treating of water to ensure its suitability to maintain potable water supplies especially for the most vulnerable, such as the sick and the very young.

See Annex 7 for field procedures to test for *E.coli* or Total Coliform.

6.5 Reading List

1. Loco, A., Juliano, L., Mataio, M., & Aroito, M. (2015). KIRIWATSAN Water Resources Assessment, Beru Island, KIRIWATSAN. EU-funded Kiribati's outer islands Water and Sanitation Project. SPC, Suva, 191p.

2. Loco, A., Mataio, M., & Iotebwa, M. (2015). KIRIWATSAN Water Resources Assessment, Nikunau Island, KIRIWATSAN. EU-funded Kiribati's outer islands Water and Sanitation Project. SPC, Suva, 147p.
3. Loco, A., Sinclair, P., Singh, A., & Mataio, M. (2015). KIRIWATSAN Water Resources Assessment, Maiana Island, KIRIWATSAN. EU-funded Kiribati's outer islands Water and Sanitation Project. SPC, Suva, 214p.
4. Loco, A., Singh, A., Mataio, M., Bwatio, E., & Sinclair, P. (2015). KIRIWATSAN Water Resources Assessment, Abaiang Island, KIRIWATSAN. EU-funded Kiribati's outer islands Water and Sanitation Project. SPC, Suva, 229p.
5. Loco, A., Singh, A., Mataio, M., Iotebwa, M, & Sinclair, P. (2015). KIRIWATSAN Water Resources Assessment, Nonouti Island, KIRIWATSAN. EU-funded Kiribati's outer islands Water and Sanitation Project. SPC, Suva, 170p.
6. Sinclair, P., Loco, A., Mataio, M., & Bwatio, E. (2015). KIRIWATSAN Water Resources Assessment, Marakei Island, KIRIWATSAN. EU-funded Kiribati's outer islands Water and Sanitation Project. SPC, Suva, 149p.
7. Sinclair, P., Loco, A., Singh, A., & Juliano, L. (2015). KIRIWATSAN Water Resources Assessment, Butaritari Island, KIRIWATSAN. EU-funded Kiribati's outer islands Water and Sanitation Project. SPC, Suva, 178p.
8. Sinclair, P., Loco, A., Singh, A., & Juliano L. (2015). KIRIWATSAN Water Resources Assessment, Makin Island, KIRIWATSAN. EU-funded Kiribati's outer islands Water and Sanitation Project. SPC, Suva, 146p.
9. Hasan, T., & Aalbersberg, W. (2008). Designing a drinking water quality monitoring programme – a practical guide for Pacific Island countries. SOPAC, Suva, 44p.
10. Mudaliar, M.M., Bergin, C., MacLeod, K. (2008). Drinking water safety planning – a practical guide for Pacific Island Countries. World Health Organisation and Pacific Islands Applied Geoscience Commission Joint Contribution Report 103, Suva, 104p.
11. Mosley, L., and Sharp, D.S., 2005. The hydrogen sulphide (H2S) paper-strip test – a simple test for monitoring drinking water quality in the Pacific Islands. SOPAC Technical Report 373. SOPAC, Suva, 24p.

7. WATER SUPPLY INFRASTRUCTURE INSPECTION

The status of water supply infrastructure in any area can be a useful indicator of water safety planning, and to identify protection and improvement measures to be taken. In the outer islands of Kiribati, inspection of water supply infrastructure was previously conducted in donor projects by ADB and documented in Falkland (2003). The main water supply infrastructure inspected includes the following:

- Household wells, including bailers for water abstraction.
- Shared or communal wells comprising of at least one *Tamana* pump and shared amongst numerous families.
- Village wells comprising of a solar pump, a storage tank, distribution pipe and nominated tap stands around the village.
- Infiltration galleries comprising of horizontal galleries allowing groundwater to be skimmed across a larger land area, a solar pump system, distribution pipe and nominated tap stands around the village.
- Household rainwater harvesting system, comprising a roof catchment, guttering and storage tanks.
- Communal rainwater harvesting system comprising of a roof catchment, guttering, down pipes, storage tanks, underground concrete cisterns and either taps or bailers for rainwater abstraction.

7.1 Purpose

To ensure that all water supply system infrastructures in the outer island communities are regularly assessed, documented and reported to both Island Council and WEU, MPWU, for appropriate and timely maintenance and potential scheduling of improvements.

7.2 Current Practice

Very little inspection on the status of water supply infrastructure has been done recently, with the last inspection report dated more than a decade ago in 2004. This lack of inspection is of concern in relation to the changes or improvements required in water supply systems in the islands. The 2013 KIRIWATSAN survey permitted an update of the 2003 inspection report, for the project's selected villages within the 8 islands. According to Martin Mataio (pers. comm. 2015), existing procedures for water supply inspection has not been consistently implemented and maintained for the outer island communities because of:

1. budgetary limits from the GoK to attend to all maintenance work, particularly the replacement of solar pumps and tanks;
2. unavailability of spare parts locally (both on the outer islands and in Tarawa); and
3. difficulty for suppliers to continue providing suitable materials due to technological advancement and changes in the market forces.

Table 5 shows the water supply inspection (Martin Mataio, pers. comm. 2015) conducted on Abaiang Island in 2003, together with the recent KIRIWATSAN survey.

Table 5. Water supply infrastructure inspection report on four (4) KIRIWATSAN target villages in Abaiang Island (Loco et. al., 2015), together with the previous inspection report in Falkland (2003).

Village/School	General Description of the Water Supply System (Falkland, 2003)	Condition of the Water Supply (Falkland, 2003)	Condition of the Water Supply 2013
Tebunginako	Communal system consists of 2 wells and 7 hand pumps.	All hand pumps broken and distribution pipe partially removed. When working, the well water was reported to have low salinity (was pumped from wide part of island).	Thirty-six wells surveyed dominated by low salinity wells, most of which requiring infrastructural improvement. Catholic church has 3 rainwater tanks but need significant infrastructural improvements. Existing system is reported to be accessed by church members only.
Aonobuaka	Communal system consists of a solar pump (0.125 Hp diaphragm) for primary school, several (9) hand pumps and 2 wells.	Solar pump not working (removed). Hand pumps not working and distribution pipes removed.	Fifty-five wells surveyed (including JSS and Primary School) dominated by low salinity wells, with most wells inadequately equipped. Several communal buildings have good roofing materials and catchment areas but require significant infrastructural improvement.
Tuarabu	Communal system for primary school consists of a solar pump (0.125 Hp diaphragm) at a well, head tank and 5 taps. Private wells in village.	System at primary school is working. Low salinity water.	Ninety-two (92) wells surveyed (including St Joseph College) with 21 operational hand pumps – most wells are inadequately equipped. Well and rainwater systems at St Joseph College, while operational, need to be rehabilitated due to highly deteriorated condition. Solar pump at secondary school is operational and there are reports of elevated salinity, possibly due to over-abstraction. Primary school solar panel was reported stolen. Forty-one existing tanks were assessed, with several buildings having potential for improved rainwater harvesting.
Taniau/Tebwanga	Private wells. No communal system.	Low salinity water.	Fifty-four (54) wells surveyed with 26 operational hand pumps. Low salinity wells with a handful of wells completely covered and accessed via *Tamana* pumps. Six existing rainwater tanks were assessed, together with the existing buildings. Communal buildings have good roof catchment but require significant infrastructural improvements.

7.3 Recommendations for Improvements

1. Standardised training on water supply inspection and basic maintenance should be conducted for all OIWTs and village representatives nominated by the community.

2. Elements of inspection should focus on:
   - status and repair of solar and *Tamana* pumps;
   - assessment of main distribution lines;
   - availability, procurement and storage of spare parts;
   - leakage detection and assessment of necessary repairs; and
   - general plumbing work to maintain operating groundwater supply system and rainwater harvesting system.

3. Assessment of existing water supply infrastructure through the following arrangements:
   a. Every village should appoint a water supply caretaker personnel or group and agree on a schedule of inspection to be conducted around the village.
   b. The appointed personnel should conduct regular and routine inspection and any observed malfunction(s) be reported to the village and OIWT in a standard report.
   c. OIWT to be updated or informed of the water infrastructure status (or any repair and maintenance needs) during the quarterly groundwater monitoring schedule
   d. Urgent maintenance needs be immediately reported to the OIWT for timely intervention.

4. Inspection reports should be verified by Island Clerk or Mayor before being sent to the WEU-OIC.

5. The WEU-OIC should:
   a. confirm receipt of the inspection report; and
   b. verify the report, provide feedback and archive for future comparison and evaluation.
   c. Design and recommend a suitable maintenance plan in a timely manner through the:
      i. confirmation of funding availability from either the government or community;
      ii. establishment of agreements with both local and overseas suppliers and contractors to provide specified materials long-term;
      iii. procurement of a store of basic spare parts; and
      iv. shipment of materials and supervision of work on the islands.
      v. Ongoing communication with the OIWT and the Island Council and village representatives.

6. Suggested features for improved groundwater and rainwater harvesting systems infrastructure are summarised in Table 6. Design principles of the systems are outlined by Sinclair et al. (2015).

Table 6. Suggested water supply infrastructural improvements.

Improved Rainwater Harvesting System	Improved Household and Communal wells	Improved Village wells or gallery systems
• Installation of proper guttering to cover the entire roof area. • Installation of down pipes, transmission pipes and inlet screens. • Installation of additional tanks, with outlet taps and adequate drainage. • Removal of overhanging vegetation to prevent roof catchment contamination from falling leaves and other organic matter, and access by animals. • Installation of first-flush elements, where suitable, to minimise contamination from dust. • Installation of screens on tank inlets to protect freshwater from organic matter, and access by mosquitoes. • Construction of fencing around the storage and outlet areas to minimise damage. • Construction of concrete cisterns for additional storage and water security.	• Substitution of coral rocks by locally-made concrete rings as casing/lining material to prevent the ingress of surface runoff and providing an additional length as parapet. • Providing proper covering to prevent the entry of foreign matter and reduce the growth of algae. • Use of concrete as apron material to prevent the infiltration of surface water close to the well. • Construction of fences to protect well infrastructure and minimise access by animals. • Use of *Tamana* pumps to reduce the need for direct access to wells and the potential of contamination from bailers. • Use of bailer stands to keep bailers off the ground where bailers continue to be used. • Decommissioning and/or relocation of wells too close to potential contaminant sources. • Backfilling of all abandoned wells up to ground level. • Boiling of all well water prior to any human consumption.	• Use of concrete rings. • Use of fitted well covers with access holes for submersible pumps and electrical cables. • Construct solar panel structures and over-head tank stands adjacent to the wells. • Install flow meters and non-return valves between the well and storage tank to monitor and regulate abstraction and flow. • Construct fence around these infrastructure for protection. • Use polyethylene distribution pipes as main line. • Install gate-valve near taps stands for isolation and flow control. • Construct taps at nominated areas.

7.4 Reading List

1. GWP, 2011. Rainwater harvesting guidelines: design, construction and specifications: Government of Kiribati, Tarawa.
2. Sinclair, P., Loco, A., and Mataio, M. (2015). KIRIWATSAN technical notes on water supply design principles. Suva: Geoscience Division, Secretariat of the Pacific Community.
3. Mudaliar, M.M., Bergin, C., MacLeod, K. (2008). Drinking water safety planning – a practical guide for Pacific Island Countries. World Health Organisation and Pacific Islands Applied Geoscience Commission Joint Contribution Report 103, Suva, 104p.
4. KIRIWATSAN database – http://ict.sopac.org/kiriwatsan/

8. DATA ANALYSIS AND MANAGEMENT

Water resources data, be it rainfall or groundwater level measurements or bacteriological sampling and analysis require significant effort and resources. All OIWTs and the WEU-OIC hence have the responsibility to ensure accurate record-keeping, archiving and dissemination of accurate, of reliable and accessible water resources information for each island.

8.1 Purpose

To ensure that all acquired monitoring data is properly recorded, systematically stored, archived, backed up, and shared with adequate data quality assurance elements, to enhance their accuracy and reliability in order to develop interest and confidence amongst relevant authorities providing useful long-term data analysis for improved management of water supplies.

8.2 Current Practice

1. Rainfall data, as mentioned in Section 3, are collected and initially processed by the OIWT. OIWTs transfer all the acquired data to the WEU-OIC; retaining a copy. The WEU, MPWU provide copies of the rainfall records to the KMS. The WEU-OIC is responsible for archiving these records in digital format. KMS are responsible for archiving the records into the National Climate database and for quality assurance and providing the data to relevant parties.
2. Periodical groundwater level and salinity measurements data are transferred to the WEU-OIC. These data are to be archived in digital format at the WEU, and can only be shared with relevant authorities at the WEU-OIC's discretion.
3. *E.coli* sampling and analysis of water sources is rarely undertaken by either MPWU or MoHMS in the outer islands due to logistical issues. This is of concern whereby there is very limited long-term and consistent information available on the quality of water supplies in villages; and the

causality of the health of the population due to contaminated water supplies and inappropriate sanitation.

8.3 Recommendations for Improvements

i) Establishment of quality assurance/quality control procedures

Quality assurance (QA) and quality control (QC), refer to mechanisms or routines that allow the timely and appropriate checking of survey methods and results to ensure accuracy and reliability. These should form an integral part of all water resources monitoring activities to ensure the representativeness and reliability of the data.

The establishment of QA\QC procedures should be practical and target outer island water technicians, island council representatives, MPWU, KMS and MoHMS staff, to improve the design and implementation of quality monitoring activities.

Outlined in Table 7 are several suggested procedures and basic steps to ensure that high quality data is collected.

ii) Improved data interpretation and system analysis

Reliable and long-term data sets are essential for the efficient management of water resources. Resourcing of long term monitoring inclusive of salaries, materials and training while expensive is necessary to ensure consistency and reliability in data sets. The adage “You cannot manage what you do not measure” reinforces the relationship between reliable long term data sets and the development of effective water resources policy and management.

It is suggested that WEU be guided by some simple principles to ensure long term usefulness and reliability of data sets:

- Use readily available and established data analysis methods for interpretation of monitoring data.
- Provide standard report templates for rainwater and groundwater monitoring.
- Data should be digitised and archived to a dedicated database (KMS national climate database, KIRIWATSAN).
- Agreed schedules for regular data collection and data transfer for each island are maintained.
- Establish internal QA/QC mechanisms to ensure the reliability and accuracy of raw data.
- Conduct regular data analysis and data quality checks.
- Provide feedback to OIWTs on data collection and follow up with OIWT’s needs and requests for support.
- Assess the performance of island-specific monitoring programme systems and suggest improvements when needed.
- Provide opportunities for regular (annual) trainings and review of datasets.

The intent is to promote a strong relationship between the WEU and all OIWT, as well as other relevant authorities, to strengthen and sustain a water-resources monitoring programme and build confidence in technicians and the data they collect.

Table 7. Suggested procedures and basic steps to follow to ensure high quality data is collected.

Rainfall measurement	Groundwater level and salinity measurement	Water *E.coli* sampling
1. Make sure that measurement or reading is recorded daily and the collection tube is cleared after every measurement event. 2. Records are recorded at 9am on a daily basis and in accordance with the established procedures 3. Ensure that any possible interference from surrounding vegetation is prevented through regular trimming and clearance. 4. Monthly rainfall records should be reviewed by Island Council representative and feedback provided to both the technician and WEU-OIC. 5. WEU OIC to ensure that rainfall measurements are undertaken in accordance with established procedures and impose appropriate penalties if work is not carried out. 6. Questions should be prompted at the Island Council and MPWU if daily records are missing. 7. Always have a carbon copy of all daily, weekly or monthly rainfall kept in the Island Council office for future reference and backup. 8. Ensure that all rainfall measurements are verified internally at the WEU before electronic storage.	1. Ensure all necessary equipment is calibrated, charged and in good working order prior to any monitoring run. 2. Advise the WEU OIC if additional equipment, batteries, or calibration standards are required prior to the next monitoring run. 3. Always have stationery to record measurements. 4. Ensure that monthly records are sent to the WEU-OIC in a timely manner. 5. Ensure that all groundwater records are verified internally at the WEU before entered into a database (KIRIWATSAN) and archived. .	1. Make sure that sampling equipment is adequately sanitised and three sample bottle volumes are used to wash the bottle to minimise any cross-contamination. 2. Make sure that samples are properly and correctly labelled to avoid any confusion. 3. Always have standards or controls, from either bottled or boiled water, and/or field duplicates from known sources, to test the accuracy and reliability of the sampling procedure. 4. Follow sampling and analysis procedures carefully to ensure confidence in results. 5. Ensure that sufficient care is taken during analysis to maintain a clean working environment to minimise cross contamination. 6. Ensure that *E.coli* results are sent to both MPWU and MoHMS for review.

iii) Reporting

It is imperative that water resources monitoring data are compiled in a standard report format that reflects water resources status during both normal and extreme climatic and tidal events. These reports, as per the suggested template provided below, will:

1. assist stakeholders at the national and island scale to review the status of the water resources and identify any emerging trends or impacts long term or from specific events.
2. allow regulatory authorities and stakeholders to plan and prepare for current and predicted issues resulting in improvements in water and sanitation issues in outer islands.

This will require a certain level of training and experience for all relevant authorities to better understand and interpret the information available and to ultimately improve on what information is required and how regularly it is provided. Examples of information that should be included in water resource monitoring data reporting include:

- Site-specific details (village, island name) and date of report.
- Water quality data and interpretation of this data (check if anomalous figures are recorded
    - For groundwater salinity records at the top and base of the well and comparison with past records will be important.

      For groundwater level, measurements should be taken in relation to a known reference point at ground level and comparisons made with past records and the tides.
    - For bacteriological assessment, the WHO guideline value for drinking water is 0 *E.coli* count/100 ml, where possible quantification of E coli should be regularly performed in selected wells to improve the understanding and risk of different water sources.
- Identification of any issues (e.g. deteriorating water quality in a specific site/village, noticeable increase in salty taste in public water supply sources; and high incidences of diarrhoea).
- Recording of the details of any incidents or factors potentially affecting water quality (e.g. wave over topping or extreme tidal events, rainfall events, location of potential contaminant source).
- Details of actions undertaken to address any water quality issues.
- Location map at appropriate scale.
- Commitments to specific areas for improvement in the next reporting period.

Newly excavated wells, infiltration galleries and potential rainwater harvesting structures should be registered as per the survey form templates provided in Annexes 2 & 3. This new information should be entered into the KIRIWATSAN I (KW1) database to expand its spatial coverage into other outer island communities.

iv) Linkage to KIRIWATSAN database

It is recommended that all water resources data should be incorporated into a digital database so that it is accessible into the future. A simple web-based database which can be updated and with basic interrogation was developed under the KIRIWATSAN Project, this KIRIWATSAN 'Water Resources Assessment" database is considered to be a useful entry point as a national, accessible store of groundwater information for the outer islands.

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

The database was designed to archive and display water resources information from well surveys, RWH assessments and storage tank conditions, of all the target villages on the eight (8) islands, namely Makin, Marakei, Butaritari, Abaiang, Maiana, Nonouti, Nikunau and Beru. The database allows the storage and viewing of the following datasets:

- All surveyed household wells and associated attributes, namely location, well construction and condition, water abstraction methods, water use, groundwater level (m), groundwater salinity, groundwater bacteriological status, proximity to contaminant sources, and site photos.
- RWH buildings, including location, roofing dimensions and, guttering and fascia board condition, and site photos.
- Existing storage tank dimensions, location, condition, and site photos.

Nevertheless, it is anticipated that the functionalities of the database may be improved and strengthened to permit the archiving of the following:

1. Island-based monthly rainfall data and perform basic statistical analysis.
2. Ongoing monitoring of water sources from rainwater and well water.
3. Historical records of island- or village-based water supply infrastructure information.
4. Information on newly-excavated household wells or village wells and rainwater harvesting systems.

The database could be expanded to cover all outer islands of Kiribati, enhancing the relevance and access to updated water resources information to a range of users. This will require dedicated resourcing and coordinated effort of the WEU within the MPWU to:

- undertake the regular and periodical updating of water resources data from all the islands into the accepted format of KIRIWATSAN database;
- conduct frequent data quality checks to ensure the accuracy and reliability of the information; and
- encourage the sharing of the database with all relevant stakeholders. The database being web based is currently accessible by all with a read only access. http://ict.sopac.org/kiriwatsan/

MPWU, with the support of government stakeholders, such as MELAD, MFMRD, should seek additional resources to sustain this initiative.

Table 8. Suggested approach to data handling, analysis and reporting.

Monitoring Parameter	Data Acquisition	Data handling and analysis and storage format at WEU	Quality assurance routine	Data report template and numbers
Rainfall records	• Daily rainfall measurements conducted by OIWT • Measurements recorded in the field form verified by Clerk of Island Council • Daily rainfall records sent by post to WEU-OIC in Tarawa	• Data received by post • Data is certified and archived by WEU-OIC • Data provided to KMS for archive in national climate database	• Island Council to undertake regular monthly checks on OIWT rainfall record books before data is forwarded to Tarawa • WEU-OIC to undertake checks on data including comparative analysis with historical data	• Monthly rainfall data comprising: o Island name, date of reporting, tabulated daily and monthly rainfall data o Additional comments from both Island Council and WEU-OIC • Updated monthly report by MPWU • Annual rainfall summary of islands to be shared to interested authorities • Raw rainfall data provided to KMS for review and archiving
Groundwater level and salinity	• Periodical (quarterly) groundwater level and salinity measurements conducted by OIWT • Measurements recorded in the field book that is verified and sighted by Island Council Clerk • Transfer of groundwater level data to WEU-OIC in Tarawa by post • During extreme events such as prolonged dry periods and/or storm surge, more frequent field data collection may be required for affected areas	• Data received by post • Data is reviewed, certified and archived by WEU-OIC • Data entered into database, such as KIRIWATSAN database or island spread sheet • Upon request data is shared with other relevant authorities • MoHMS • Island Council and • National Disaster Office	• Island Council to undertake regular quarterly checks on OIWT groundwater level and salinity record books • Island Council should sight and verify all quarterly records before sending to Tarawa • WEU-OIC to conduct checks on data including comparative analysis with historical data	• Island Groundwater level monitoring report should include: o Village name o Survey date/time o Groundwater level (m) and salinity EC (mS/cm) o Comments on anomalous groundwater level and salinity • WEU-OIC to review or analyse groundwater level data and provide feedback • Summarised island groundwater level and salinity results should include: o Reporting period o Island-wide groundwater level

Monitoring Parameter	Data Acquisition	Data handling and analysis and storage format at WEU	Quality assurance routine	Data report template and numbers
				and salinity monitoring o analysis of current groundwater level and salinity results o implication on island-wide groundwater abstraction and management
Water *E.coli* bacteriological sampling	• Periodical (annual or as needed) *E.coli* measurements conducted by OIWT and MoHMS staff on both groundwater and rainwater sources used for drinking depending on available sampling apparatus and storage facilities • During WASH outbreaks or extreme climatic events, urgent and more frequent *E.coli* sampling of drinking water sources may be requested	• Data received by post • Data is reviewed, certified and archived by WEU-OIC & MoHMS OIC • Data entered into appropriate database, such as KIRIWATSAN or existing MoHMS • Upon request data is shared with other relevant authorities o Island Council and o National Disaster Office (NDO)	• WEU-OIC and MoHMS OIC should review sampling and analysis methodology and *E.coli* results	• Village or Island Water *E.coli* monitoring report must include: o Village name o Survey date/time o *E.coli* status or count o Comments on anomalous *E.coli* trends on drinking water sources • WEU-OIC to review or analyse *E.coli* report and provide feedback to Island Council and affected villages • Raw water quality data should be provided to MoHMS for review and archiving • Summarised island *E.coli* results should be shared with NDO and other authorities

9. LOGISTICAL CONSIDERATION AND FUNDING

The previous sections highlight the technical aspects of a water resources monitoring programme in an outer island setting. These improvements will require access to additional resources, including equipment for fieldwork, transport and trained personal, which in turn, will necessitate major logistical adjustments and financial assistance (Hasan & Aalbersberg (2008)). This section will outline relevant logistical considerations and financial cost implications.

9.1 Purpose

To highlight key logistical support and major financial needs for an effective water resources monitoring programme in Kiribati's outer islands.

9.2 Current Practice

At present, the key activities carried out by the OIWTs are groundwater level and salinity measurements, and water supply inspection. As such, limited funding is allocated by the Government to allow completion and reporting of these activities.

According to Martin Mataio (MPWU Hydrogeologist, interview, May 2015), the major costs around outer islands monitoring include transport, including bike hire and boat hire, and fuel. A summary of these costs is provided in the Table 9.

Table 9. Major costs involved in conducting groundwater level and salinity measurements, usually given to OIWTs (Source: Martin Mataio, MPWU Hydrogeologist, interview, May 2015).

Items	Rate
Motor Bike Hire	$20/day
Fuel	$5/day
Boat Hire to islet	$100/return trip
Boat Fuel	$40

Table 9 does not include equipment and consumable costs such as:

- replacement or repair of TPS W84 salinity meter;
- purchase of measuring tapes;
- maintenance of rain gauge;
- fuel for generator to charge TPS internal battery;
- purchase of stationery; and
- Procurement of *E.coli* sampling consumables.

It is worthwhile noting that logistical needs and costs will vary from island to island depending on variables such as:

1. island sizes and village sizes;
2. number of wells identified for monitoring
3. presence of islet(s); and
4. presence of existing water systems from previous donor projects (Martin Mataio, Hydrogeologist, interview, May 2015).

For instance, an island like Abaiang, which has eighteen (18) villages, including two (2) inhabited islets, namely Noutaea and Ribono, it is estimated to take 4 to 5 days to conduct routine monitoring compared with Marakei, estimated to take 2 to 3 days for current monitoring demands. Despite these differences in the number of days required between islands, in each case there is significant costs imposed which needs to be funded as per the major costs shown in Table 9.

It is also noted that OIWT do not have proper office space within the Island Council, even though they are responsible for the inspection and assessment of all water supply across the island. It is important that there is a space available for OIWT to be able to review and archive monitoring data records as well as store equipment, tools and spare parts.

9.3 Recommendations for Improvements

For an effective monitoring programme in the outer islands, the following logistical considerations should be made:

i) Technical Equipment and Field Support

a) Improvement of technical and equipment support such as the following:

- Regular training of OIWTs and community representatives on groundwater and rainwater assessment and monitoring.
- Periodical replacement of monitoring equipment, including (but not limited to) salinity meters, tape measures, standard calibration solutions, buckets and other sampling equipment.
- Purchase of consumables namely, generator fuel, transport fuel, boat hire and motor-bike hire, stationery, generator cost of posting of reports and data.
- Procurement of suitable *E.coli* sampling apparatus and ongoing consumables.
- Establishment of OIWT office space in Island Council area.
- Establishment of internal QA/QC mechanisms at both island and national levels.
- Upgrading and updating water resources database with all outer islands water resources information.
- Basic tools for undertaking water supply repairs.
- Provision of basic transport, motorbike hire or purchase.

b) Should internet coverage in the outer islands improve significantly, consideration should be given to:

- assigning a laptop to each OIWT to permit electronic data entry and storage in remote areas; and
- allocating monthly internet fees to allow the alternative mode of transmission of data via electronic mail.

c) Establishing linkages between MPWU and other relevant GoK authorities such as MoHMS, MIA, NDO and KMS to ascertain how parties can better coordinate; improve the transfer of technical skills, share costs in the management of water resources monitoring activities.

ii) National Level Support

With regard to its national obligation to public health, as well as the water security and improved livelihood of all i-Kiribati, there is a need by the GoK to incorporate water resources monitoring into its planning portfolio. The proposed monitoring programme will require a specific allocation of resources to ensure adequate funding is available for implementation. It is suggested that:

1. Improved water supply in the outer islands becomes a government priority. Monitoring of water resources is an essential aspect for developing improved water supplies, requiring specific budgetary allocation for monitoring. This could be facilitated through a more integrated approach amongst authorities to optimise support and results. The suggested approach could include the following:
    a. MPWU to conduct periodical groundwater level and salinity measurements and rainfall measurements through OIWT on a scheduled basis with all the basic logistical support available.
    b. MPWU and MoHMS to coordinate the scheduled bacteriological sampling and analysis on public or communal water supply in the outer islands.
    c. MIA to assist in the collection of regular reports on water supply infrastructure and the archiving of raw water resources information for the islands, coupled with support for the periodical review of all groundwater level, groundwater quality and rainfall records as part of their responsibility.
    d. NDO to consider funding and coordinating the collection of water level and quality data with MPWU and MoHMS during extreme events.

2. GoK to consider additional financial assistance to MPWU, MELAD, KMS, MIA and MoHMS, specifically in the aspects of monitoring and data management to:
    a. Improve and strengthen national capacity to undertake water resource activities.
    b. Strengthen the access to and the reliability of water resources data
    c. Provide special discretionary funding for monitoring to allow monitoring during extreme climatic/tidal events.

3. Financial management system should be established and practiced whereby proper acquittals are processed with adequate evidence (including routine monitoring reports) to permit the provision of future financial requests.

4. Donor agencies and organisations such as the EU, NZAID and ADB, be called upon to invest in outer island's monitoring activities as part of their ongoing support to the country.

5. Recognise that outer island communities need to operate autonomously for day to day water supply operation and management. In this regard they should be provided with the support mechanisms to further develop this self-reliance recognising that national government has an important coordination role and support with logistics. Island communities, due to their isolation, are cash poor and with limited resources and access to equipment, skills, and consumables. The national government can provide the necessary support to promote the self-management and operation, as well as the reporting structures to assist national government with its overall coordination of resources across its many isolated communities.

10. LINKAGE TO EXISTING POLICIES FOR OUTER ISLANDS

The proposed activities highlighted in these monitoring guidelines will need to support and link into existing and proposed water and development policies for outer islands to generate longer term sustainability. This will require a commitment by other aspects of Kiribati government to support MPWU to undertake this coordination role.

10.1 Purpose

To promote integrated water resources policies that supports the governance and management of water resources through evidence based long-term monitoring.

10.2 Current Practice

The current institutional arrangement within the GoK with respect to the governance and protection of water resources include the WEU, PUB, MoHMS, MIA and MELAD (ADB, 2004), each enacting the following policies:

- Public Utilities Ordinance (1977)
- Land Planning Ordinance (1977) & State Lands Act (2001)
- Environment Act (1999)
- Local Government Act (1994)

Most of these policies were designed in response to the delineation and management of the Bonriki Water Reserve in South Tarawa. ADB (2004) recorded that these institutions operate in a fragmented manner focussing on their specific areas of interest and they have failed over time in:

- appreciation of needs, culture, land tenure and land-use requirements of the local communities;

- demonstrating institutional capacity in terms of both human and technical resources;
- enforcement of existing provisions in the current framework to safeguard groundwater resources; and
- improving awareness levels on factors affecting water quality.

Furthermore it is suggested that continuing and considerable difference of opinions exist between the Government, Island Councils, villages and families on the ownership of water resources and any land issues associated with the protection of water resources and water supply systems hampering further development and management of water supply systems.

White and Falkland (2010) highlighted six major objectives that need to be addressed in government policies that will help return control of the coordinated protection and management of water resources to both local and national levels. These include:

- improving understanding and monitoring of water resources and their use;
- increasing access to safe and reliable water supplies and appropriate sanitation;
- achieving financial, social and environmentally sustainable water resources management;
- increasing community participation in water management and conservation;
- improving governance in the water and sanitation sector; and
- providing training opportunities for the mentoring of staff in the sector.

It is important that Government continues to address these issues in the outer island context of isolation and self-reliance to develop practical policies which promote ongoing dialogue with the Island Council and the outer island communities incorporating practical enforcement of policies and legislation, for improved protection and governance of water resources in the outer islands.

10.3 Recommendations for Improvements

It is suggested that:

i. GoK consider adopting these monitoring guidelines for water resources for use in the outer islands in relation to natural (climatic and tidal variabilities and/or extremes), together with human-induced (land-use and pollution) pressures.

ii. GoK create a TOR for adopting this monitoring guideline as part of the existing National Water Resources Policy.

iii. Key government authorities, namely MPWU, MoHMS, KMS, MIA, NDO and MELAD, should:

    a. explore the possibility of integrating existing legislation to address island-specific water-related challenges;
    b. incorporate the proposed monitoring guideline into their framework and work plan;
    c. identify and clarify responsibilities and cost capacity to design island-specific monitoring programme; and
    d. coordinate and periodically review the water resources monitoring programme.

iv. Island-specific water resources policies, under the guidance of key government authorities and the support of community groups/leaders, could be developed to accommodate existing by-laws and development plans for each island or village. This activity is aimed at strengthening the protection and management of freshwater resources and encouraging ownership at the local level.

v. Wide ranging consultations and awareness raising, and support, will be needed at both local and national levels to implement monitoring guidelines supported by a legal framework to assist in the management and protection of freshwater resources.

10.4 Reading List

1. Hasan, T., & Aalbersberg, W. (2008). Designing a drinking water quality monitoring programme – a practical guide for Pacific Island countries. SOPAC, Suva, 44p.
2. Mudaliar, M.M., Bergin, C., MacLeod, K. (2008). Drinking water safety planning – a practical guide for Pacific Island Countries. World Health Organisation and Pacific Islands Applied Geoscience Commission, Suva, 104p.
3. ADB (2003). Promotion of Effective Water Management Policies and Practices, particularly on:
    - Strategic Actions
    - Kiribati Water Sector Road Map
    - Groundwater protection

11. AWARENESS AND TRAINING PROGRAMME

Acceptance and resourcing of monitoring of freshwater resources at the national, local and community level will be critical to the long-term protection and sustainable management of freshwater in Kiribati. This section will present technical, financial and community aspects of supporting the awareness and training across different sectors of the GoK and in the outer islands.

11.1 Purpose

To highlight specific areas of training and awareness needed to support the implementation of these proposed guidelines in both the immediate and longer term.

11.2 Current Status

Awareness and training is undertaken in most projects, including water related projects such as ADB's Promotion of Effective Water Management Policies and Practices, EU-funded Pacific Hydrological Cycle Observing System (Pacific HYCOS), World Bank-funded Kiribati Adaptation Project (KAP) Phase 1, 2 and 3, AusAID-funded Bonriki Vulnerability Assessment (BIVA) and the EU-funded KIRIWATSAN Project, but is seldom seen as a core activity of line ministries in government. In general, awareness and training at the project level consists of engaging government officials in relevant ministries in key technical and administration activities to assist with specific tasks which have included in the past:

- Groundwater level and salinity monitoring around the Bonriki Water Reserve.
- Freshwater lens thickness estimation through geophysical techniques namely EM-34 and resistivity.
- Household and village wells infrastructure and water level assessment.
- Rainwater harvesting potential assessment,
- Design of culturally appropriate and gender sensitive water supply systems.
- Project planning and management.
- Data management and data analysis.
- Community consultations.

Significant efforts have also been made through specific projects to engage target communities in addressing:

1. key water and sanitation issues and needs;
2. gender sensitive and culturally-appropriate solutions; and
3. community contributions in the maintenance and governance of water supply and sanitation systems.

It is suggested that these lessons and approaches of these projects are utilised, supported and maintained by the Government to warrant the optimum engagement of island communities and the inclusiveness and sustainability water resource monitoring.

11.3 Recommendations for Improvements

Whilst basic water resource monitoring practices are established by previous projects, it is required that certain specific area, namely technical training, inter-departmental communication and community engagement, should be targeted and strengthened. These are outlined below:

i) Technical training

To be focussed on key water-related activities in the following areas:

1. Annual training on rainfall collection, reading and recording.
2. Routines and standardised training on rainwater harvesting potential assessment.
3. Annual groundwater level measurement practice.
4. Groundwater salinity measurement and equipment calibration procedures.
5. Groundwater and rainwater *E.coli* sampling and analysis procedures.
6. Basic water supply inspection and maintenance practice.
7. Proper data management and reporting routines.

ii) Inter-departmental awareness

Developing awareness across and between government departments on the use and application of water resources monitoring data will improve the support for water resources management and thereby the support for improved monitoring data as its benefits will be demonstrated. Data from monitoring, where widely shared and made accessible, will improve the demand for water resources data and encourage general support for improved water resources management. The following ministries have an interest in the development and support of outer islands and should be targeted for specific awareness activities:

- MPWU (including PUB),
- MELAD,
- MIA (including island councils),
- MFMRD,
- MFAED and
- MoHMS.

Awareness activities should include

1. Understanding of current water resources issues, particularly in the outer islands at the village level.
2. Acceptance of the need for water resource monitoring guidelines into the GoK work/development plan.
3. Consideration of the budgetary and logistical requirements for monitoring of water resources and associated cost benefit analysis on that investment.
4. Establishing communication lines between relevant ministries to better understand common objectives and develop opportunities for coordinated actions.
5. Improved understanding of the current water resources policy and how monitoring is an integrated part for to improve the governance and sustainable management of water resources in the outer islands.

These awareness activities will help to improve general understanding of needs and identify legislation shortfalls which may result in improvements in island-specific or generic water-related legislation and policies.

iii) Community awareness & education

Water resources in outer islands are in general considered to be owned, operated and managed by the communities which access them. Critical in the management and protection of water resources, is to engage the communities and island village councils that rely on these water resources, as it is these stakeholders who ultimately have the most vested interest in the sustainable management of their water resources. Awareness raising and education should include:

- Understanding the linkages between groundwater processes and human activities and *E.coli* contamination.

- Establishment of a village water committee to undertake routine water supply inspection and maintenance.
- Understanding of climatic impacts and man-made over-abstraction impacts on water resources.
- Understanding of possible climate change events and how communities should adapt.
- Re-aligning the village development plan with consideration of the available freshwater lens areas.
- Formulation of village-based by-laws to safeguard freshwater resources and associated infrastructure.

11.4 Reading List

1. Hasan, T., & Aalbersberg, W. (2008). Designing a drinking water quality monitoring programme – a practical guide for Pacific Island countries. SOPAC, Suva, 44p.

2. Mudaliar, M.M., Bergin, C., MacLeod, K. (2008). Drinking water safety planning – a practical guide for Pacific Island Countries. World Health Organisation and Pacific Islands Applied Geoscience Commission Joint Report 103, Suva, 104p.

12. CONCLUSIONS AND RECOMMENDATIONS

The protection of highly-vulnerable fresh groundwater resources of the outer islands of Kiribati requires the formulation, implementation and maintenance of a sound water resources monitoring programme to:

1. improve the understanding of the groundwater resources, particularly those factors which impacts on its availability and use;
2. improve the protection, governance and access to designated public water source areas; and
3. improve the livelihood, security and public health of communities in response to climate variability and climate change effects.

Major recommendations will be grouped in two parts under technical and management aspects.

i) Technical improvements include:

1) Training and capacity building is required on a routine basis for key positions in the governing authorities, including OIWT, medical assistants, village representatives, and Island Council representatives to both refresh staff in these roles and train new staff. This training should include (but not be limited to) the following:

- Regular training of the following water resources monitoring elements:
    - recommended rainfall and groundwater data collection practices;
    - appropriate water quality assessment techniques;
    - basic plumbing and design and maintenance of water supply systems.

- Recording of data and presentation on water resources to be consistent. Establishment and implementation of QA/QC mechanisms for data reliability.
    - Archiving of information for future analysis.
    - Development of locally appropriate reporting templates and practices.
    - Maintaining an accessible database, such as KWI database and associated training.

2) Provision of adequate funds from GoK to ensure that the required logistical support is available to conduct the following:

- Routine rainfall measurements and its associated QA/QC routine and data transfer to Tarawa.
- Routine water resource monitoring across the island and the associated data recording, transfer and management (in Tarawa).
- Routine inspection of water supply infrastructure and its associated data transfer/management (to Tarawa).
- Periodical collection and analysis of *E.coli* counts in all drinking water sources and its associated QA/QC protocols and data transfer and management.
- All the above activities during and after extreme climatic and tidal events.

ii) Management improvements include:

1) Strong data management protocols will allow the acquisition, recording, storage and sharing of high quality data required for meaningful island-based planning and water resources management in the long term.

2) Generating enough funding with the GoK to sustain the proposed monitoring programme through:

- providing adequate budgetary allocation through various GoK authorities to undertake activities is critical;
- the sharing of long-term groundwater and rainwater monitoring costs as well as during natural disaster events; and
- establishing suitable financial management system to sustain the monitoring programme.

3) Improving and strengthening the integration between key government authorities through frequent/strong communication, planning and coordination towards:

- adopting the monitoring guidelines as a tool for improved water resources understanding and management;
- cross-sectoral water resources monitoring to enhance its governance, management and protection; and
- establishing island-specific water resources policies that will guide the community groups on the assessment, improvements and monitoring of freshwater resources.

Table 10 illustrates the different water quality parameters and simple tests available to assess these parameters in the field.

Table 10. Various water quality field-testing methods and associated estimated costs.

Parameter	Water Source	Technique	Level of training required	Instrumentation required	Calibration/Method	Estimated Cost	Good Laboratory Practices
Salinity	Well Water/ Rainwater	Portable TPS	Basic training required Efficient to use in the field	TPS WP84 Salinity meter, Hanna EC tester	Require 2.76 mS/cm calibration standard. Recommended to do calibration each morning of field survey.	$1200 AUD	Date, time and results of last successful calibration are stored, and can be recalled when required. GLP information can be printed or downloaded to PC with the RS232 serial port interface. Warning of failed calibration is provided.
Temperature	Well Water/ Rainwater	Portable TPS	Basic training required Efficient to use in the field	TPS WP84 Salinity meter, Hanna EC tester	Temperature Compensation, Automatic, 0˚C to 60 ˚C.		
Microbiology *(E.coli* and Total Coliform)	Well Water/ Rainwater	EC Compact Plate	Requires rigorous training Most appropriate for quantification of *E.coli* and Total Coliform	EC Compact plate, 5 ml/100 ml syringe, 0.45 µm filter paper, filter housing, sample bottles, tweezers, distilled water, incubator, detergent	Refer to Annex 7 for methodology	$3 AUD per test	Sample collection and preparation as per procedure outlined on Annex 7
	Well Water/ Rainwater	Collilert 18	Basic training required Presence and absence test only, no quantification	Collilert reagents, sample bottles, uv lamp	Refer to Annex 7 for methodology	$4 AUD per test	
	Well Water/ Rainwater	Hydrogen Sulphide Test	Basic training required Presence and absence test only, no quantification	Hydrogen Sulphide Reagent, sample bottle, incubator	Refer to Annex 7 for methodology	–	
Nitrates	Well Water/ Rainwater	Nitrate and Nitrite Test Strips	Basic training required Efficient to use in the field	Nitrate and Nitrite Test Strips, sample bottles	Nitrate 0 to 50 mg/L ppm NO3--N, Nitrite 0 to 3.0 mg/L ppm NO_2--N	$50 AUD/25 Test strips	

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Personal Communication

Martin Mataio (30 May 2015), Hydrogeologist, Water Engineering Unit, MPWU (A. Loco, Interviewer)

14. LIST OF ANNEXES

1 – Conventional Rainfall Measurement and Recording Techniques

2 – Rainwater Harvesting Field Survey Sheet

3 – Groundwater Well Field Survey Sheet

4 – Detailed Instructions for Groundwater Level and Salinity Measurements

5 – TPS WP84 Conductivity Meter Operation and Calibration (TPS Ltd, 2014)

6 – Sampling procedures for Drinking Water (Olszowy, 2008)

7 – Bacteriological contamination field procedures for presence of *E.coli*/Total Coliform

- i) Collecting water samples for *E.coli* analyses
- ii) Water sample collection - SOP
- iii) *E.Coli* sampling procedures
- iv) EC-compact plate sampling procedures
- v) H_2S strip method procedures

Annex 1

Conventional rainfall measurement and recording techniques

PART A – HYCOS MANUAL RAINFALL INSTALLATION AND OBSERVATION INSTRUCTIONS

General Rules to collect Rainfall Data

1. The rain gauge must be checked and cleared of any debris, grass, leaves, or insects regularly and grass is is to be kept low and clear of the raingauge.
2. The log book comes with log sheets to accommodate three years of data. For each month there will be three sheets, one original and two carbon copies.
3. Site name/number and the month and year are essential to filled in. The log sheet is of no use if site and month is unknown.
4. The raingauge must be read for data at 9.00am country standard time everyday. A 24hr period would then hence be from 9.00am to 9.00am.
5. Enter rainfall for the preceding 24 hours, measured in millimetres to one decimal place, at 9.00am on the date it was measured.
6. After each reading is taken the measuring cylinder or flask must be emptied and correctly seated in the gauge.
7. Should an observation happen to be missed, measure the accumulated rainfall. Then enter the reading as usual, but bracket the dates from the last reading to show that it is not a single day's rainfall. In the Comments Colum write "2 day reading" "3 day reading" etc as applicable
8. When there is no rainfall/precipitation, NO entry should me made in the "Rainfall" columns (no 0000, Nil or dots). However a comment of "no rain recorded" can be made in the weather conditions and comments column.
9. If the rainfall collected is less then 0.1mm then enter "TRACE" in the "rainfall" column.
10. The time column must be filled in the actual time of reading irrespective of the standard 9.00am.
11. If it is raining at the standard reading time, wait for the rain to stop and take a reading then, recording the time and filing comment that delay in reading.
12. Initials of the observer are compulsory; it is advisable that the actual name and the resulting initials are stated at least once in the "Additional Comments" right at the bottom of the page for future reference.
13. General weather conditions at the time of reading and from previous day or night should be recorded.
14. The person who takes the last reading for the month must add up the total and fill in the other details required at the bottom of the page before forwarding sheets for data entry and archive.
15. "Annual Accumulated total end of previous month" is the total of all previous months of rainfall for that year. (This would be the "Annual Accumulated Total to date" from the previous log sheet brought forward)
16. "Annual Accumulated Total to date" is total of all rainfall recorded till the end of that month and should be filled in at month end. (This shall be carried forward to "Annual Accumulated total end of previous month" for the next month)
17. Make note of any general comments on maintenance, grass clearing etc in the "Additional Comments".
18. At the end of each month the completed logsheet will be taken out by the observer and forwarded to the Meteorological office for registering and data entry. One carbon copy shall be provided to the alternate data archival location (NHS, PWD, SOPAC),and the third left in the log book
19. Refer to the Example Log sheet on the next page.

PACIFIC HYCOS
PACIFIC HYDROLOGICAL CYCLE OBSERVING SYSTEM

MANUAL RAINGAUGE OBSERVATIONS

SOPAC Raingauge (Name of Station)	999 (Station Number)	May (Month)	2009 (Year)

Date	Time of Reading	RAINFALL (millimetres) Hundreds	Tens	Units	Tenths	Weather Conditions and Comments	Initials of Observer
1	9.00am			2	·6	Fine weather, early morning drizzle	KR
2	8.52am				·	No rain recorded	KR
3	9.12am		1	0	·2	Rained early morning. Clearing by 9am	KR
4	10.25am		3	6	·3	Delay due to heavy rain at 9am	LY
(5					·		
6)	9.03am		8	5	·5	2 Days	KR
7	9.01am				·	No rain recorded	LY
8	9.15am	TRACE			·		KR
9	9.00am			6	·4	Drizzle last night	KR
10	9.08am			9	·8	Light showers at night	KR
11	9.10am				·	no rain	KR
12	9.06am				·	no rain	KR
13	9.03am		3	4	·8	Fine now. Heavy rain last night	KR
14	9.00am			8	·4	Light rain. Weather fine at recording	KR
15	9.16am	TRACE			·		LY
16	9.00am			0	·8	Drizzle early morning	LY
(17					·		
18					·		
19)	9.00am			0	·4	3 days (no significant rain noted)	KR
20	9.08am	TRACE			·		KR
21	9.00am			0	·4	Grass, debris cleared. Rain slightly	KR
22	9.12am				·	no rain recorded	KR
23	9.10am				·	no rain recorded	KR
24	9.15am	TRACE			·		LY
25	9.06am			1	·2	Slight rain early morning	LY
26	9.00am				·	No rain. Fine conditions	KR
27	9.03am				·	No rain recorded Sunny, Fine weather	KR
28	9.10am		4	3	·2	Heavy rainfall	KR
29	9.16am		2	2	·8	Rainfall previous night	KR
30	9.00am	TRACE			·	No rain observed	KR
31	9.00am	TRACE			·	Fine now. No rainfall observed	KR

TOTAL this month 262.8

Annual Accumulated total end of previous month 126.4 April

Annual Accumulated Total to date 389.2

Greatest fall in one day this month 43.2 millimetres on the 28th of May

The rain gauge should be examined every morning at 9.00 am. Should an observation happen to be missed, measure the accumulated rainfall. Then enter the reading as usual, but bracket the dates since the last reading to show that it is not a single day's rainfall. When there has been no precipitation NO entry should be made (not 0000 Nil or Dots). Enter rainfall for the preceding 24 hours, measured in millimetre s to one decimal place, at 9.00am on the date it was measured

Additional Comments
KR - Komal Ram LY - Linda Yuen. An error in the recording on the 21st as guage was blocked.. A wet month. Rainguage cleared of debris, Grass cut and check on the 21st of May. Rainguage calibrated on 31st May.

PART B – EXAMPLE OF COLLECTED DATA, ABAIANG ISLAND DATA

Table A1-1. Historical monthly rainfall data on Abaiang Island from 1950 – 2014 (with gaps).

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

1988	400	338	421	106	219	122	15	34	8	19	3		
1989		11	26	49	108	69	47	53	28	24	102	176	
1990			206										
1991			183	79	205	270	120	344	418	243	379	315	
1992	230	333	330	418	200								
1993													
1994										402	218		
1995													
1996													
1997													
1998													
1999													
2000	180	41	152	105	149	94	187	114	85	149	195	109	1560
2001	167	166	259	208	386	183	381	253	143	77	269	381	2873
2002	705	491	542	279	189	420	163	458	260	353	343	365	4568
2003	720	353	549	125	125	184	153						
2004													
2005													
2006													
2007													
2008													
2009													
2010											76		
2011	20	9	0	114	299	246	381	110	343	93	44	48	1710
2012	208	21	113	188	132	159	221	255	249	64	173	178	1962
2013	175	89	98	269	127	24	64	53	238	150	46	74	1400
2014	251	74	317	441	216								

Table A1-2. Basic statistical analysis of discontinuous 1950 – 2014 monthly rainfall.

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

Annex 2

Groundwater well survey sheet

Annex 2 - KIRIWATSAN - Well survey

Island name: ☐☐☐ Team number: ☐ Village Name: ____________

Well Number: ☐☐ Name of well owner: ____________

Location: of well N: ☐☐ ☐☐ ☐☐☐ Date: ☐☐ / ☐☐ / ☐☐

E: ☐☐☐ ☐☐ ☐☐☐ Time: ☐☐ : ☐☐

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

1 Casing Type
1. Cement
2. Coral rock
3. Steel
4. PVC/PE
5. Unlined
6. Other

2 Well Covering
1. None
2. Covered
3. Uncovered
4. Partially covered

3 Well Covering condition
1. None
2. Replace/repair
3. Adequate
4. Good

4 Well Covering Material
1. Cement
2. Coral rock
3. Steel
4. PVC/PE
5. Unlined
6. Other

5 Fencing condition
1. None
2. Replace/repair
3. Adequate
4. Good

6 Fencing material
1. None
2. Steel
3. Timber
4. Other

7 Well Apron
1. None
2. <0.3
3. 0.3-0.8m
4. >0.8m

8 Well Apron Material
1. None
2. Cement
3. Coral rock
4. Timber
5. Other

9 Well Apron Condition
1. None
2. Cracked
3. Adequate

24 No. Of photos taken ☐

Photo nos. ....

10 Abstraction type
1. None
2. Bucket/tin
3. Tamana pump
4. Diesel or electric pump
5. Solar pump
6. Other

11 Pump Status
1. None
2. Working
3. Not working

12 Use of Water
1. Drinking/cooking
2. Washing/gardening/toilet
3. All of the above
4. Not used

13 No of Households using the well ☐☐

14 No. Of people using the well ☐ ☐☐

15 Sanitation Practice
1. Ikiribati pit toilet
2. Imatang - Pour/flush
3. Beach/Bush
4. Other

16 Distance to toilet (m) ☐ ☐☐

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

18 Contamination distance (m) ☐ ☐☐

19 Internal well diameter (m) ☐ ☐☐

20 Parapet height above ground (m)

21 DTWT from parapet measuring point (m)

22 TD from measuring point (m)

23 Salinity Top mS/cm ☐☐ ☐☐

24 Salinity Bottom mS/cm ☐☐ ☐☐

25 Bacteriological sample Yes ☐ No ☐

26 Improvements
1. Fencing
2. improved well cover
3. Concrete Apron
4. Increase well parapet
5. Bucket off ground
6. Replace tamana pmp
7. Remove rubbish
8. Cut vegetation back
9. Clean out well
10. Relocate pig pen
11. Relocate toilet
12. Other

24 Comments

Annex 3

Rainwater harvesting survey sheet

Annex 3 - KIRIWATSAN - RWH survey

Island name: ☐☐☐ Team number: ☐ Village Name: ____________

Building Number: ☐☐ Name of well owner: ____________

Location: Building N: ☐☐ ☐☐ ☐☐☐ Date: ☐☐ / ☐☐ / ☐☐

E: ☐☐☐ ☐☐ ☐☐☐ Time: ☐☐ : ☐☐

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

Roof Area

1 Length (m)

2 Width (m)

3 Height (m)

4 **Roof material**
1. Metal
2. Thatch
3. Other

5 **Roof condition**
1. Replace/repair
2. Adequate
3. Good

6 **Building Type**
1. Church
2. Manneba
3. Government
4. Private
5. Other

6 **Fascia board condition**
1. None
2. Replace/repair
3. Adequate
4. Good

7 **Guttering condition**
1. None
2. Replace/repair
3. Adequate
4. Good

8 **Guttering coverage of roof area**
1. <25%
2. 50%
3. 75%
4. 100%

9 **Downpipe condition**
1. None
2. Replace/repair
3. Adequate
4. Good
5. House
6. Other

No. Of photos taken

Photo nos.

10 **Screens on tank entry points**
1. None
2. Replace/repair
3. Adequate
4. Good

11 **Abstraction type**
1. None
2. Tap
3. Bucket
4. Pump
5. House
6. Other

13 **Storage dimensions**

Storage	Height	Diameter	Type
			eg Plastic, Cement, Steel, Fibreglass, Wood, Other

Storage	Height	Width	Length

14 **Storage condition**
1. None
2. Replace/repair
3. Adequate
4. Good

15 **Overhanging Vegetation** Yes ☐ No ☐

16 **Bacteriological sample** Yes ☐ No ☐

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

18. Comments

Annex 4

Groundwater level and salinity measurement procedures

A4. 1 Ground water level or Depth to water table measurement

Groundwater level in a hand-dug well or borehole is also known as depth to the water table (DTWT). Methods and instruments used to collect and record groundwater levels can vary substantially. Depth to water table should be measured and recorded before every monitoring event.

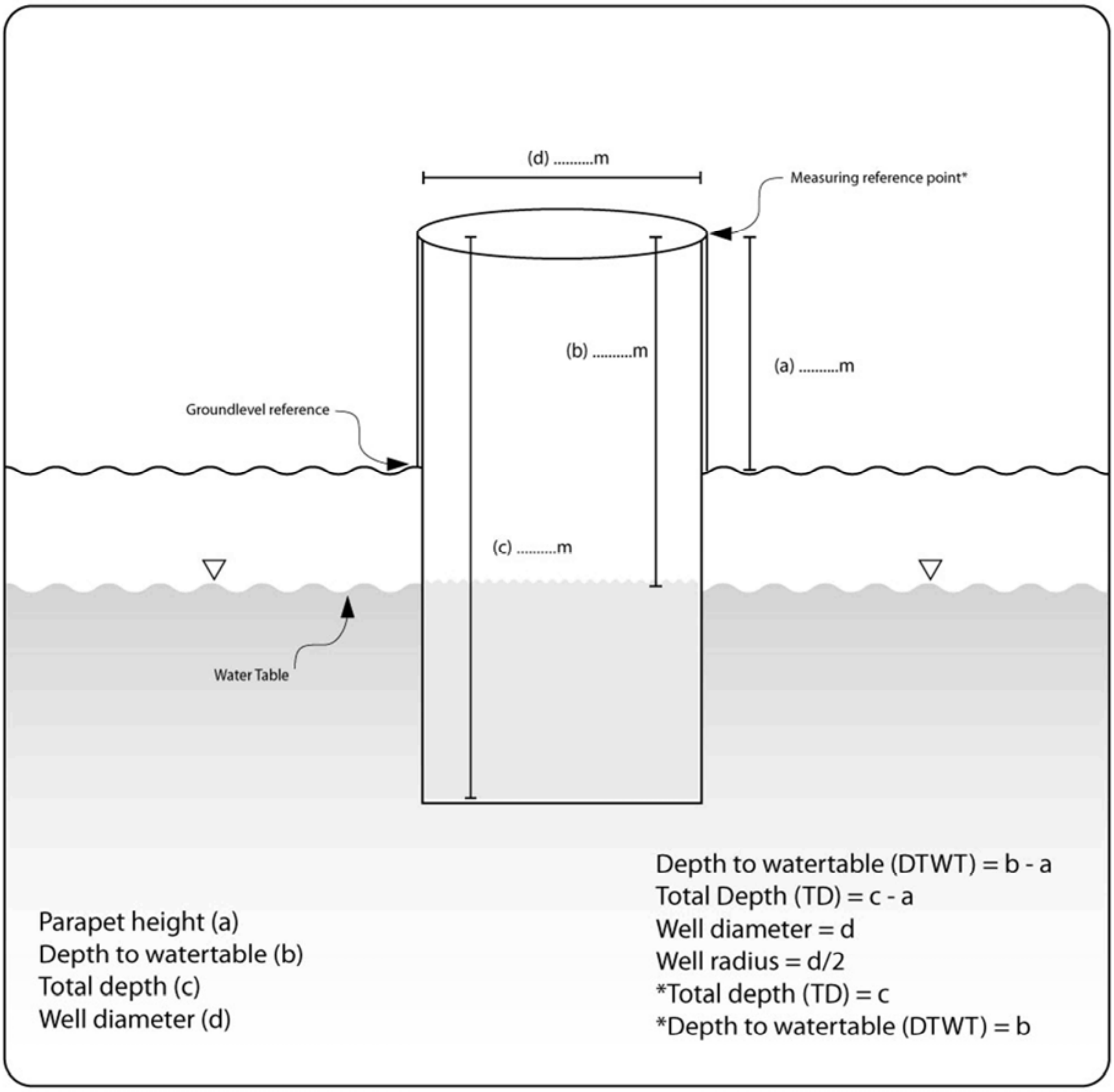

Figure A4.1. *Schematic of groundwater level measurement.*

Follow the instructions below for **water table (DTWT**) measurements.

1. Select a point of reference from the ground level
2. Lower the measuring tape into the well until it hits the water.
3. Lift and drop the tape several times to find the exact water level, this should give a reading accurate to within 1 cm.
4. Record the reading on the tape measure from the top of the parapet.

5. Measure the parapet form the ground level
6. Subtract the height of the parapet to get the depth to the water table (DTWT).
7. Refer to diagram above for well parapet and calculating DTWT
8. Ensure that the tape is cleaned thoroughly with tap water before using it again to prevent contamination of the next well. Dry and roll the tape

Calculations

- DTWT = b – a

Follow the following instructions for measuring the **total depth (TD)** of the well.

1. Lower the measuring tape into the well until it hits the base of the well.
2. Lift and drop the tape several times to “feel” the bottom of the well.
3. Record the reading on the tape measure from the top of the parapet.
4. Subtract the height of the parapet to get the total depth (TD) of the well.
5. Record the measurement in the field sheet.

Calculations

- TD = a – c

Well Diameter: Minimum distance (m) across the well taken from the inside of the casing that is diameter for circular casing or the shortest side for a rectangular well casing.

Depth to water: The measured distance from the top of the casing or measuring point to the top of the standing water (m)

Total depth: The measured distance from the top of the casing or measuring point to the bottom of the well (m)

A1.2 Groundwater Salinity measurement

Electrical conductivity (EC) is an indirect measure of water salinity, and one of the most common and convenient methods used to test water. Electrical conductivity is slightly affected by the temperature, so all results should be normalised to a standard temperature of 25°C. The EC is also strongly dependent upon the ionic composition of water. Chloride (Cl-) and sodium (Na+) are most commonly the main ions influencing groundwater EC.

Follow the instruction below for **salinity** measurement and depicted by Figure A4.2 below;

1. Before going to the site, calibrate your TPS WP 84 salinity meter (Refer to Annex 5).
2. On site, rinse the electrode in water to be tested.

3. To measure salinity at the surface (**salinity at top**) place the electrode in the well, ensuring it is fully immersed within the top 0.1m from the surface of water.
   a) Record the salinity measurement when the digital readout gives a stable reading.
   b) Record the results in the field sheet.
4. For base salinity (**salinity at bottom**) measure release the electrode cable until the electrode reaches approximately 0.1 m form the base.
   a) Record the salinity measurement when the digital readout gives a stable reading.
   b) Record the results in the field sheet.
5. Rinse the electrode with rainwater water.

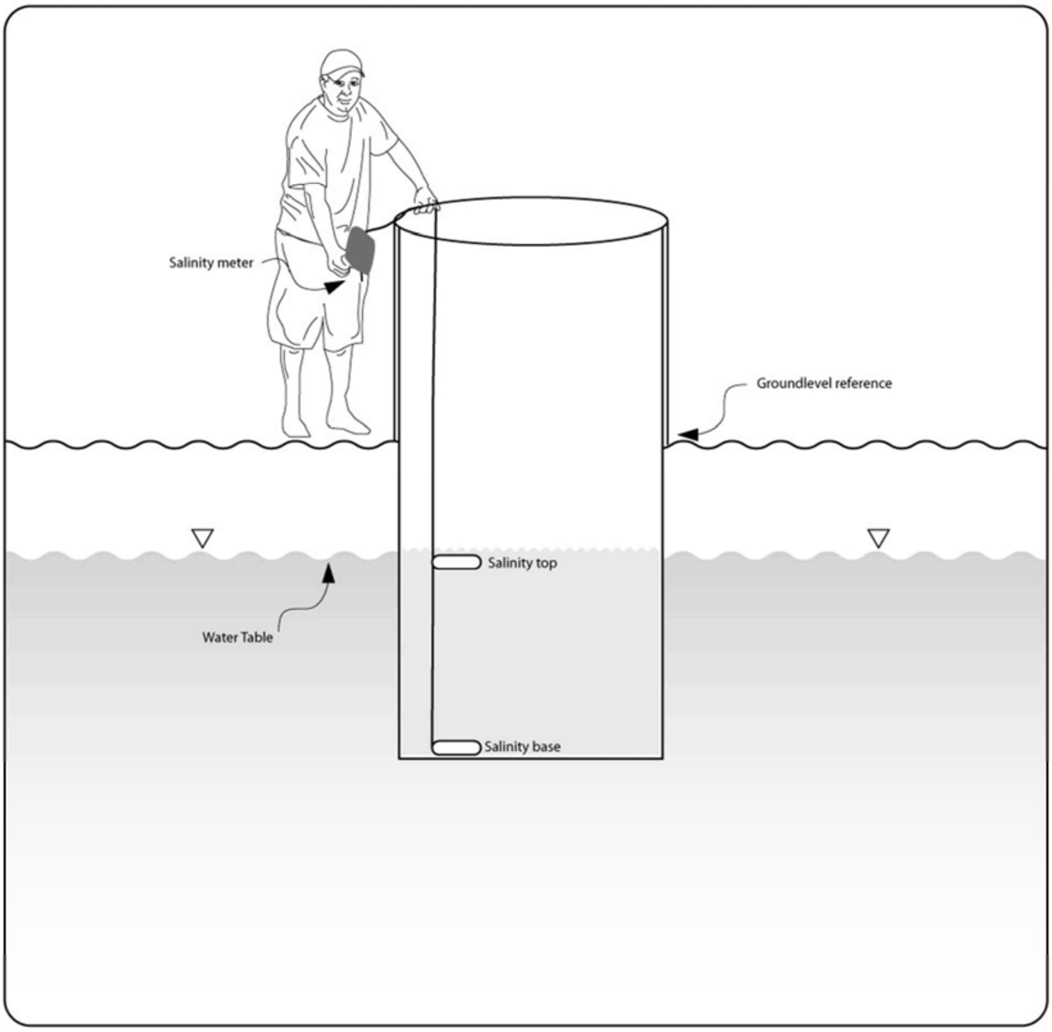

Figure A4.2. *Schematic of groundwater salinity measurement.*

Annex 5

TPS WP84 Conductivity meter operation and calibration

Congratulations !

You have purchased the latest in Handheld Conductivity-TDS-Salinity-Temperature instrumentation. We trust that your new **WP-84** will give you many years of reliable service.

The **WP-84** is a breeze to operate. This manual has been designed to help you get started, and also contains some handy application tips. If at any stage you require assistance, please contact either your local TPS representative or the TPS factory in Brisbane.

The manual is divided into the following sections:

1. **Table of Contents**
   Each major section of the handbook is clearly listed. Sub-sections have also been included to enable you to find the information you need at a glance.

2. **Introduction**
   The introduction has a diagram and explanation of the display and controls of the **WP-84**. It also contains a full listing of all of the items that you should have received with your **WP-84**. Please take the time to read this section, as it explains some of items that are mentioned in subsequent sections.

3. **Main Section**
   The main section of the handbook provides complete details of the **WP-84**, including operating modes, calibration, troubleshooting, specifications, and warranty terms.

4. **Appendices**
   Appendices containing background information and application notes are provided at the back of this manual.

Model WP-84
Conductivity, TDS,
Salinity, Temp Meter

Version: 4.0
Date: 27-Jan-2014

TPS Pty Ltd

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Contents

1. Introduction 5
1.1 WP-84 Display and Controls 5
1.2 Unpacking Information 7
1.3 Specifications 8

2. WP-84 Menu Structure 10

3. Operating Modes 11
3.1 Selecting Conductivity, TDS (setting factor) or Salinity Mode 11

4. Conductivity (TDS/Salinity) Calibration 12
4.1 Calibration Procedure 12
4.2 Calibration Notes 14
4.3 Calibration Messages 14

5. Temperature Calibration 15
5.1 Calibration Procedure 15
5.2 Calibration Notes 15
5.3 Calibration Messages 16

6. ATC Coefficient 17
6.1 Setting the ATC Coefficient 17
6.2 Calculating the ATC Coefficient of a Solution 18

7. Good Laboratory Practices (GLP) 19
7.1 To recall GLP information on the display 19
7.2 Failed Calibration 19
7.3 Printing GLP Information to the RS232 Port 20
7.4 Instrument Serial Number 20
7.5 Additional GLP Features 20

8. Notepad Function 21
8.1 Recording Readings into the Notepad 21
8.2 Recalling Records from the Notepad 21
8.3 Erasing Records from the Notepad 21
8.4 Printing Records from the Notepad to the RS232 Port 22

9. Automatic Data logging 23

10. RS232 Port 25
10.1 Setting the Baud Rate 25
10.2 Sending Readings to the RS232 Port 25
10.3 RS232 Configuration 25
10.4 Communication and Statistical Software 25
10.5 Commands 26
10.6 Data Format 27
10.7 GLP Data Format 27

10.8 Importing Data into Microsoft Excel 28

11. Battery Saver Function 30

12. Recharging the Battery 31

13. Clock Function 32

13.1 Setting the Clock 32
13.2 Displaying or Hiding the Clock 32

14. Selecting k=0.1 or k=10 Sensors 33

15. Initialising the WP-84 34

16. Instrument firmware version number. 34

17. Troubleshooting 35

17.1 General Errors 35
17.2 Conductivity/TDS/Salinity Troubleshooting 36
17.3 Temperature Troubleshooting 38

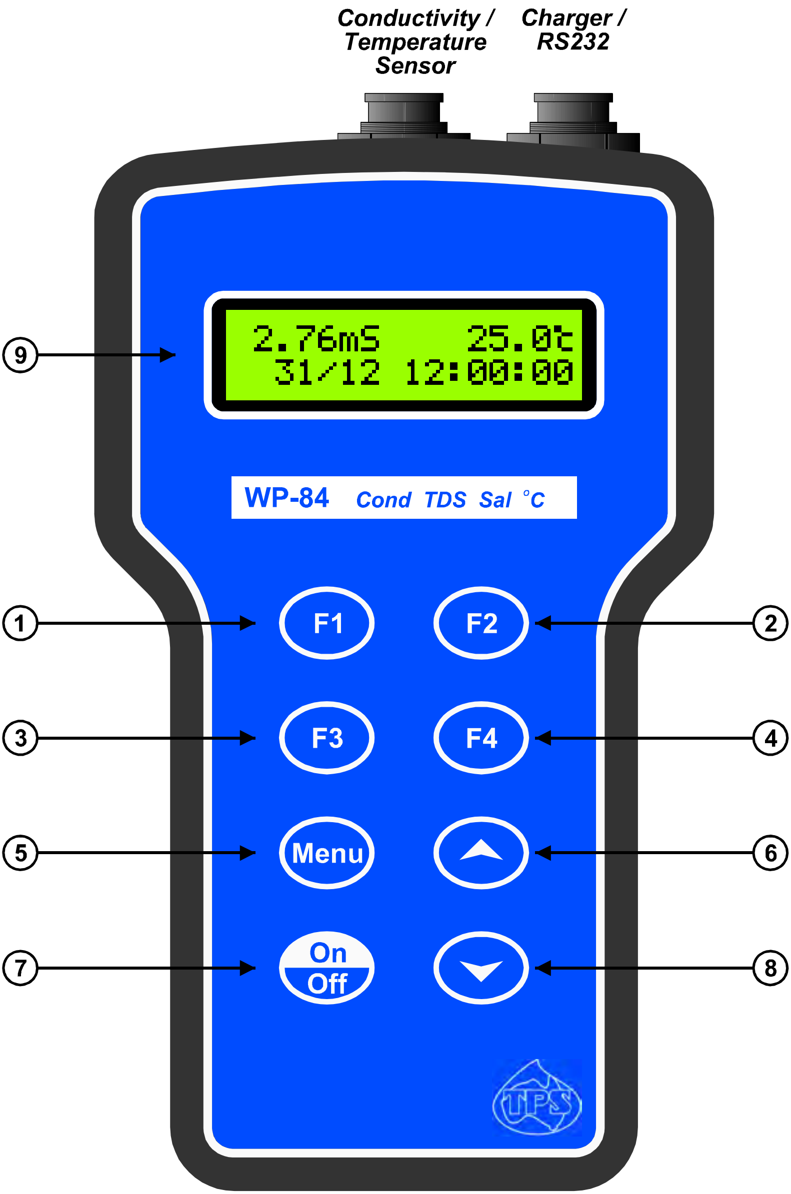
18. Appendices 39

18.1 Care, Cleaning and Maintenance of Conductivity Sensors 39
18.2 Replatinising Conductivity Sensors 40

19. Warranty 41

1. Introduction

1.1 WP-84 Display and Controls



① F1

Press to record readings into memory. See section 8.1.

② F2

Press to show or hide the date and time. See section 13.2.

Also used to select k=0.1 or k=10 sensor, when the standard k=1 sensor is not being used.

③ F3

Press to start or stop automatic logging. See section 9.

Alternatively, press to transmit current reading plus date and time to the RS232 port. See section 10.2.

④ F4

Only used within the menu system on the **WP-84**.

⑤ Menu

Press to access the user-friendly menu system which makes the **WP-84** a breeze to operate.

⑥ ▲ and ⑧ ▼

The ▲ and ▼ keys are used when calibrating temperature readout (section 5), setting the clock (section 13.1), setting the automatic logging period (section 9), and displaying GLP information (section 7.1).

The ▲ key is also used to initialise the **WP-84** at turn-on. See section 15.

⑦ On/Off

Switches the **WP-84** on and off.

⑨ **Display**

32 character alpha-numeric display with user-friendly menu and prompting system. Shows Conductivity/TDS/Salinity and Temperature simultaneously. Date and time can also be displayed.

1.2 Unpacking Information

Before using your new **WP-84**, please check that the following accessories have been included:

			Part No
1. **WP-84** Conductivity-TDS-Sal-Temp instrument			122159/1 122159/3 122159/5
2. Conductivity/ATC/Temperature Sensor:	k=1		1, 3 or 5m cable
(see cable label for part No)	k=10		1, 3 or 5m cable
	k=0.1		1, 3 or 5m cable
3. Conductivity Standard, 200mL:		2.76 mS/cm	122306
	or	58.0 mS/cm	122315
	or	150.0 uS/cm	122320
4. Battery charger			130037
5. Manual			

*Options that may have been ordered with your **WP-84**:*

1. Extended cable 130040
2. RS232 Serial Interface Cable 130041
3. Communication software for Windows 95 and later 130086
4. USB to Serial Adaptor (requires 130041 also) 130087
5. Hard Carry Case 130059
6. Battery charger lead for 12V cigarette lighter socket 130046
7. Battery charger lead for 12V DC, with battery clips................ 130052
8. Solar Panel 130012

1.3 Specifications

Conductivity

Ranges ....4 ranges, with automatic range selection.
k=0.1 Sensor ..0 uS/cm to 2000 uS/cm
k=1.0 Sensor ..0 uS/cm to 20.00 mS/cm
k=10 Sensor ..0 uS/cm to 200.0 mS/cm

Resolution.........................0.05% of selected range
Accuracy...........................±0.5% of full scale of selected range at 25 ^{O}C

TDS

Ranges: ....4 ranges, with automatic range selection.
k=0.1 Sensor ..0 ppM to 1000 ppM
k=1.0 Sensor ..0 ppM to 10.00 ppK
k=10 Sensor ...0 ppM to 100.0 ppK

Resolution.........................0.1% of selected range
Accuracy...........................±0.5% of full scale of selected range at 25 ^{O}C

Salinity ....k=0.1 Sensor 0 % to 0.10 %
0 PSU to 1.0 PSU
k=1.0 Sensor ..0 % to 1.19 %
0 PSU to 11.9 PSU
k=10 Sensor ..0 % to 8.00 %
0 PSU to 80.0 PSU

Resolution.........................0.01% / 0.1 PSU
Accuracy...........................±0.5% of full scale of selected range at 25 ^{O}C

Temperature

Range ....-10.0 to 120.0 ^{o}C (Sensor limit 60 ^{o}C)
Resolution.........................0.1 ^{o}C
Accuracy...........................±0.2 ^{o}C

General Specifications

Temperature Compensation:

Conductivity/TDS/Salinity .. Automatic -5 to 70 ^{o}C

Calibration:

Conductivity/TDS/Salinity........Auto Standard Recognition 150uS/cm, 1413uS/cm, 2.76mS/cm, 12.88mS/cm, 58.0mS/cm

Conductivity Span Range ....k=0.1 Sensor: k=0.075 to k=0.133
k=1.0 Sensor: k=0.75 to k=1.33
k=10 Sensor: k=7.5 to k=13.3

Temperature............................Use a reference thermometer.

Temperature Sensor Offset ....-10.0°C to +10.0°C

Memory ....3600 readings including date and time.

Automatic Data logging ....User-set for one reading every 1 to 90 seconds, 1 to 90 minutes, or 1 to 24 hours.

RS232 Output ....300, 1200, 9600 & 19200 baud.
8 bits, no parity, 1 stop bit, XON/XOFF Protocol.

Clock...Calendar clock displays date, month, hours, minutes & seconds. Year is recorded in memory and transmitted to the RS232 port, but is not displayed.

Battery Saver ....On : Auto switch-off after 5 minutes.
Off : Continuous use.
Bar Graph display of battery charge level. Readout of battery voltage available for troubleshooting.

Good Laboratory Practices..........Date, Time and Value of last Conductivity and Temperature calibration are stored, and can be recalled or sent to the RS232 port at any time.

Power..6V NiMH Rechargeable Battery for approximately 40 hours operation.

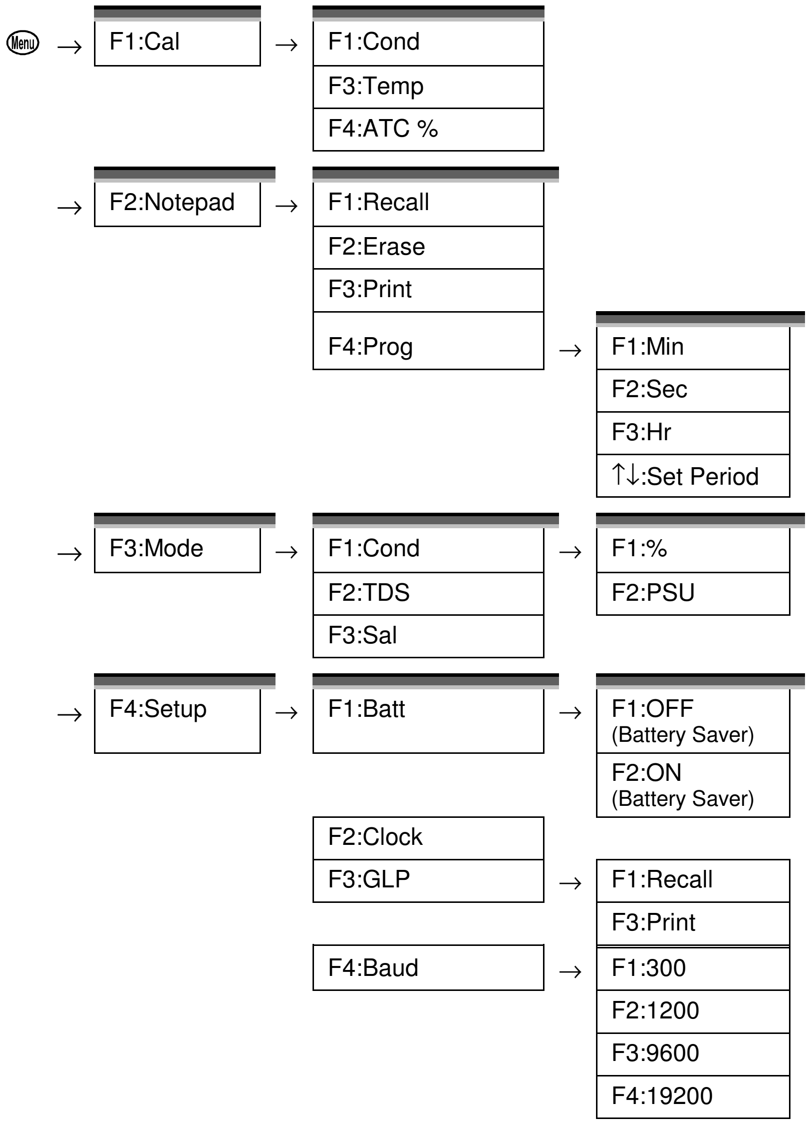
Dimensions ....195 x 110 x 55 mm

Mass ....Instrument only : Approx 520g
Full Kit : Approx 2.5kg

Environment................................Temperature : 0 to 45 °C
Humidity : 0 to 95 % R.H.

2. WP-84 Menu Structure

A detailed breakdown of the menu system of the **WP-84** is shown below. This diagram provides a quick reference for the **WP-84** menu functions.



3. Operating Modes

3.1 Selecting Conductivity, TDS (setting factor) or Salinity Mode

To select Conductivity, TDS or Salinity mode…

Select the Mode menu (Menu → **F3:Mode**)…

1. Press F1 to select the Mode Menu.

F1:Cond.	F2:TDS
F3:Sal.	

2. Press F1 to select Conductivity mode.
   Press F2 to select TDS mode.
   You will now be asked to enter the TDS Factor.

→0.65← TDS factor	
↑↓:Set	F1:Save

   Press F3 to select Salinity mode menu.

Select units	
F1:%	F2:PSU

   Press F1 to select % units.
   Press F2 to select PSU units.

   Press Menu to quit and retain the current selection.

4. Conductivity (TDS/Salinity) Calibration

To achieve accurate Conductivity/TDS/Salinity results, the **WP-84** requires calibration to an allowable Conductivity standard. The TDS and Salinity values are derived from the Conductivity reading and do not require a separate calibration. The conductivity of a solution varies with temperature. The **WP-84** uses Automatic Temperature Compensation (ATC) referenced to the fixed temperature of 25^{o}C.

A "∗" in place of the decimal point indicates that the Conductivity/TDS/Salinity readout is not calibrated, or a past calibration has failed. The " ∗ " will be removed once a Conductivity calibration has been successfully performed in Conductivity standard.

4.1 Calibration Procedure

1. Plug the Conductivity sensor into the **Conductivity** socket.
   If a k=0.1 or k=10 sensor is being used, ensure that the **WP-84** is set to the correct k factor before using the instrument (see section 14).
2. Switch the meter on.
3. Rinse the Conductivity sensor in distilled water. Shake off as much water as possible. Blot the outside of the sensor dry. DO NOT BLOT THE SENSOR WIRES.
4. **Zero Calibration**

   Let the sensor dry in air.

   Select Conductivity Calibration. (Menu → **F1:Cal.** → **F1:Cond.**)
5. When the reading has stabilised at or near zero, press the F1 key to calibrate.

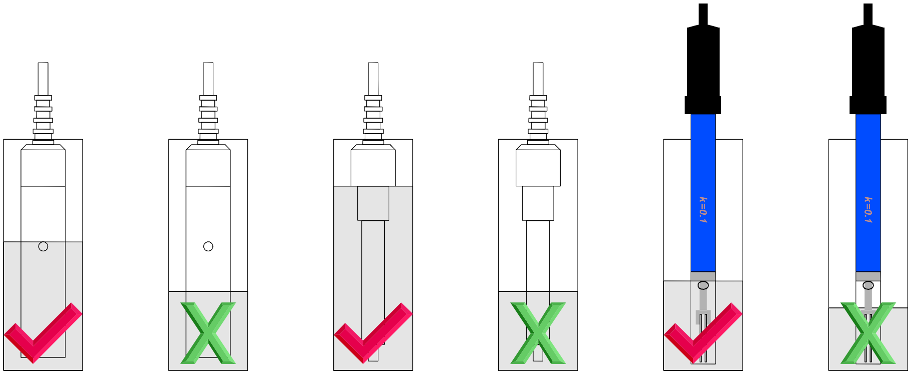
   A " ∗ " will not be removed after a zero calibration.
6. **Standard Calibration**
   Allowable Conductivity standards are 150uS/cm, 1413uS/cm, 2.76mS/cm, 12.88mS/cm and 58.0mS/cm, and should be selected according to your range of interest.

   If the **WP-84** does not recognise the standard, it will display the message, "**NOT STD**" during calibration. Calibration will fail if this message is displayed.

For plastic bodied k=1 and k=10 sensors, place the sensor into a sample of Conductivity standard, so that it is immersed at least to the vent hole in the white plastic cover. The white plastic cover MUST be in place for correct readings.

For plastic bodied k=0.1 sensors, the white plastic cover MUST be removed for correct readings.

For glass bodied sensors, immerse the sensor at least to the vent hole in the glass body.



Plastic body k=10 and k=1 Sensors ***Plastic body k=0.1 Sensor*** ***Glass body k=0.1 Sensor***

DO NOT place the sensor directly into the bottle of standard. Discard the used sample of standard after use. It is advisable to use a narrow sample vessel to minimise the use of standard solution.

7. Select Conductivity Calibration. (Menu → **F1:Cal.** → **F1:Cond.**)
8. When the reading has stabilised, press the F1 key to calibrate.

   The ∗ will now be replaced by a decimal point, if calibration was successful.

1. The **WP-84** is now calibrated for Conductivity and is ready for use in this mode.

4.2 Calibration Notes

1. A Zero calibration should be performed at least monthly. In low conductivity applications (where a zero error is particularly significant) a zero calibration may have to be done weekly.
2. A Standard calibration should be performed at least weekly. Of course, more frequent calibration will result in greater confidence in results.
3. The **WP-84** does not require re-calibration when alternating between Conductivity, TDS and Salinity modes.
4. All calibration information is retained in memory when the **WP-84** is switched off, even when the battery is removed. This information can be recalled or printed later using the GLP function (see section 6).
5. The **WP-84** displays the value of the standard to which it will attempt to calibrate. Ensure that the standard value displayed corresponds to the standard that you are using.
6. If the **WP-84** does not recognise the standard, it will display the message, "**NOT STD**" during calibration. Calibration will fail if this message is displayed.

4.3 Calibration Messages

1. If a Zero calibration has been successfully performed, the **WP-84** will display the following message and the zero value of the sensor. For example…

```
Calibrate OK
Zero= 0.00 uS
```

2. If a Standard calibration has been successfully performed, the **WP-84** will display the following message and the k factor of the sensor. For example…

```
Calibrate OK
k=1.00
```

3. If a Standard calibration has failed, the **WP-84** will display the following message and the failed k factor of the sensor. For example…

```
Calibrate fail
k=1.50
```

5. Temperature Calibration

5.1 Calibration Procedure

1. Plug the Conductivity/Temperature sensor into the **Sensor** socket.
2. Place the sensor into a beaker of room temperature water, alongside a good quality mercury thermometer. Stir the sensor and the thermometer gently to ensure an even temperature throughout the beaker.
3. Select Temperature Calibration (Menu → `F1:Cal.` → `F3:Temp`).
4. The reading from the sensor is now displayed on the right of the display, and the value you are going to set is shown on the left. For example…

```
→ 25.0←     20*0°c
↑↓:Set     F1:Cal.
```

5. When the reading on the right has stabilised, press the ▲ and ▼ keys until the reading on the left shows the same temperature as the mercury thermometer.
6. Press the F1 key to calibrate the temperature readout.

   Alternatively, press Menu to quit and retain the current calibration settings.

   The * will now be replaced by a decimal point, if calibration was successful.

   Alternatively, press the Menu key to abort temperature calibration.

5.2 Calibration Notes

1. Temperature calibration information is retained in memory when the **WP-84** is switched off, even when the battery is removed. This information can be recalled or printed later using the GLP function (see section 7).
2. Temperature does not need to be re-calibrated unless the sensor is replaced or the meter is initialised.

5.3 Calibration Messages

1. If a temperature calibration has been successfully performed, the **WP-84** will display the following message and the offset value of the sensor.

```
Calibrate OK
Offset=  1.0°c
```

2. If a temperature calibration has failed, the **WP-84** will display the following message and the failed offset value of the sensor.

```
Calibrate Failed
Offset= 10.5°c
```

6. ATC Coefficient

The Automatic Temperature Compensation (ATC) Coefficient is the rate at which the WP84 compensates for temperature effects on the Conductivity of the solution. The following all affect the ATC Coefficient of a solution…

- The type of salts dissolved in the solution.
- The concentration of the salts dissolved in the solution.
- The temperature of the solution.

It is therefore impossible to set a single ATC Coefficient in the factor which will be correct for all solutions which the **WP-84** will be used to test.

The ATC Coefficient is set to 2.0 %/^{O}C in the factory. This figure is suitable for environmental waters whose predominant dissolved salt is Sodium Chloride at moderate concentrations, being measured between approximately 15 and 30 ^{O}C.

The calculation of Salinity from the Conductivity reading incorporates the ATC Coefficient as defined for sea water. The user set ATC Coefficient is not used.

6.1 Setting the ATC Coefficient

1. Select the ATC entry screen ((Menu) → **`F1:Cal.`** → **`F4:ATC %`**).
2. The ATC entry setting screen is displayed…

   ```
   Enter ATC →2.0←
   ↑↓:Set   F1:Store
   ```

   Use the (▲) and (▼) keys to scroll to the desired ATC Coefficient setting. The available range is 0.0 to 4.0 %/^{O}C.
3. Press (F1) to store the new setting.
   Press (Menu) to quit and retain the current setting.

Note

The ATC Coefficient is set to 2.0 %/^{O}C during calibration and returns to the user setting when finished.

6.2 Calculating the ATC Coefficient of a Solution

1. Set the ATC Coefficient to zero using the procedure detailed in section 6.1.
2. Ensure that the temperature function has been calibrated (see section 5.1). The conductivity function does not need to be calibrated at this point.
3. Warm or cool the solution to approximately 5 ^{O}C below the temperature at which you expect to take sample measurements. Record the Conductivity and Temperature readings once both have become stable.
4. Warm the solution to approximately 5 ^{O}C above the temperature at which you expect to take sample measurements. Record the Conductivity and Temperature readings once both have become stable.
5. Apply the following formula, where C1 and T1 are the first readings taken, and C2 and T2 are the second readings taken…

$$\text{ATC Slope} = 100 \times \left(10^{\left(\frac{\mathrm{Log}\left[\frac{C2}{C1}\right]}{T2 - T1} \right)} - 1 \right)$$

6. Enter the result that is obtained as the ATC Coefficient of the solution, as per the procedure detailed in section 6.1.

Note

To assist in calculating the ATC Slope, the following information can be entered into a spreadsheet. This example has been specifically written for Microsoft™ Excel™, although the syntax should be similar for other spreadsheet software.

	A	B
1	Conductivity 1	*<Enter first Conductivity reading>*
2	Temperature 1	*<Enter first Temperature reading>*
3	Conductivity 2	*<Enter second Conductivity reading>*
4	Temperature 2	*<Enter second Temperature reading>*
5	ATC Slope	=100*((10^((LOG10(B3/B1))/(B4-B2)))-1)

A ready-made file can be downloaded from the Downloads section of the TPS Web Site : http://www.tps.com.au/downloads

7. Good Laboratory Practices (GLP)

The **WP-84** keeps a record of the date and time of the last Conductivity and Temperature calibrations as part of GLP guidelines.

7.1 To recall GLP information on the display

1. Select the GLP menu (Menu → **F4:Setup** → **F3:GLP**).
2. Select **F1:Recall** from the menu.
3. The instrument model, firmware version number, and instrument serial number are displayed, along with a prompt describing how to scroll through the GLP information. For example…

```
WP84  V4.0 S1234
↓:More  ↑:Back
```

4. Press the ▼ key to sequentially scroll through the GLP information for all parameters. Press the ▲ key to scroll back to previous data. The sequence of information displayed is shown over the page. Press Menu to abort at any time.

GLP display sequence…

```
WP84  V4.0 S1234
↓:More  ↑:Back
```

▼

```
Cond Zero 0.00uS
@ 31/12/10 12:00
```

▼ ▲

```
k=1.00 @ 2.76mS
@ 31/12/10 12:10
```

▼ ▲

```
Temp Offset 1.0°c
@ 31/12/10 12:30
```

▼

Exit

7.2 Failed Calibration

If calibration has failed, the GLP function will reset the date and time to zero. The **WP-84** still shows the results of the last successful calibration. For example…

```
Cond Zero 0.00uS
@ 00/00/00 00:00
```

or

```
k=1.00 @ 2.76mS
@ 00/00/00 00:00
```

Note that these calibration values are still used if further measurements are taken without re-calibrating.

7.3 Printing GLP Information to the RS232 Port

The GLP information stored in the instrument's memory can be sent to a printer or PC via the RS232 port.

Ensure that the **WP84** RS232 cable is connected to the instrument and to the printer or PC.

1. Select the GLP menu (Menu → **F4:Setup** → **F3:GLP**).
2. Select **F3:Print** from the menu.
3. The GLP information is sent to the RS232 port in formatted ASCII text. For example…

```
WP84  V4.0 S1234 @ 31/12/10 13:00
Conductivity Zero=    0.00uS          @ 31/12/10 12:00
Conductivity k=       1.00 @ 2.76mS   @ 31/12/10 12:10
Temperature  Offset=   1.0oC          @ 31/12/10 12:30
ENDS
```

7.4 Instrument Serial Number

In case the serial number that is fitted to the rear of the **WP-84** is removed or becomes illegible, it is also available on the **WP-84** display.

- The serial number is displayed at turn-on, for example…

  ```
  WP84  V4.0 S1234
  Con TDS Sal Temp
  ```

  where **S1234** is the serial number.
- The serial number is displayed when recalling the GLP information (section 7.1).
- The serial number is included on the print-out of GLP information (section 7.3).

7.5 Additional GLP Features

Another GLP requirement is to record the date and time of every reading. The **WP-84** does this when readings are recorded with the Notepad function (section 8) or the Automatic Logging function (section 9).

8. Notepad Function

8.1 Recording Readings into the Notepad

To record readings into the Notepad memory…

1. Press (F1) in normal display mode. The display should now look like this…(when in Conductivity mode)

```
 2.76mS     25.0°c
F1:  1    12:00:00
```

2. Press (F1) to record the Conductivity/TDS/Salinity, Temperature, Date and Time into the notepad. This will be labelled as reading number 1.
3. Repeat steps 1 & 2 as often as required. The maximum number of readings that can be stored in the Notepad is 3600.

8.2 Recalling Records from the Notepad

To recall records from the Notepad onto the **WP-84** display…

1. Select the Notepad menu ((Menu) → **`F2:Notepad`**).
2. Select **`F1:Recall`** from the menu.
3. Record number 1 is now displayed, for example…

```
 2.76mS     25.0°c
#  1      F2:Clock
```

4. Press (F2) to alternatively display the date and time or the data for this record.
   Press (▲) to move forward through the records.
   Press (▼) to move backward through the records.
   Press and hold the (▲) or (▼) keys to roll rapidly through the readings.

8.3 Erasing Records from the Notepad

To erase all records from the Notepad:

1. Select the Notepad menu ((Menu) → **`F2:Notepad`**).
2. Select **`F2:Erase`** from the menu
3. The **WP-84** now asks if you are sure that you wish to erase all records…

```
Erase, You Sure?
F1:Yes  F2:No
```

   Press (F1) to erase all records from the Notepad.
   Press (F2) to quit without erasing the records from the Notepad.

8.4 Printing Records from the Notepad to the RS232 Port

1. Connect one end of the RS232 cable to the **Charger**/**RS232** socket of the **WP-84**. The charger, optional solar panel, or optional car battery lead can be connected into the spare socket on the cable for long term use, if required.
2. Connect the other end of the RS232 cable to an RS232 Printer, or to COM1 or COM2 of a PC.

   When using a PC, it must have a software utility installed which can communicate with the RS232 port. Windows 95, 98 & ME are shipped with Hyper Terminal, which is suitable for this purpose.
3. Ensure that the baud rate for the printer or PC and the **WP-84** are the same.

   If necessary, alter the baud rate of the **WP-84** (see section 10.1).

   The **WP-84** uses XON/XOFF protocol. Ensure that the printer is set accordingly.
4. Select the Notepad menu (Menu → **`F2:Notepad`**).
5. Select **`F3:Print`** from the menu.

   Printing starts as soon as F3 is pressed. The display shows the word "**`Printing`**" until printing is completed.

<u>Note</u>

Downloading the recorded readings is as simple as clicking on the toolbar using the optional WinTPS RS232 Communication Software. This is part number 130086 and is available from TPS or your distributor.

9. Automatic Data logging

The **WP-84** can automatically log records into the Notepad. First the logging period must be programmed, then automatic logging can be started and stopped as required.

1. Select the Program menu (Menu → **F2:Notepad** → **F4:Prog.**).
2. The display should now look like this…

```
→00← F1:Min F2:Sec
↑↓:Period    F3:Hr
```

3. Use the ▲ and ▼ keys to set the period at which the **WP-84** will automatically log records.
4. When the logging period has been correctly set, select whether this period is in minutes, seconds or hours.

   Press F1 to save the period as minutes.

   Press F2 to save the period as seconds.

   Press F3 to save the period as hours.

   For example, if the period was set to **05**, followed by F2, then the **WP-84** will automatically log a record every 5 seconds.
5. The **WP-84** will ask if the records are to be logged into the Notepad, or sent directly to the RS232 port.

   Press F1 to log records into the Notepad (maximum of 3600 readings).

   Press F1 to send records directly to the RS232 port.
6. The automatic logging function is now programmed, and can be started and stopped as required.
7. To start automatic logging, press F3 in normal display mode.

   If the **WP-84** is logging into the Notepad, the display will look like this…

```
 2.76mS    25.0°c
Log#  1 12:00:00
```

   The log number will increment and the **WP-84** will beep each time a reading is recorded.

Continued over the page…

Automatic Data logging, continued…

If the **WP-84** is sending records directly to the RS232 port, the display will look like this…

```
 2.76mS    25.0°c
Sending 12:00:00
```

The **WP-84** will beep each time a record is sent to the RS232 port.

8. Press Ⓕ3 to stop automatic logging.

Notes

1. The clock must be set before the **WP-84** will allow automatic logging to start. The message “**`Clock Not Set`**” is displayed if the clock is not set.
2. The Battery Saver function (section 11) is disabled while the meter is in Automatic Data logging mode, to stop the meter switching off while logging data. Even when the memory is full and the meter stops logging, the Battery Saver function is still disabled. This allows the data to be downloaded and the memory to be reset remotely.

10. RS232 Port

10.1 Setting the Baud Rate

1. Select the RS232 Set-up menu (Menu → **F4:Setup** → **F4:Baud**).
2. The available baud rates are listed on the display…

```
 F1:300  F2:1200
>F3:9600 F4:19200
```

   The arrow shows the current selection.
3. Press F1 to select 300 baud
   Press F2 to select 1200 baud
   Press F3 to select 9600 baud.
   Press F4 to select 19200 baud.
   Press Menu to quit and retain the current setting.

10.2 Sending Readings to the RS232 Port

Press F3 to instantly send readings to the RS232 port whenever the **WP-84** is in normal display mode. This function is disabled if the automatic logging period is set to greater than zero (see section 9).

Records can be sent directly to the RS232 port rather than stored in memory during automatic data logging. See section 9 for details.

10.3 RS232 Configuration

The **WP-84** RS232 configuration is 8 bits, No Parity, 1 Stop Bit, XON/XOFF Protocol.

10.4 Communication and Statistical Software

Communication between the **WP-84** and a PC can be handled with any RS232 communication software. **Win*TPS*** RS232 communication software for Windows® 95 and later is optionally available (part number 130086).

Once the data is saved to disk, the next problem is how to use it. The data sent by the **WP-84** is formatted in fixed-width columns that can be imported by programs such as Microsoft® Excel® and Lotus 123®.

Information on how to use the software and import data is provided in the manual provided with the **Win*TPS*** CD-ROM.

10.5 Commands

The following commands can be sent from a PC to the **WP-84**. Note that <cr> denotes carriage return and <lf> denotes a line feed.

Action	Command	Notes
Request current data	?D<cr>	Returns the current Conductivity/ TDS/Salinity, Temperature, date and time from the **WP-84**. The log number returned is set to Zero.
Request logged data	?R<cr>	Returns all logged records from the **WP-84** memory. The data ends with the message **ENDS**<cr>
Erase logged data	?E<cr>	Erases all logged records from the **WP-84** memory. Returns the message **ERASED**<cr> to confirm that the records have been erased.
Request status information	?S<cr>	Returns the model name, firmware version number, instrument serial number and number of logged readings in memory, eg: **WP84♦♦V4.0♦S1234♦9999**<cr>, where ♦ are spaces. Note that the number of logged readings is right-justified.
Request GLP information	?G<cr>	Returns all calibration GLP information, plus the instrument model and current date (see section 10.6 for data format and hand-shaking).

10.6 Data Format

Data is returned to the RS232 port by the **WP-84** in the following format. Please note that a "♦" shown anywhere in this section denotes one space.

LLLL♦DDDDDDUUU♦TTTTTToC♦♦dd/mm/yy♦hh:mm:ss

where…

LLLL	is the Log Number. Maximum 4 characters, right justified. A Zero is sent for instant readings (section 10.2).
DDDDDD	is the Conductivity/TDS/Salinity Data. Maximum 6 characters, right justified.
UUU	is the Conductivity/TDS/Salinity unit description, either "**uS♦**", "**mS♦**", "**ppM**" ,"**ppK**", "**%♦♦**" or "**PSU**"
TTTTTT	is the Temperature Data. Maximum 6 characters, right justified.
oC	is the Temperature unit description.
dd/mm/yy	is the date, month and year data.
hh:mm:ss	is the hours, minutes and seconds data.

Notes

When requested by a PC with the ?D or ?R commands (section 10.5), each line of data is terminated with a carriage return.

When the data is sent by the **WP-84** using the Print function (section 8.4) or Send function (section 10.2), each line of data ends with a carriage return and a line feed.

10.7 GLP Data Format

GLP information is returned as 6 lines terminated by a carriage return. The computer must respond with a character after receiving each line. For example…

```
WP84  V4.0 S1234 @ 31/12/10 13:00
Conductivity Zero=    0.00uS         @ 31/12/10 12:00
Conductivity k=       1.00 @ 2.76mS  @ 31/12/10 12:10
Temperature  Offset=   1.0oC         @ 21/12/10 12:30
ENDS
```

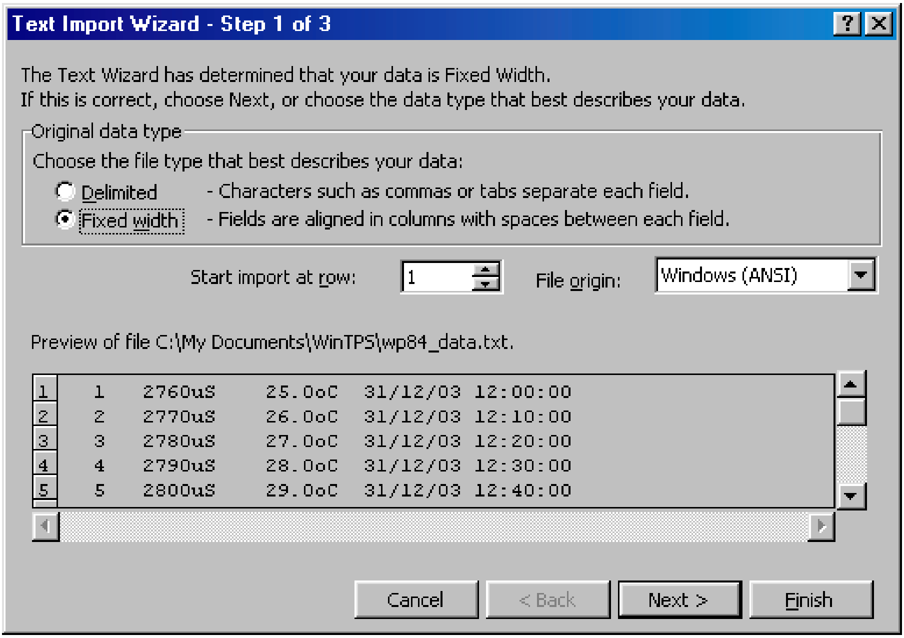
10.8 Importing Data into Microsoft Excel

The following procedure details the method for importing a **WP-84** text data file into Microsoft® Excel®.

1. Start Microsoft® Excel® and select File → Open
2. In the "Files of type:" pull-down box, choose "Text Files (*prn; *.txt; *.csv)".
3. Navigate to the folder where your data file is stored and double-click it to start the Text Import Wizard.

   Note: The default data folder for the WinTPS software is "C:\My Documents\WinTPS".

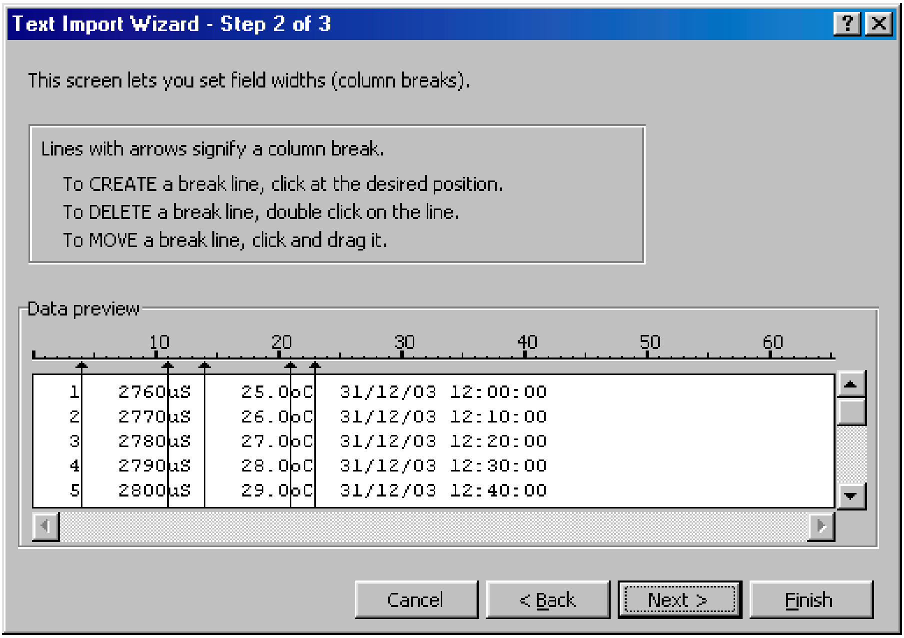
4. In step 1 of the Text Import Wizard select "Fixed width", as per the sample screen below, then press "Next >".



Continued over the page…

5. Step 2 of the Text Import Wizard allows you to select the points at which each data field will break into a new column. The sample screens below show where TPS recommends the breaks be inserted.

   Press “Next >” after the column breaks have been inserted.



6. Simply press “Finish” at step 3 of the Text Import Wizard. TPS recommends that the data format for each column be set once the data is in spreadsheet format.

   For help on formatting the data columns, charting, graphing or other operations please consult the Microsoft® Excel® help file. Alternatively please contact TPS and we will try to provide further assistance.

11. Battery Saver Function

The **WP-84** is equipped with a battery saver function. If no button has been pressed for five minutes, the unit beeps and flashes the display for 20 seconds, and then shuts off. This function can be switched off for continuous use.

To enable or disable the battery saver function…

1. Select Battery Saver Set-up (Menu → **F4:Setup** → **F1:Batt**).
2. The battery saver menu is now displayed…

   The arrow indicates the current selection.

   The bar graph and percentage indicate the approximate level of charge in the battery.

3. Press F1 to disable the battery saver function for continuous use.

   Press F2 to enable the battery saver function. The meter will switch itself off if no key has been pressed for five minutes.

   Press Menu to quit the battery saver menu and retain the current setting.

Notes

1. For troubleshooting purposes, the battery volts can also be displayed in the battery saver menu. Press F3 to display battery volts.
2. The symbol flashes when the battery volts drops below 5.60 volts. At 5.00 volts the meter turns itself off.
3. The Battery Saver function is disabled while the meter is in Automatic Data logging mode (section 9), to stop the meter switching off while logging data. Even when the memory is full and the meter stops logging, the Battery Saver function is still disabled. This allows the data to be downloaded and the memory reset remotely.

12. Recharging the Battery

The ▯ symbol flashes when the battery drops below 5.60 volts. The battery should be recharged at this point. If the battery is not recharged, the **WP-84** will switch itself off when the battery drops below 5.00 volts.

To recharge the battery…

1. Plug the battery charger, solar panel, or car cigarette lighter adaptor into the **Charger**/**RS232** socket. **DO NOT** plug into the **Sensor** socket, as this will damage the **WP-84**.
2. Charge for approximately 8 hours for full capacity. The **WP-84** has special circuitry to prevent overcharging, so the charger can be used continuously.
3. To ensure optimum battery life and capacity, the **WP-84** should only be charged once the ▯ symbol starts to flash.

13. Clock Function

13.1 Setting the Clock

1. Select the Clock Set-up menu ((Menu) → **`F4:Setup`** → **`F2:Clock`**).
2. The display now shows the current date and time. The cursor starts at the day. For example…

```
 31/12/10 12:00
F1:← F2:→  ↑↓:Set
```

3. Press the ▲ and ▼ keys until the day is correct.
4. Press (F2) to move to the month. Press the ▲ and ▼ keys until the month is correct.
5. Press (F2) to move to the year. Press the ▲ and ▼ keys until the year is correct.
6. Press (F2) to move to the hour. Press the ▲ and ▼ keys until the hour is correct.
7. Press (F2) to move the cursor to the minutes. Press the ▲ and ▼ keys until the minutes are correct.
8. Check that the date and time are correct.

   Press (F2) to save the settings.

   If any changes are needed, press the (F1) key to move left to the desired position.

   Press (Menu) to quit without resetting the clock.

Notes

1. The **WP-84** does not test for a valid day of the month when setting the clock (eg: attempting to enter 31/02/10 is not corrected).
2. The **WP-84** does test for leap years.

13.2 Displaying or Hiding the Clock

The date and time are normally displayed along with the Conductivity/TDS/Salinity and Temperature readings. Press (F2) in normal operation to alternatively display or hide the clock.

14. Selecting k=0.1 or k=10 Sensors

The **WP-84** automatically recognises a k=1.0 sensor. The **WP-84 does not** automatically recognise k=0.1 or k=10 sensors. When a k=0.1 or k=10 sensor is used, the **WP-84** must be set to the correct k factor before use. The following procedure describes how to select a k=0.1 or k=10 sensor.

1. Switch the meter **OFF**.
2. Connect the k=0.1 or k=10 sensor.
3. Press and HOLD the (F2) key while switching the meter back on.
4. The k factor selection menu is now displayed (only if the k=0.1 or k=10 sensor is connected). For example…

   ```
   Select      F1:k=.1
   k Factor >F2:k=10
   ```

   The arrow indicates the current selection.
5. Press (F1) to select a k=0.1 sensor.

   Press (F2) to select a k=10 sensor.

   Press (Menu) to quit buffer selection and retain the current setting.

Notes

1. The manual k factor selection is kept in memory when the meter is switched off, even if the battery is removed.
2. The manual k factor selection is reset to k=10 during initialisation.
3. The **WP-84** will always automatically recognise a k=1.0 sensor, regardless of the manual k factor selection.
4. Calibration settings for k=0.1, k=1.0 and k=10 sensors are **NOT** stored separately. The **WP-84** requires re-calibration when a new k factor sensor is connected.
5. The message "`Connect k=10/0.1`" appears when the **WP-84** cannot detect a k=10 or k=0.1 sensor connected to the **Sensor** socket. Check that the sensor is correctly connected. If the message persists, return the k=10 or k=0.1 sensor to the factory for checking.

15. Initialising the WP-84

If the calibration settings of the **WP-84** exceed the allowable limits, the unit may need to be initialised to factory default values. This action may be required if the sensor is replaced.

To initialise the **WP-84**…

1. Switch the **WP-84** off.
2. Press and hold the  key while switching the **WP-84** back on.
3. The following messages should be displayed…

```
Initialized
MUST ReCalibrate
```

then…

```
WP84s V4.0 S1234
Con TDS Sal Temp
```

   (The "s" after **WP-84** is shown when the RS232 serial port option is fitted)

4. The meter then displays Conductivity and Temperature. Note that the decimal points have been replaced with a "*" to indicate that the unit requires re-calibration.

Note

When the **WP-84** is initialised, the manual k factor selection is re-set to k=10. See section 14 if you wish to select a k=0.1 sensor.

16. Instrument firmware version number.

If you need to email, phone or fax TPS for any further technical assistance, the version number of your **WP-84** firmware may of benefit to us. The version number is displayed by the **WP-84** at turn-on.

17. Troubleshooting

17.1 General Errors

Error Message	Possible Causes	Remedy
Factory Cal. Failed **See Handbook**	The EEPROM chip which contains the factory calibration information has failed.	The unit must be returned to TPS for service.
Memory Failed Calibration Lost then… **Initialised MUST ReCalibrate**	User calibration settings have been lost or corrupted.	Re-calibrate the instrument. A full 2-point calibration will be required for Conductivity (see section 4.1) and a 1 point calibration for temperature (see section 5.1).
Flashing symbol.	Battery is below 5.60 volts.	Recharge the battery. Note that the unit will switch itself off when the battery falls below 5.00 volts.
Meter displays the word **OFF**, and switches off.	Battery is below 5.00 volts.	Recharge the battery. If this fails, check the charger. If charger OK, replace the battery.
Meter will not turn on.	1. Battery is exhausted. 2. Faulty Instrument	Recharge the battery. If this fails, check the charger. If charger OK, replace the battery. Return to factory for repair.
Battery does not charge up when charger is connected.	1. Faulty battery charger or faulty battery. 2. Faulty instrument.	1. Connect the charger and switch the power on. Display the battery volts in the battery saver menu (see section 11). If the battery volts are increasing then the charger is OK. If the battery volts do not increase, then the charger is faulty. Replace the charger or the battery, as required. 2. Return to factory for repair.

17.2 Conductivity/TDS/Salinity Troubleshooting

Symptom	Possible Causes	Remedy
Unit fails to calibrate, even with new sensor.	Calibration settings outside of allowable limits due to previous failed calibration.	Initialise the unit. See section 15.
Unit attempts Span calibration instead of Zero calibration.	Sensor has Zero error.	Thoroughly rinse sensor in distilled water and allow to completely dry in air before attempting zero calibration. If instrument does not calibrate at Zero with sensor disconnected, then the instrument is faulty.
Standard calibration fails, and k factor is greater than 0.133, 1.33 or 13.3, (depending on k factor of sensor).	1. Sensor is not immersed deeply enough.	Immerse sensor at least to the vent hole in the white plastic cover.
	2. Sensor may have a build-up of dirt or oily material on sensor wires.	Clean sensor, as per the instructions detailed in section 18.1.
	3. Platinum-black coating has worn off.	Sensor requires replatinisation. Return to the factory, or see details in section 18.2.
	4. Standard solution is inaccurate.	Replace standard solution.
	5. Sensor is faulty.	Return sensor to factory for repair or replacement.
	6. Faulty instrument.	Return to factory for repair.
	7. k-factor incorrectly set if using k=0.1 or k=10 sensor.	Set the correct k-factor, as per section 14.

Continued next page...

Conductivity/TDS/Salinity Troubleshooting, continued...

Standard calibration fails, and k factor is less than 0.075, 0.75 or 7.5, (depending on k factor of sensor).	1. White protective cover is not fitted or upside down. 2. Standard solution is inaccurate. 3. Sensor may have a build-up of conductive material, such as salt. 4. Sensor is faulty. 5. Faulty instrument. 6. k-factor incorrectly set if using k=0.1 or k=10 sensor.	The white protective cover MUST be fitted for correct readings. The vent hole must be towards the cable end of the sensor. Replace standard solution. Clean sensor, as per the instructions detailed in section 18.1. Return sensor to factory for repair or replacement. Return to factory for repair. Set the correct k-factor, as per section 14.
Inaccurate readings, even when calibration is successful.	1. Sensor may have a build-up of dirt or oily material on sensor wires. 2. Platinum-black coating has worn off.	Clean sensor, as per the instructions detailed in section 18.1. Sensor requires replatinisation. Return to the factory, or see details in section 18.2.
Readings drift.	1. Sensor may have a build-up of dirt or oily material on sensor wires.	Clean sensor, as per the instructions detailed in section 18.1.
Readings are low or near zero.	1. Sensor may have a build-up of dirt or oily material on sensor wires. 2. Sensor is not immersed deeply enough. 3. Sensor is faulty. 4. Faulty instrument. 5. k-factor incorrectly set if using k=0.1 or k=10 sensor.	Clean sensor, as per the instructions detailed in section 18.1. Immerse sensor at least to the vent hole in the white plastic cover. Return sensor to factory for repair or replacement. Return to factory for repair. Set the correct k-factor, as per section 14.
Display flashes “ATC” and “LIMIT”	The Temperature is not within the ATC limits.	Cool/Heat solution before taking measurements.

17.3 Temperature Troubleshooting

Symptom	Possible Causes	Remedy
Displays "**OVR°C**" when sensor is plugged in.	1. Faulty sensor. 2. Faulty instrument.	Fit new sensor. Return to factory for repair.
Temperature inaccurate and cannot be calibrated.	1. Faulty connector. 2. Faulty sensor. 3. Faulty instrument.	Check the connector and replace if necessary. Fit new sensor. Return to factory for repair.

18. Appendices

18.1 Care, Cleaning and Maintenance of Conductivity Sensors

18.1.1 Care of Conductivity sensors

The conductivity section of the sensor supplied with your **WP-84** consists of two platinum wires that are plated with a layer of "platinum-black". This is quite a soft layer and is required for stable, accurate measurements. In time, the platinum-black layer may wear off in some applications, at which time the sensor will require replatinising (see section 18.2). You can help to maintain the platinum-black layer by following these simple rules:

1. **NEVER** touch or rub the sensor wires with your fingers, cloth etc.
2. Avoid using the sensor in solutions that contain a high concentration of suspended solids, such as sand or soil, which can abrade the sensor wires. Filter these types of solutions first, if possible.
3. Avoid concentrated acids. If you must measure acids, remove the sensor immediately after taking the measurement and rinse well with distilled water.

Conductivity sensors can be stored dry. Ensure that the sensor is stored in a covered container, to avoid dust and dirt build-up.

18.1.2 Cleaning of Conductivity of Sensors.

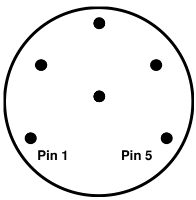
Platinised platinum Conductivity sensors can only be cleaned by rinsing in a suitable solvent. **DO NOT wipe the sensor wires**, as this will remove the platinum-black layer.

1. Rinsing in distilled water will remove most build-ups of material on the sensor wires.
2. Films of oils or fats on the sensor wires can usually be removed by rinsing the sensor in methylated spirits.
3. Stubborn contamination can be removed by soaking the sensor in a solution of 1 part Concentrated HCl and 10 parts distilled water. The sensor should not be soaked for more than approximately 5 minutes, otherwise the platinum-black layer may start to dissolve.
4. If all of these methods fail, then the last resort is to physically scrub the sensor wires, which will remove the contaminant and the layer of platinum-black. Use only a cloth or nylon scouring pad. DO NOT USE STEEL WOOL. The sensor will then need to be cleaned in HCl, as per step 3 and replatinised, as per section 18.2.

18.2 Replatinising Conductivity Sensors

There are several ways to replatinise Conductivity sensors.

1. The simplest way is to return the sensor to the TPS factory. We can fully clean the sensor, replatinise it and test all aspects of its performance.
2. An automatic replatiniser is available from TPS, along with replatinising solution. This will plate the sensors for the right amount of time at the correct current. Ordering details are as follows…
   Automatic Conductivity Sensor Replatiniser .... Part No 122160
   20mL Platinising Solution (suitable for approx 30 uses) Part No 122300
3. Conductivity sensors can be manually replatinised, according to the following procedure…
   1) Soak the sensor in a solution of 1 part Concentrated HCl and 10 parts distilled water for approximately 5 minutes.
   2) Rinse the sensor well in distilled water.
   3) Immerse the sensor in platinising solution at least to the vent hole in the white plastic cover. Platinising solution is available from TPS (part no 122300). Alternatively, platinising solution can be prepared by dissolving 1g of Hydrogen Chloroplatinate (H_2PtCl_{16}) in 30mL of distilled water, and including about 0.01g of Lead Acetate ($(CH_3COO)_2Pb$) and a drop or two of concentrated HCl.
   4) Apply a direct current of 10mA between pins 1 and 5 of the sensor plug, as per the diagram below. Reverse the polarity every 30 seconds. After approximately 8 minutes (4 minutes per sensor wire), they should have an even "soot" like appearance. Avoid excess current and this will cause incorrect platinising.
   5) After platinising, rinse the sensor well in distilled water.
   6) If you have any doubts about any of these steps, then you should consider returning the sensor to the factory. The cost of replatinising is quite low, and you will be guaranteed of the best possible result.



Sensor Connector

19. Warranty

TPS Pty Ltd guarantees all instruments and sensors to be free from defects in material and workmanship when subjected to normal use and service. This guarantee is expressly limited to the servicing and/or adjustment of an instrument returned to the TPS Pty Ltd Factory Service Centre, freight prepaid, within twelve (12) months from the date of delivery, and to the repairing, replacing, or adjusting of parts which upon inspection are found to be defective. Warranty period on sensors is six (6) months.

Freight costs to and from the factory are the responsibility of the purchaser. Shipping damage is not covered by this warranty.

TPS Pty Ltd accepts no liability for any incidental or consequential damages caused by or resulting from the use or misuse of this equipment either due to failure of the equipment, incorrect calibration, incorrect operation, or from interpretation of information derived from the equipment. Specifications are subject to change without notice. This warranty becomes invalid if modifications or repairs are carried out on this unit by unauthorised persons. There are no express or implied warranties which extend beyond the face hereof.

Procedure for Service

Please read service details on our **'Service' web page** first:
http://www.tps.com.au/service.htm

TPS Pty Ltd has a reputation for prompt and efficient service. If you feel that this equipment is in need of repair, please re-read the manual. Sometimes, instruments are received for "repair" in perfect working order. This can occur where batteries simply require replacement or re-charging, or where the sensor simply requires cleaning or replacement.

Return the instrument AND ALL SENSORS to TPS Pty Ltd freight pre-paid. It is your responsibility as the sender to ensure that TPS Pty Ltd receives the unit, so consider using a trackable freight service.

Please check that the following is enclosed with your equipment:

- **A TPS 'Service / Return Goods Form' – see web link below:** http://www.tps.com.au/Service/Service%20form_web.pdf
- **Your full name**
- **Your company name**
- **Your email address or fax number**
- **Your return street address**
- **A description of the fault. (Please be specific - "Please Repair" does not describe a fault.)**

Your equipment will be repaired and returned to you by express air freight where possible.

For instruments beyond warranty period, a repair cost will be calculated from parts and labour costs and emailed to you. If you decline to have the equipment repaired, the complete instrument will be returned to you freight paid, not serviced.

TPS Pty Ltd has only one service location, which is located at our factory in Brisbane:

Service Department
TPS Pty Ltd
4 Jamberoo Street
Springwood, QLD 4127
Australia
T: (07) 32 900 400
F: (07) 3808 4871
E: tps@tps.com.au
W: www.tps.com.au

Annex 6

Sampling procedures for drinking water

Sampling Procedures for Drinking Waters

1 PURPOSE

This standard operating procedure outlines details for collection of drinking water samples for chemical, microbiological and radiological analysis. Details of the type of sample containers and preservatives to be used are also included. These procedures should be utilized by drinking water service providers. The sampling procedures and details of containers and preservatives are based on requirements outlined in AS/NZS 5667.1 (1998).

2 BACKGROUND

Drinking water service providers are required to monitor and report on drinking water quality in accordance with a monitoring notice issued by the regulator (Department of Natural Resources and Water (NRW)) under the *Water Supply (Safety and Reliability) Act 2008*. This will require monitoring for *Escherichia coli* (*E. coli*) in accordance with the requirements of the *Public Heath Regulation 2005* and for other parameters as appropriate to individual schemes.

This monitoring program will be used to identify gaps in water quality information and to help service providers identify key water quality parameters for their schemes for the development of their Drinking Water Quality Management Plans (DWQMP). Queensland Health, in consultation with NRW and service providers will assist in an audit of drinking water supplies for the following parameters as required for individual schemes:

- Microbiological Testing (Micro) – *E. coli*
- Standard Water Analysis (SWA)
- Heavy Metals (HM) (Al, As, Cd, Zn, Cr, Ni, Fe, Mn, Cu, Zn)
- Mercury (Hg)
- Fluoride (F)
- Pesticides
- Phytoplankton (algae, cyanobacteria)
- Disinfection By-Products – DBPs (Trihalomethanes and Haloacetic acids)
- Radiological testing - Alpha and Beta Activity

At the completion of the survey, an on-going mandatory monitoring program will be implemented to best assess drinking waters supplied by drinking water service providers throughout Queensland.

3 REFERENCES

3.1 AS/NZS 5667.1 (1998) Water Quality – Sampling: Guidance on the design of sampling programs, sampling techniques and preservation and handling of samples.

4 PRELIMINARY CONSIDERATIONS

In general, all samples that are collected for analysis must be representative of the water facility being tested. In some cases, consideration should be given to submission of composite samples to minimize sample numbers. Once samples are collected in their respective containers (see Table 2), avoid prolonged exposure to the sun. It is good practice to immediately place collected samples into the carriage containers (e.g. esky). In addition, samples should be delivered as soon as possible to the laboratory. Always label each of the sample containers with a unique identifier and any other information that may be relevant. Furthermore, record the name of sampler, date and time of sampling, location of sample and the unique identifier on laboratory sample submission forms (if possible, restrict the unique identifier to a simple alpha/numeric number).

Water samples may be collected from a tap outlet, standing water body or a bore and some important sampling procedures are as follows:

4.1 From a tap (reticulated town water, tank water, other storage facilities with a tap outlet):

- If there are several taps in the area of test, choose a tap which is most frequently used.
- Remove any external fittings such as filters and remove any contaminants (e.g. grease, slime, sediment build-up etc) around the spout with a clean cloth. Tap cleanliness is particularly important with microbiological testing. Tap outlets which are suspected to be contaminated must be disinfected first before taking the sample. Disinfect by swabbing the outside of the tap and as much of the inside as possible with a 0.1% sodium hypochlorite solution. Prepare the 0.1% solution by diluting commercially available sodium hypochlorite solution (approx 10%) by a factor of 100. Allow to stand for a few minutes (to allow full disinfection) before proceeding to the next step shown below.

  CAUTION: Sodium hypochlorite is a strong oxidizing agent and is highly corrosive. Handle with great care and wear appropriate PPE (gloves, safety glasses). If contact with skin or clothing occurs, wash immediately with copious quantities of water.

- Turn the tap on to a steady stream and run for at least 2-3 minutes to remove any stagnant water in the plumbing network.
- Depending on the parameter(s) you want tested, proceed as shown below in Table 1.

4.2 Surface waters – shallow and deep (lakes, rivers, creeks, streams etc)

Surface Water Samples (shallow depth)

- The sample should be representative of the source of supply. In this respect, it is important to consider location and depth of the water. Taking samples very close to the bank may not be representative of the source of supply.
- For a surface water sample, simply hold the bottle firmly and plunge the neck downwards to a depth of about 0.5m. Turn the bottle until the neck points upward and mouth is directed towards the current (if present). If a sample is taken from a boat, always collect the sample from the upstream side of the boat.
- Alternatively, a clean bucket (of about 10L capacity) or other suitable vessel such as a large beaker can be used to collect the surface sample. Dip the bucket or beaker into the stream, withdraw and then transfer to the laboratory sample container.
- If a composite sample is to be submitted for analysis, pour equal portions of freshly collected samples into a suitable container.
- Depending on the parameter(s) you want tested, proceed as shown below in Table 1.

Depth Water Samples(deep waters)

- Collect the water sample using a suitable depth sampling device (e.g. hosepipe, grab, pump etc). Be careful not to disturb bottom sediment.
- If a composite sample is to be submitted for analysis, pour equal portions of freshly collected samples into the appropriate container (see Table 2).
- Depending on the parameter(s) you want tested, proceed as shown below in Table 1.

4.3 Groundwaters (bores, wells - pump operated)

- Operate the pump to flush out stagnant water from the pipe. Operation time will depend on the depth of the bore and diameter of the pipe-work.
- Do not sample a newly drilled bore/well or a rarely used one unless the facility has been pumped for more than 48 hours.

- Collect the sample from the tap which should be located on the discharge side of the pump (do not collect the water sample from a tap located on the inlet side to the pump as this will not be representative of the water reaching the users).
- Depending on the parameter(s) you want tested, proceed as shown below in Table 1.

5 COLLECTION OF WATER SAMPLES

Table 1 indicates procedures in collecting water samples for different parameters.

Table 1: Collecting water samples for different parameters.

Parameter	Method of Collection
Pesticides and DBPs (trihalomethanes and haloacetic acids)	• If the sample requires preservation (see Table 2), add the preservative (sodium thiosulphate for pesticides and ammonium chloride for DBPs) to the empty sample container. • For pesticide samples, collect the water sample as indicated in 4.1, 4.2 or 4.3 (depending on the situation) and fill the container to near full capacity. However, when samples are collected for the DBPs (i.e. trihalomethanes and haloacetic acids) fill the bottle to just overflowing (but do not let overflow) to exclude all air in the bottle i.e. no air bubbles can pass through the water sample. **Do not pre-rinse the bottle and do not let the bottle overfill.** • Seal the bottle with the top ensuring that the top for pesticides contains an inner Teflon liner seal. If there is no Teflon liner, cover the top of the bottle with aluminium foil and then seal with the cap. • Agitate the bottle by hand for 1 minute to disperse the preservative (if added). • Label the bottle and place in an esky at 4°C (using frozen briquettes) or other suitable container for transportation to the laboratory. **Do not freeze**. • For pesticide analyses, please indicate what pesticides or herbicides are being used in the area; if this is not known, please indicate what crops are grown in the area.
Phytoplankton	• Samples for phytoplankton identification and enumeration are usually collected from standing water bodies – please refer to Section 4.2 for method of collection. • A representative sample may be obtained by sampling several sites and pooling these samples at equal volume to produce a composite. Alternatively, individual samples may be submitted. • Collect the water sample (shallow or deep waters) as described in 4.2 above and add 5mL lugol preservative if delivery time to the laboratory is expected to exceed 48hrs. If lugol is added, the water sample will change colour to a straw colour. • Seal the bottle and mix well. • Label the bottle and place in an esky at 4°C (using frozen briquettes) or other suitable carry container for transportation to the laboratory. • Generally, sampling frequency is weekly to detect changes in algal species and abundance. Standing waters may only require fortnightly sampling especially in times of low cell growth. • Routine sampling should be conducted within the same predetermined time period in the day as time of day may be critical to the result.
SWA, HM, Hg, F, Alpha Beta Activity	• Collect the sample as indicated in 4.1, 4.2 or 4.3 depending on the situation and rinse container out with the water at least twice and then fill to near full capacity. • Where applicable, add the appropriate preservative to the sample container (see Table 2). • Seal the bottle with the cap and mix well to disperse the preservative. • Label the bottle and place in a suitable container for transportation to the laboratory. Samples for SWA, HM, Hg and F can be transported at ambient temperatures but samples for alpha beta activity should ideally be transported chilled in an esky at 4°C.
Microbiological	• Fill the container to near full capacity as indicated in Sections 4.1, 4.2 or 4.3 (depending on the situation) and seal with the yellow screw cap. **Do not put fingers inside the container at any time and do not rinse the container.** • Please note that the container for microbiological testing already has preservative added. • Mix well to disperse the preservative. • Label the jar and place in esky at 5°C ± 3°C (using frozen briquettes) or other container for transportation to the laboratory. • For meaningful results, the samples must reach the laboratory within 24 hrs.

6 CONTAINERS

Details of sample containers and preservatives for water sampling are shown in Table 2.

CAUTION: Care should be taken when handling all preservatives. In particular, nitric acid is extremely corrosive and can cause severe burning or blindness if splashed into the eyes. Always use gloves and safety glasses when handling preservatives. If contact with skin or clothing occurs with any of the preservatives, wash immediately with copious quantities of water.

Table 2: Sample containers for water samples requiring analyses for parameters shown below. See Appendix for illustrations of the bottles.

Parameter	Container	Washing	Volume Required	Preservative	Comments
Alpha beta Activity	P (code MB/P4)	Acid washed	500mL	Nitric Acid (1.5%) Note 1 and chill	Filter samples if particulate matter is present. Use (0.45µm) Transport chilled to the laboratory.
Disinfection By-Products	G (code MB/G8)	Solvent washed	200mL	Ammonium Chloride (0.2g) (Note 2)	Transport chilled to the laboratory.
Heavy Metals (Al, As, Cd, Zn, Cr, Ni, Fe, Mn, Cu, Zn)	P (code MB/P6)	Acid washed	250mL	Nitric Acid (1%) (Note 3)	May be transported at ambient temperature.
Fluoride	P (code MB/P5)	Detergent washed	250mL	Nil	May be transported at ambient temperature.
Mercury	G (code MB/G7)	Acid washed	250mL	Nitric Acid /Potassium Dichromate (approx 1%) (Note 4)	May be transported at ambient temperature.
Microbiological Testing (*E. coli*)	Sterile yellow screw cap polystyrene (code NW/BOTT)	Sterile	250mL	30mg sodium thiosulphate and chill	Samples must be kept chilled and delivered to the laboratory within 24hr. Preservative already added to the container.
Pesticides	G (code MB/G1)	Solvent washed	1L	80mg sodium thiosulphate and chill (Note 5)	If the water is not chlorinated there is no need to add the sodium thiosulphate preservative. Transport chilled to the laboratory.
Phytoplankton	P (code MB/P2)	Detergent washed	1L	5mL Lugol and chill	Use the preservative only if the sample cannot be submitted to the laboratory within 48hr. Transport chilled to the laboratory.
Standard Water Analysis (SWA)	P (code MB/P2)	Detergent washed	1L	Nil	May be transported at ambient temperature.

Notes:

1. Add 7.5mL concentrated nitric acid (from supplied container) to approximately 500mL sample, replace cap and mix well.
2. Add the ammonium chloride solid to the water sample, replace cap and mix well.
3. Add 2.5mL concentrated nitric acid (from supplied container) to approximately 250mL sample, replace cap and mix well.
4. Add 4mL of the prepared concentrated nitric acid/potassium dichromate mixture (2 mL concentrated HNO_3 plus 2mL of $K_2Cr_2O_7$ 50mg/mL) to approximately 250mL sample and mix well.
5. If the water has been chlorinated, add 80mg sodium thiosulphate for preservation.
6. P = Plastic (High Density Polyethylene - No 2 on Recycle triangle)
   G = Amber Glass Bottles with Teflon liner seal

7 ORDERING CONTAINERS

Please use QHFSS form 18292 for ordering bottles and containers which are free of charge for Local Government clients. Simply fill out the form and fax the completed form to QHFSS (Fax 3274 9022). Copies of form 18292 may be obtained by contacting any of the contacts shown below or by contacting Dora Bertini on Ph 3274 9066.

8 CONTACTS

Microbiological: John Bates Ph 3274 9101 or Bruce Gray Ph 3274 9075
Radiological: Ross Kleinschmidt Ph 3274 9124
Disinfection By-Products/Pesticides/Phytoplanktons: Mary Hodge Ph 3274 9087 or Simon Christen Ph 3274 9088
Standard Water Analysis/Heavy metals/Mercury/Fluoride: Henry Olszowy Ph 3274 9071 or Eugene Lee Ph 3274 9058

9 AMENDMENT HISTORY

Version	Date	Author	Changes
0 (New)	September 2008	Dr H A Olszowy	First Edition
1	October 2008	Dr H A Olszowy	Added further information to Section 2 Background

APPENDIX

Illustrations of Containers

MB/P4 - Red label acid washed plastic 500mL for alpha beta activity, preservative 7.5mL concentrated nitric acid.

MB/G8 – Blue label solvent washed glass 200mL for disinfection by-products, preservative 0.2g ammonium chloride.

Queensland Government
Queensland Health

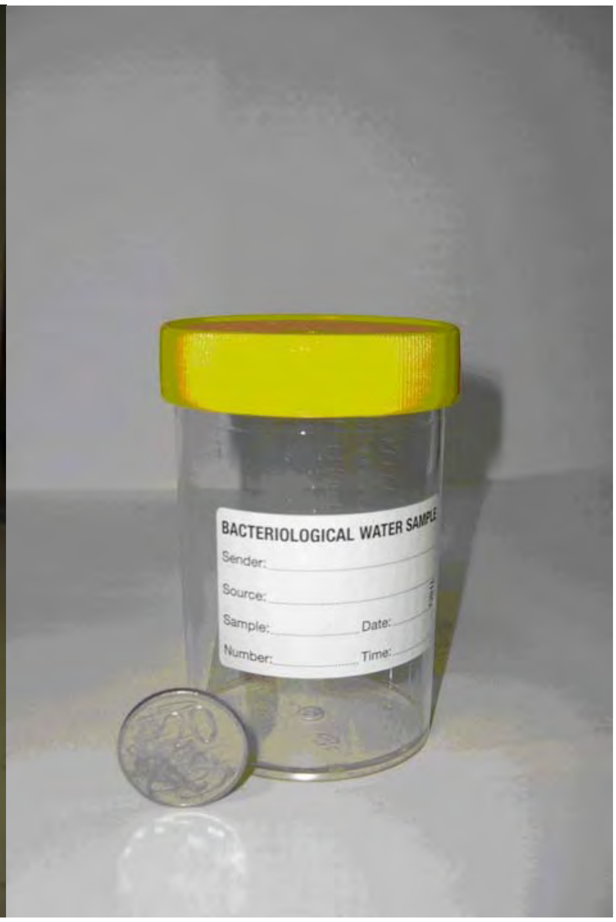
APPENDIX (Cont)

Illustrations of Containers

MB/P6 – Red label acid washed plastic 250mL for heavy metals; preservative 2.5mL concentrated nitric acid.	**MB/P5 –** Green label detergent washed 250mL plastic bottle for fluoride; no preservative required.

APPENDIX (Cont)

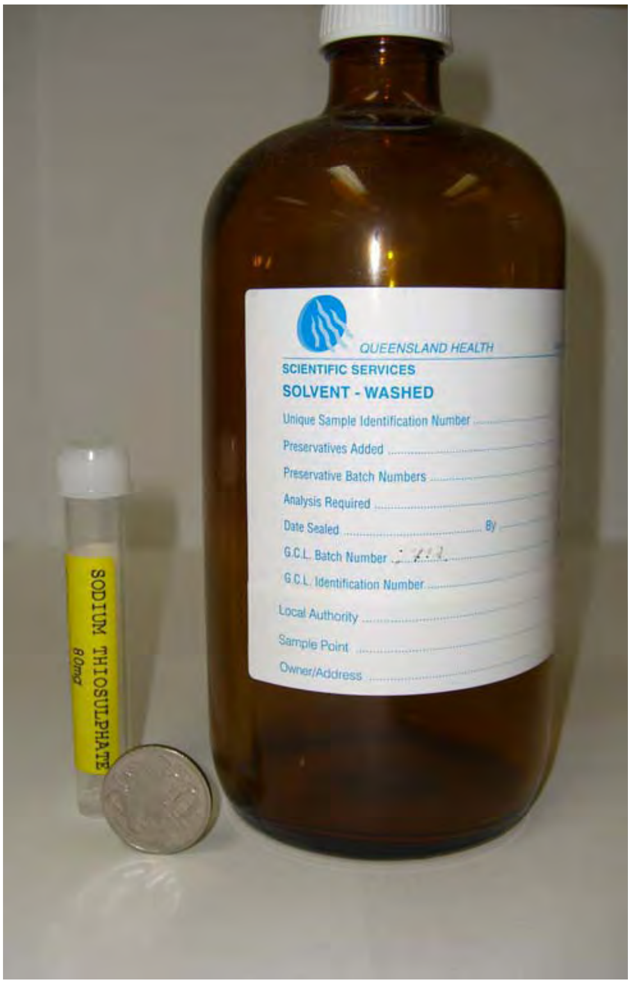
Illustrations of Containers



MB/G7 – Red label acid washed 250mL glass bottle for mercury; preservative consists of 2mL concentrated nitric acid plus 2mL potassium dichromate.	**NW/BOTT –** Yellow screw cap 250mL sterile polystyrene jar for microbiological testing; 30mg sodium thiosulphate preservative has already been added to the jar.

APPENDIX (Cont)

Illustrations of Containers



MB/G1 – Blue label solvent washed amber glass bottle for pesticides, preservative 80mg sodium thiosulphate only if water is chlorinated. Keep samples chilled.

MB/P2 - Green label detergent washed plastic bottle for standard water analysis (SWA) and phytoplankton. No preservative is required for SWA. For phytoplankton, use 5mL lugol (not shown) as preservative only if the sample cannot be submitted to the laboratory within 48hr. Transport chilled to the laboratory.

Annex 7

Freshwater E.coli sampling and analysis procedures

A7. WATER QUALITY SAMPLING AND ANALYSIS

This annex provides various sampling procedures that can be used in the outer islands. It should be noted that the procedures will give some indications of *E.coli* presence but have variations in how tested samples are prepared and store or incubated.

After all, these suggested procedures have been tested previously in Kiribati and have generated huge interest amongst governing authorities in relation to providing the level of water sources bacteriological contamination, particularly during.

Note: It is also very important to note features such as water color and algal growth in well, and this may indicate high nutrient levels in well and may prompted *E.coli* sampling.

A7.1 Procedure for Collecting Source Water Samples for *E.coli* Analyses

Check to make sure the following materials are available before collecting sample:

1. Detergent to wash hands before sampling.
2. Sterile, non-toxic, glass or plastic container with a leak-proof lid. Container should be capable of holding 120-mL or 250-mL with ample headspace to facilitate mixing of sample by shaking prior to analysis (Nalgene polypropylene wide-mouth bottles).
3. Marker pens to label sample.

Collecting the Sample

1. Record the sample number, sample location, samplers name, observations, and sampling date and time in a sampling log book if the sample.
2. Water taps used for sampling should be free of aerators, strainers, hose attachments, mixing type faucets, and purification devices. The service line should be cleared before sampling by maintaining a steady water flow for at least two minutes (until the water changes temperature).
3. Adjust the flow of water out of the tap or hose so the water will not splash out when it is collected into the sample container.
4. If there is not an inline tap that allows for the sampling of source water prior to treatment, samples should be collected as close to the intake as possible.
5. For wells water samples should be collected close to the surface using a grab sampling technique. Samples may be collected manually by direct submersion of the bottle into the water or by using a grab sampling device, as simple as a metal pole with an adjustable clamp at one end that holds the sampling bottle in place. In case grab sampler is not available use clean container to get the water out of the well and fill the sampling bottle.
6. Using aseptic technique (i.e., sanitize tap, do not touch the inside of the sample container, etc.), fill the E. coli sample container, leaving at least 1 inch of head space. Do not expose an opened container any longer than necessary. Record the sample number, date and time of sample collection, sample location, and analysis requested on the sample container.

7. Immediately following sample collection, tighten the sample container lid, ensuring that you don't touch the inside of the bottle or the lid. Place the samples in box with ice to preserve the sample for analysis.
8. If the sample will be shipped off-site for analysis, and will not be shipped for several hours, place the sample container upright in a refrigerator to maintain the sample at a temperature of less than 10°C, but not freezing, prior to shipment. If a refrigerator is not available, wrap the sample with insulation such as bubble wrap or paper towels (to prevent freezing), place the sample in a ziplock bag, and place the bag containing the sample in the shipping cooler with wet ice or ice packs. Replace with fresh ice or ice packs immediately prior to shipment.

A7.2 Water Sample Collection – Standard Operating Procedure

Sampling from Well

1. Wash hands and dry with clean tissue.
2. Label the sample bottle appropriately, Date, Time, Household Number and Census Block Number.
3. Abstracted well water with use of clean abstracting bucket/tin cans, ensuring that it does not touch the walls of the well.
4. Take sample from at least a depth of 30- 40 cm.
5. Rinse the abstracting device with well water three times before taking sample and transferring to the sampling bottle.
6. With cleans hands carefully remove the cap of the sampling bottle, and fill it with 100 ml of sample.
7. Strongly shake the sample to dissolve sodium thiosulphate in the sample bottle. Securely close the bottle the by screwing the cap back on the bottle.
8. Collect water in the bucket which has been rinsed three times with sample water.
9. Record salinity measurement and Temperature.
10. Record any other relevant comments, on the groundwater physical sheet.

Sampling From Tap

1. Remove any attachments from the tap.
2. Open the tap and flush the system for at least a minute.
3. Wash hands and dry with tissue.
4. Label the sample bottle appropriately, Date, Time, Household Number and Census Block Number.
5. With clean hands carefully remove the cap of sampling bottle and fill it with 100 ml of tap water. Securely close the bottle by screwing the cap back on the sampling bottle.
6. Strongly shake the sample to dissolve sodium thiosulphate in the sample bottle.

7. Collect water in the bucket which has been rinsed three times with sample water.
8. Record salinity measurement and Temperature.
9. Record any other relevant comments, on the physical sheet.

A7.3 *E.Coli* Sampling Procedure: Collilert 18 Presence and Absences Test Procedure

Presence/Absence Test Procedure

1. Carefully separate one Snap Pack from the strip, taking care not to accidentally open adjacent pack.
2. Tap the Snap Pack to ensure that all of the Collilert powder is in the bottom part of the pack.
3. Open one pack by snapping back the top at the score line.

Caution: Do not touch the opening of pack.

4. Add the reagent powder to the sample bottle.
5. Aseptically cap and seal the vessel.
6. Shake until the reagent powder dissolves.
7. Incubate for 24 hours at 35° ± 0.5°C. (Used Esky for incubation for this survey.)
8. Read the results at 24 hours.
9. Fluorescence indicates presence of E. Coli.

Result Analysis

Upon incubation period, if no yellow colour is observed, the test is negative.

For samples with observed colour change;

- If the sample has a yellow colour, the presence of total Coliforms is confirmed. If colour is not uniform, mix by inversion then recheck.

- If yellow is observed, it was checked for fluorescence, by placing a 6 watt 365 nm UV light within five inches of the sample in a dark environment, ensuring the light is facing towards

A7.4 EC-compact plate Sampling Procedures

Standard Membrane Filtration Method

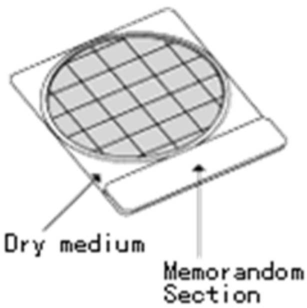
(Adapted from the USA Environmental Protection Agency (EPA) and American Public Health Association methods (APHA) (EPA, 2000; APHA, 1995)

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 as cool as possible and in the dark, but not in a freezer. So either in a chilly bin or a bag with cool elements. Samples need to be processed within 12 hours of collection, make sure no melted water comes into contact with the sample.

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

3 X Compact Dry Plates



These plates contain dehydrated agar that allow the bacteria to grow once rehydrated
1 X 50 ml sterile syringe
1 X 20/15/10 ml syringe
1 X sterile filter housing
2X GN6 Metricell gridded white filters (PallGellman)
Tweezers for filters (not sterile)
Bleach
Sterile/Boiled Water
1X 20/10 ml syringes

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

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

PROCEDURE

1. Field Sampling Procedure

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

2. Pre-sampling procedure (sample bottles sterilisation)

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

3. Lab Sampling Preparation

<u>Set-up procedures</u>

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

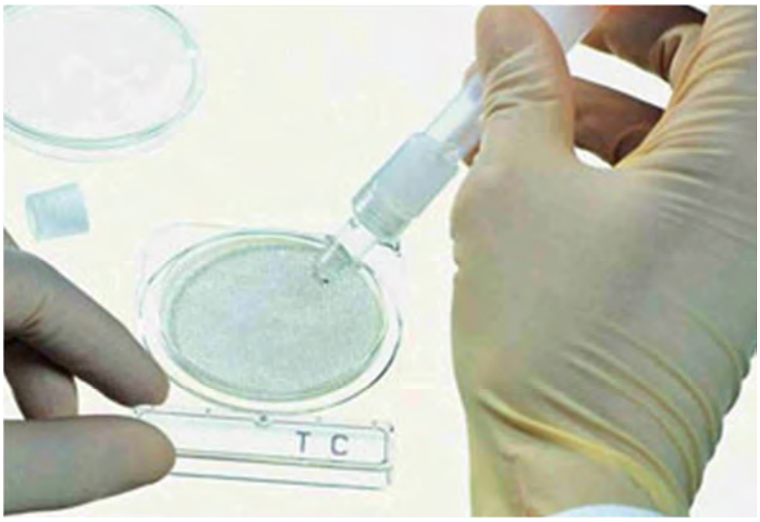
h. Prepare a bucket or container for storing all unused sample water and wastewater.

<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 1 ml syringe with boil water before filling and pouring 1 ml sterile water onto the first plate for our 1 ml CONTROL.
c. Rinse the 1 ml syringe thoroughly with boil water (3 times) to clean it before filling it up with sterile water to cool it down.
d. Fill the 1 ml syringe with sample water and 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 the rehydrated 1 ml plates in a cooler box and record the incubation start time.

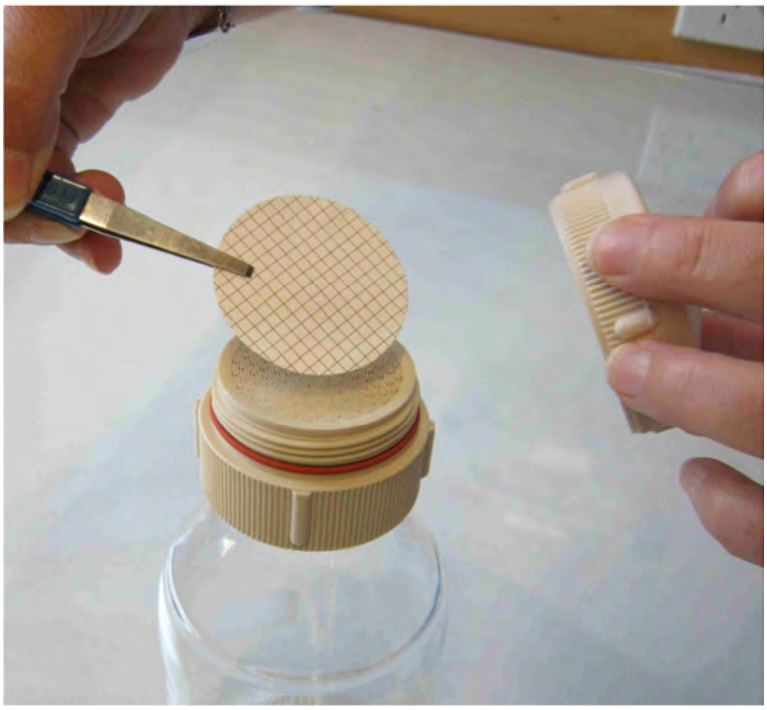
<u>50 ml sample preparation</u>

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



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

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



i. Sanitise the tweezers again in bleach and sterile water.

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

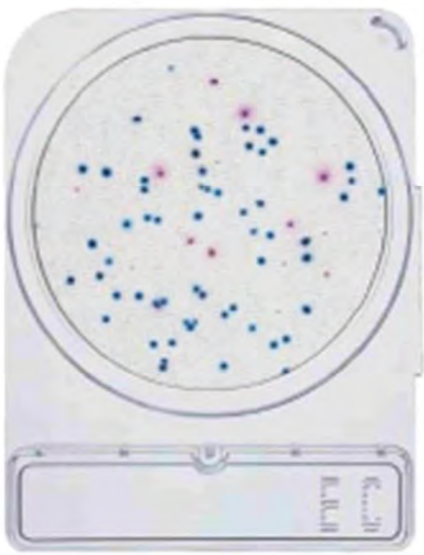
k. Use the sanitised tweezers to transfer the filter paper from the housing to the re-hydrated plate.
l. Repeat steps **d to e** until all samples have been prepared for 50 ml analysis.
m. For the CONTROL, use sterile water, instead of sample water, and subsequent to thoroughly rinsing the syringe and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

4. Post sampling procedure

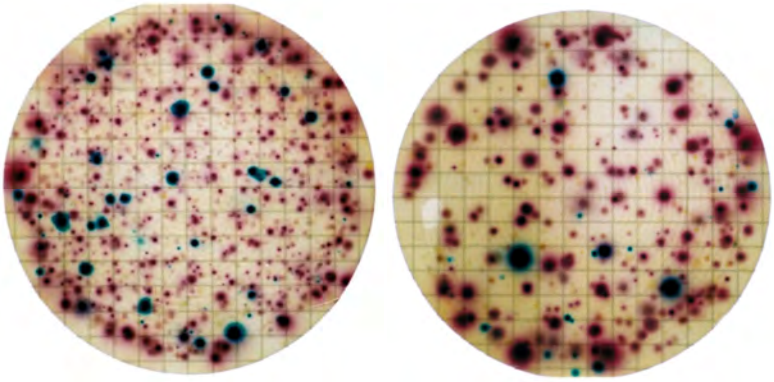
a. Repeat pre-sampling routine to prepare for the next sampling phase

Counting Procedure:

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



The number of red and blue colonies = Total Coliforms
The number of blue colonies = *E.coli*
Or the filters on Compact Dry may look like this, again count the number of blue and red colonies.



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

Cleaning of Equipment:
Clean the syringes and filter housing using 5% bleach and then **3** times with boiled water to remove any residual bleach. Then put a large pot of water on the stove to boil. Let this come to the boil and boil it for 10minutes to kill any pathogens in it. Then place the syringes and filter housings in it and boil it for a further 10minutes. Turn of the stove and let the syringes and filter housings cool down in the water with a lid on the pot and remove while they are still warm but as hot as to burn you and place them in a clean plastic container or zip lock bags.

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

A7.5 H_2S Strip Method Procedures

Introduction:
The H_2S strip method is used as a field kit to assess the microbial quality of water. The H_2S strip method detects hydrogen sulphide producing bacteria.

The H_2S strip method was developed for testing water. It is a simple, affordable, on site method, which has >85 % correlation when compared to faecal coliforms normally used to assess water quality. The method does not require expensive laboratory equipment such as filtration apparatus and incubators.

Methodology:

The H_2S (hydrogen sulphide) test was originally developed over 20 years ago, to detect in a volume of water, the production of H_2S by enteric bacteria associated with faecal contamination. The contamination is detected by formation of a black precipitate from the reaction of the H_2S with iron in the medium. This relatively simple, low-cost test has been studied, modified in various ways, tested and used to some extent in many parts of the world as an indicator of faecal contamination of drinking water. A method for preparing and conducting the test is detailed as follows.

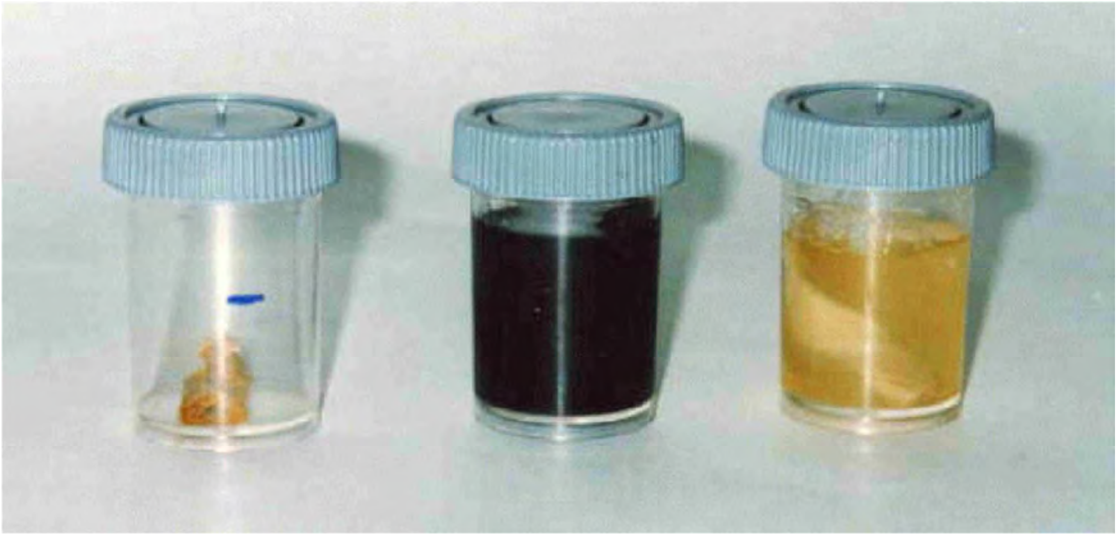
Preparation of H_2S test containers

1. Any type of glass bottle or tube with a volume of between 20 ml to 200 ml, which has a heat resistant cap/lid, can be used. The bottles or tubes are first cleaned and calibrated to indicate a 10 ml, 20 ml or 100 ml volume, or any volume in-between – depending upon their size. Calibration is done with a graduated cylinder or other measuring device. A glass marking pencil, permanent ink pen or tape can be used to mark the desired volume.
2. The medium used in the test is prepared from the following chemicals, which are dissolved into distilled or dechlorinated tap water while stirring.
3. If not immediately used, the media can be sterilized and stored in a refrigerator until ready for use.
4. Taking tissue paper, filter paper, non-toxic paper towelling, absorbent pads used for membrane filtration, or any other type of absorbent material (coasters used in bars work well if no black ink is used), place a measured quantity of media onto the paper so that a pad or paper strip for a 10 ml test sample contains 0.5 ml of media, a 50 ml sample will use 1 ml of media and a 100 ml sample will require 2.5 ml of media (a pipette graduated at 0.1 ml intervals may be necessary for this). Alternatively, paper strips can be cut to a size that has absorbed 0.5 ml of media. If the sample to be tested is 10 ml, use one strip; if 50 ml, use two strips; and if 100 ml, use five strips. The next step is to dry the strips in an oven at about 55oC. These reagent-impregnated strips can be stored dry (in an envelope or preferably a zip-locked bag) for several months – until ready for use. It is always advisable if the health authority supplies prepared strips to the community.
5. When ready to conduct the test, a strip or strips are introduced into the appropriate (clean) sample bottle, loosely capped and sterilised. This can be done with an autoclave or a simple pressure cooker for 15 minutes at 115^{o}C. It can also be done by steam (in a rice steamer) for about 30 minutes or in a hot air oven at about 120^{o}C for 60 minutes. The tubes or bottles are then allowed to cool and the caps or lids tightly sealed. The tubes or bottles should be stored in a dark place until ready for use.

Reading and interpreting results

1. After sampling, place all test samples in a dark place and incubate at room temperature for a total of three days. Every 12-18 hours examine the samples for changes in colour. The date and time of each observation is recorded on the report form and the observations are recorded as follows: (–) = no change; (+) = slight change, the paper strip or water has turned grey; (++) = the paper strip is partially black; (+++) = the strip and the water sample itself are noticeably black.

2. As noted above, a colour change indicates the presence of bacteria of faecal origin. The speed of the reaction will determine the density of organisms present; i.e. the quicker the reaction the higher the number of faecal organisms present. This can also be interpreted in terms of a risk factor. For example, no colour change until day three indicates a lesser risk than a (+++) change within 12 hours.



Empty sample bottle (left) positive result (middle) negative result (right)

3. Positive results would indicate that the water is contaminated and results of sanitary survey should be considered to determine the source of contaminant. For example, if the tank inlet is not screened and the results of the H2S test are positive on the first day, the users should disinfect the water as outlined in Appendix E and the tank inlet should be screened.
4. Boil or treat the water until further results are obtained and you know the water is safe to drink.
5. If bottles are damaged do not use.

Sampling procedure:

1. At the time of sampling, label each container with a sample number. Also record the date, time and location of collection on the container with a glass marking pencil or permanent ink pen.

2. Flame the mouth of the tap nearest to the tank and let the water run freely for at least 30 seconds. Place the opened H2S sample collection bottle under the tap and collect the pre-calibrated amount being careful not to contaminate the cap. It should be noted however that samples should not be collected from taps that are leaking and flaming the tap is not necessary if you are testing the quality of the water as it is actually consumed. Each day of sampling, a control is collected. This is a sample that is known to be uncontaminated, such as boiled water, commercially bottled water, or water treated with chlorine. The control sample is used as a benchmark to compare colour change in the test samples and to ensure that the sample bottles have been properly sterilised prior to use.

   Note: There will be slight change in the colour of the sample to a pale yellow or light brown due to the colour of the reagent, which is normal.