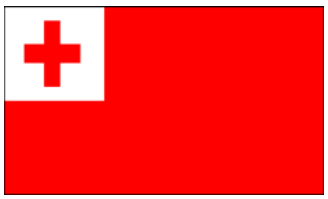

TONGA

WATER SAFETY PLANS – NUKUALOFA URBAN SUPPLY

Water Safety Plan Programme
A Project Funded by AusAID- 2006- 2007

SOPAC

Australian Government
AusAID

NOTE

This report is one in a six series produced for the Tonga Water Safety Plan programme funded by AusAID and implemented by Pacific Applied Geoscience Commission (SOPAC) and World Health Organisation (WHO). For ease of reference and retrieval this report is available digitally in the SOPAC publications library system as **SOPAC Technical Report No**…..

SOPAC wish to acknowledge the kind cooperation of Tonga Water Board, Ministry of Health and the Water safety Plans Steering Committee, Tonga to make this project a success.

List of Other Reports:

Water Supply System Description – Nuku'alofa /Lomaiviti
Improvement Schedules – Nuku'alofa Urban Supply
Water Safety Plan - Rain Water Tank
Water Safety Plan – Lomaiviti Rural Supply
Monitoring Plans - Urban and Rural Supply

Name of Urban Supplier: TONGA WATER BOARD

Address: Head Office, P.O. Box 92, Ph 23-299. Corner Taufa'ahau Rd and Old Falemahaki Rd, Nuku'alofa, Tonga

Production Address: Matakieua Well Fields, Matakieua, Tonga tapu.
Cover photo: Matakieua concrete reservoirs collecting water pumped from the well fields. (Taniela Kailahi-TWB)Report compiled by Taniela Kailahi (TWB) on behalf of the Steering Committee for Nuku'alofa Water Safety Plan

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I. Introduction:

Access to safe drinking water is a basic need and is one of the most important contributors to public health and to the economic health of communities. Pacific island countries have yet to overcome the challenge of providing a safe and adequate supply of drinking water to its populations. Infectious, waterborne diseases, such as Typhoid and Cholera and newly emerging pathogens are a major cause of morbidity and mortality within the Pacific region.

The World Health Organization (WHO) report that about 2 million people in the world die each year due to diarrhoeal diseases, most of them are children less that 5 years of age. The worst affected are the populations in developing countries. Lack of access to safe drinking water is one of the main contributors to this situation.

Traditional approaches that rely on sampling and testing water have failed to achieve extensive improvement in access to safe drinking water. Pacific island countries are committed to achieving targets specified in the Millennium Development Goals (2000), including halving the proportion of people without access to safe drinking water by 2015. A new strategy is now being promoted globally that is based on risk management principles – drinking water safety planning.

1.1. Tasks

The five day mission to Tonga from 12-16 March 2007 was convened to review the Water Safety Plan and Improvement Schedules compiled by the Tonga Water Safety Plan Steering Committee and the Tonga Water Board.

Mr. Roly Hayes (engineer) also joined the mission to carry out the assessment of the Nuku'alofa Urban Water Supply. Other experts on this mission were Drinking Water Assessors from New Zealand Ministry of Health.

The team reviewed the water safety plan, carried out field assessment and water analysis. The Tonga Water Board Engineer was consulted and reference was made to the Tonga Water Board Reports. At the end of the week draft reports were presented and discussed with Tonga Water Board and the Water Safety Plan Steering Committee.

1.2 Administrative Support

Administrative support was given by Tonga Water Board for the transport for field work and office space. A good commitment was shown by Tonga Water Board as the lead agency in the project. All information was made available to the mission team by the Tonga Water Board

1.3 Key Personnel

Judy Williamson, Drinking Water Assessor, Ministry of Health, New Zealand
Rebecca Fox, Drinking Water Assessor, Ministry of Health, New Zealand
Scott Rostrom, Drinking Water Assessor, Ministry of Health, New Zealand
Roly Hayes, Water Engineer, Dunedin, New Zealand
Davendra Nath, Water Safety Plan Project Officer, (SOPAC)
Katusi Fielei, Chief Engineer, Tonga Water Board
Lindsy Lavemai, Water Manager/Coordinator, Tonga Water Board
Taniela Kailahi. Project Engineer, Tonga Water Board

2. Project Objectives: What is a Water Safety Plan?

The main objective of the Water Safety Plan Programme in the Pacific is to produce Water Safety Plans for urban and rural drinking water supply systems involving all in-country stakeholders.

A Drinking Water Safety Plan (DWSP) is a comprehensive risk assessment and management tool that encompasses all stages in the drinking water supply from catchment to consumers. It draws on principles and concepts from other risk management approaches including Hazard Analysis Critical Control Point (HACCP) and the 'multi-barrier approach'.

The Improvement Schedules are part of the Water Safety Plans and are compiled after the risk assessment of the water supply system has been completed.

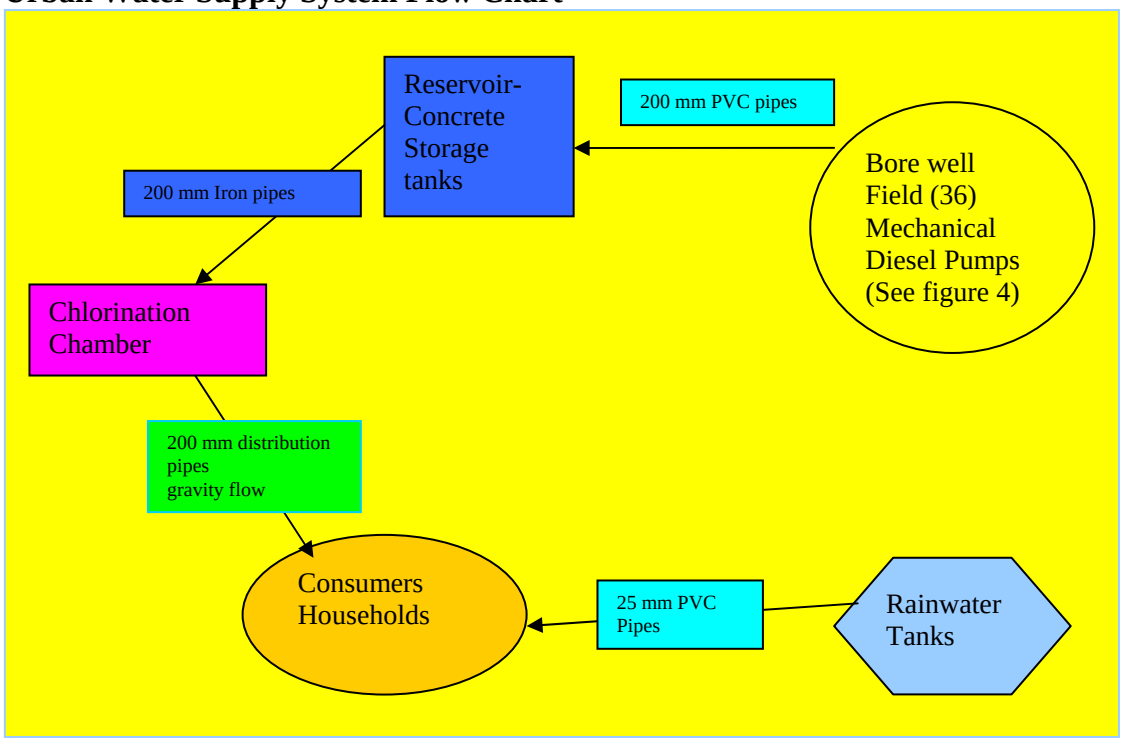
The key objectives of a Water Safety Plan are to:

- Prevent the contamination of source waters;
- Treat water to reduce or remove contaminants; and
- Prevent re-contamination during storage, distribution and handling

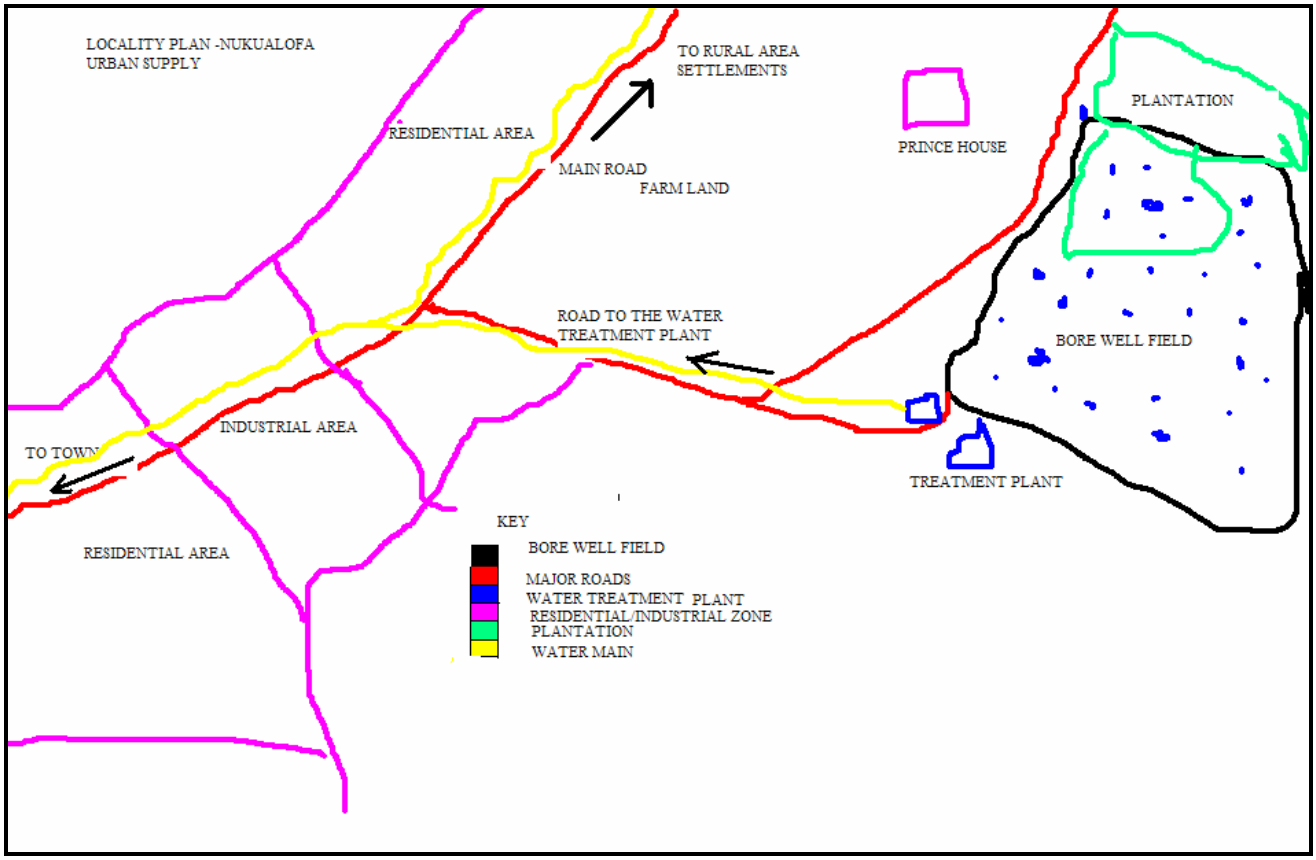
3. Nuku'alofa Urban Water Supply Description

Nuku'alofa urban water supply system flow diagram and locality plan can be seen below. Since the water is from deep bore wells there is no filtration system in place and thus chlorination is the necessary process to eliminate pathogens from water prior to consumption.

Urban Water Supply System Flow Chart



NUKUALOFA- Urban Supply - Mataki-Eua Locality Plan



Mataki-eua was selected as the urban system pilot site and so the following is true for the system set up.

There are currently 36 pumping units with a mixture of both electrical and diesel powered units. The water at intake is collected in 6 large cement storage tanks, water is then treated by calcium hypochlorite. Then the treated water is gravity fed to the distribution system which feeds the city of Nuku'alofa. Chlorination Injection point on the main outlet pipe situated within fifteen meters from the storage tank in a pit next to the bulk meters. The Water Safety Plan was based on the methodology provided at a training workshop arranged by SOPAC and assisted by the expert from New Zealand Ministry of Health water assessors as well as a consultant Dr Jan Gregor.
A steering committee was formed and divided into two groups, rural and urban each with a team leader. Both groups conducted risk assessments of the pilot sites; Mataki-eua urban and Lomaiviti rural. From the identified risks, teams followed the guidelines for Developing and Implementing Water Safety Plans based on the Water Safety Plans Book 1&2, WEDC Publications 2005

Photograph 2: Operator servicing pump engine at Matakieua Well field (Taniela Kailahi-TWB)

WATER SAFETY PLAN

SUPPLY NAME: Nuku'alofa Urban Supply

Flow Chart

Catchments & Intake

- Source: Freshwater lens (groundwater)
- A network of wells (hand-dug or tube).
- Very little soil cover with porous (limestone) ground underneath
- Diesel operated and electrically operated pumps
- Covered well-head and some non covered or exposed
- Pump shed at each well to protect the pumps, but not secure (sheds are not locked), some with no protection.
- Diesel storage at every well and refilled regularly depending on fuel efficiency.

Storage & Treatment

- Each of the wells pump water into 6 cement reservoirs
- Treatment: dosing with Calcium Hypochlorite.
- Chlorine dosing is done via an injector at the main line, prior to distribution for Nuku'alofa area. .
-

Distribution

- Distribution is by gravity feed to the city of Nuku'alofa.
- Supply rate is 6/7 ML per day for Nuku'alofa supply.
- Every property is required to connect to the reticulated system
- Households have the option of supplementing the reticulated supply with Rainwater Catchment. Most households have a rainwater tank

Worksheets

Catchment & Intake

List what could happen that may cause drinking-water to become unsafe (deterioration in water quality)	Is this under control?	If not, judge whether this needs urgent attention. *Urgent attention is needed for something that happens a lot and/or could cause significant illness/Responsible agent/s for immediate action.*
1. Contaminated aquifer water from surface activities (e.g. farming, household waste-water and sewage) in the recharge zone reaches the well.	No. The porous nature of the ground offers little protection against contaminants entering the aquifer. The extent/area of the groundwater lens is currently unknown.	Yes/Matakieua well field is the sole responsibility of TWB. e.g. TWB – bore drilling/ maintenance/protection MoH – village bore influence Lands & Survey – Responsible for the rest of the island of Tongatapu.
2. Diesel spills and leaks in the pump-shed could seep into the well though cracks in casing.	No. Condition of casing, wellheads etc appears to be old and worn-out.	Yes/TWB – Production
3. Sabotage / Vandalism	No. Even though some security personnel have been recruited, the area is too wide and wells too many to assign security guards to all of them. Evidence that fuel is sometime stolen however deliberate wellhead damage uncommon. of sabotage	Yes/TWB Production staff and Police
4. Poor workmanship/construction of well casing, leading to corrosion of the casing.	No. There is no current Tongan Drilling standard for well drilling. Australian and New Zealand standards is used as a guide but it is not enforced. Current boreholes in varying state	Yes/ More likely a TWB responsibility
5. Natural disaster makes source unsafe (massive saltwater intrusion from earthquake) or makes extraction not possible Well head, pump and engine is damaged by natural disasters .i.e. , earthquakes, cyclone, tsunami etc.	No. Most urban systems cannot be relied on during significant natural disasters Clarify expectations with Emergency Management Department on satisfactory contingency plans However establish and follow emergency contingency plans for all repair works more so	Seek immediate help of emergency water supply from the Disaster Management Office

	immediately after a natural disaster.	
6. Significant redundancy built into well field	Yes. Establish and follow maintenance schedule for all repair works. Use manufacturer's maintenance recommendation to tabulate schedules.	TWB-Production section
7. Inadequate staff training.	Yes. Provide appropriate staff training by authorized and qualified personnel. Pass on knowledge from senior staff to new recruits.	TWB – Training for operators, mechanics, engineers for the production and distribution section of the Engineering department.
8. Oil spillage in the pump engine base due to poor design. ?Risk for health and safety issues within the well field	Yes. Would require an efficient design for cases of spillages. For example, for the base concrete, design so a fall towards a safe discharge/containment area.	TWB-Production section
9. Old borehole is not seal properly.	No. The old bore hole is no longer used and provides a conduit through to the water lens	*Yes. TWB, - production
10. Agricultural activities/chemical usage.	Yes – discussion with TWB suggest chemical usage in the borefield is not an issue therefore consider under control. No regulation to control the agricultural activity that is near to the water source. Within wellfield TWB has control over land use? More a village concern?	* No.
11. Not considered relevant for Matakieua situation	No. Insufficient fund and technical knowledge of the village water committee about water machine is limited. Village	*Yes. Insufficient amount of water received by the communities and water pressure is low/MOW, TWB

Storage & Treatment

List what could happen that may cause drinking-water to become unsafe (deterioration in water quality)	Is this under control?	If not, judge whether this needs urgent attention. *Urgent attention is needed for something that happens a lot and/or could cause significant illness. Also, identify responsible agent(s) for immediate action.*
1. Chlorine dosing failure due to power outage.	Yes. During power outage, operators switch to manual dosing at the reservoirs.	TWB, e.g. Engineer - Distribution Section
2. Residual Chlorine levels in distribution, too high or too low.	No. The monthly testing for residual chlorine is not sufficient.	Yes/ TWB. – distribution with feedback loop to production
3. There is no treatment / barrier for protozoa, so it could be assumed that they are present in water.	No scoping of water lens will help identify if this is a risk	Yes. Consider treatment / removal/MOH, TWB.
4. Chlorine dosing system does not operate properly .i.e. dosing pump not working, tubing blocked and inefficient dosing by the pump.	No. Establish and follow proactive maintenance schedule for dosing pump and pump head with all necessary data recorded. Have a back up system either manual dosing or another automatic dosing system in standby in case of dosing system failure.	TWB, treatment section
5. Chlorine dosing rate does not counteract fluctuation in water quality accordingly.	No Follow monitoring procedures for FAC measurements to confirm a chlorine residual of no less than 0.2 mg/L. Increase measurements during prolonged period of heavy rain fall.	TWB, treatment section

6. FAC samples taken incorrectly.	No. Must provide appropriate training for staffs to take samples and recording results. Establish? Sampling procedures and time schedules.	TWB - chemist,
7. Chlorine level in dosing solution is too high because of spillage of chlorine into dosing solution and supplied batch concentration is too high.	No. Establish dosing procedures and train staff in chemical handling. Labels on chemical containers must all be clearly labelled.	TWB - chemist,
8. Leakages in the storage tank/reservoir.	No. Establish proactive maintenance schedules to inspect and repair necessary works.	TWB. Production section
9. Accumulation of sediments in storage tank.	No. Establish and follow a cleaning/maintenance schedule .i.e. once a year. Construct two storage tanks or consecutive in line connected tanks with the first tank feeding through to the last. Draw water from the very last tank hence reducing the sediments carried through.	TWB-Production section
10. Vandalism/sabotage.	No. Put up a security fence to stop unauthorized access to the storage tank.	TWB-Production section
11. Treatment facilities/storage tank/reservoir is damaged by natural disasters .i.e. flooding, landslide, earthquakes.	No. Establish and follow emergency contingency plans immediately after natural disasters.	Yes-TWB Production section and Disaster Management Office for emergency supply's
12. Inadequate staff training.	NO. Provide appropriate staff training by authorized and qualified personnel. Pass on knowledge from senior and more experienced staff to new recruits.	TWB-CEO/Foreign Aid

13. No treatment of calcium content in water(water hardness) Risk = people drinking alternative sources which are potentially unsafe sources because of aesthetics in reticulated	No.	Yes-Hard water is not inherently unsafe, but because a high proportion of the population drink alternative sources .i.e. unsafe rain water, so attention to the aesthetics qualities of the water is required. TWB-Production section

Distribution

List what could happen that may cause drinking-water to become unsafe (deterioration in water quality)	Is this under control?	If not, judge whether this needs urgent attention. *Urgent attention is needed for something that happens a lot and/or could cause significant illness. Also, identify the responsible agency(s) for immediate action.*
1. There is not enough contact time with chlorine before the first consumer, resulting in water not properly disinfected.	No. The first few consumers are less than 200m away.	Yes/TWB distribution section
2. Illegal connections could lead to cross-contamination	No. Illegal connections are discovered only when meter readers are out to read meters. The illegal connection could go un-noticed for several weeks.	Yes. More stringent enforcement of the relevant laws is needed/TWB/ e.g. Engineer - Distribution Section
3. Cross-connection of Rainwater system with the reticulated supply could lead to cross-contamination. Same issue as (2) – putting reticulated supply at risk through backflow of contaminated water	No. No relevant laws, policies to restrict / control household rainwater systems.	Yes. TWB is not responsible beyond the household meters. Consumers responsible for cross-connections. However, TWB has powers to prosecute if situation renders.
4. Low Pressure could result in some communities being deprived of water.	No. It is assumed that gravity feed is sufficient to supply water to all households connected to the system.	Yes. /TWB/Distribution section
5. Leakages within the distribution network could result in cross-contamination.	Yes. A Leak detection programme has been mobilized by the TWB.	TWB/ Distribution section
6. Breakages in underground pipeline from other activities such as digging for electrical/ telephone cables, construction etc.	No	Yes/TWB/Utility companies

7. Free available chlorine levels in the distribution system could be too low.	No. Current monitoring for FAC is insufficient.	TWB/ Engineer - Distribution Section
8. Water is contaminated as a result of repair works in the distribution system.	.No	Yes/TWB-Distribution section
9. Danger of backflow. See 2 and 3 above	No. Use appropriate backflow prevention devices, double check valve and ensure air gaps.	TWB Engineer - Distribution Section
10. Drop in water pressure. Due to high demand	No. Numerous reports of insufficient water to parts of the network	TWB- Distribution Section
11. Vandalism/sabotage.	No. Cannot stop vandalism/sabotage but can reduce and prevent likely hood of both. If possible, lock and secure tools, equipments, enclosures, and parts etc.	Yes/POLICE
12. Inadequate staff training.	No. Get staff trained by authorized and qualified personnel. Pass on expertise, training, experience to new staff by more senior experienced staff.	CEO – TWB Engineer/Manager - Distribution Section
13. Damages to the distribution network from natural disasters .i.e. floods, landslides and earthquakes.	No. Establish and follow emergency contingency plans for natural disasters during and after an event.	Yes/TWB-consult with Disaster Management Office for emergency water supply.
14. Damage to exposed pipelines.	Yes. Endeavour to bury/protect/encase all exposed pipelines. Have warning signs posted to inform the public.	TWB-Distribution Section

Plan to Manage the 'Needs Urgent Attention'

Catchment & Intake

Risks that 'Needs Urgent Attention'	Improvement Schedule: How can you remove or reduce or remedy the cause and by when? Indicate where additional resources will be needed.	Until remedied, how will you know when this is actually causing deterioration towards unsafe drinking water?	What contingency management plan is in place until the cause is removed, reduced or remedied? Who needs to know and how quickly? Who can help?
1. Contaminated aquifer water from surface activities (e.g. farming, household waste-water and sewage) in the recharge zone reaches the well.	Carry out full analysis of the source water to identify what chemical or microbiological (including protozoa) contaminants may be present Improve treatment (based on what you find out from the source water analysis)	Water smells, looks or tastes abnormal Increase in Public dissent about taste, appearance or smell of water. Cannot maintain adequate levels of residual chlorine.	Send out public health messages through local media informing consumers about possible risk of contamination. Advise them to take necessary precautionary measures e.g. boil or filter water. Advise consumers to switch to rainwater for drinking/bottled water.
2. Diesel spills and leaks in the pump-shed could seep into the well though cracks in casing.	Inspect casings, wellheads, pipe fittings, joints, valves etc and repair or replace as necessary. Include these inspections into the regular maintenance schedule.	Water smells of fuel, appears discoloured or 'oily' and tastes abnormal. i.e. Customer complaints Regular monitoring results show presence of Hydrocarbons or Oil in water.	As in 1 above.
3. Sabotage / Vandalism	Secure wellheads and pump-sheds to ensure that vandals do not get access to the well, pumps or piping.	Water smells, looks or tastes abnormal Pump breaks down and there are signs of sabotage or vandalism.	Warn the public through the media .
4. Poor workmanship/construction of well casing, leading to corrosion of the casing.	Construction of the well casing to be carried out by authorized and qualified personnel. All work to be carried out according to current	Damage to the pump and fittings. Casings falling apart and coming loose. Noisy vibrations to the loose joints of the casings. Water quality	As in 1 above.

	standards .i.e. Australian/New Zealand standard supervised by an authorized/qualified civil engineer.	will be reduced as a result of contaminant seepage into the well through loose casing joints. Water will change in color slightly darker and positive tests fro other potential contaminants. Currently only visual reactionary control measure. No testing or prioritization of bore upgrading/repair	
5. Well is too close to contamination sources .i.e. rubbish dip, chemical waste dumped close to well.	If possible remove/reduce or isolate source of contamination and likelihood of well being contaminated. Major contamination might require implementing emergency and contingency procedures .i.e. well polluted by chemicals from nearby rubbish dip.	Water smells looks and tastes abnormal. Chemical analysis is not occurring	As in 1 above.
6. Well head, pump and engine is damaged by natural disasters .i.e. floods, landslides, earthquakes etc.	Establish and follow an emergency/contingency plans for all natural disaster events. Follow the maintenance schedule and make sure all repair and servicing works are up to date especially during cyclone season etc.	Site inspection after natural disaster occurs	As in 1 above.
7. Old borehole is not seal properly.	Construct appropriate seal cover for the borehole opening. Ensure cover is not easily damaged or broken into in case someone gets hurt.	No testing is occurring for this scenario. Water tastes, smells, and looks abnormal.	As in 1bove.

Storage and Treatment

Risks that 'Needs Urgent Attention'	Improvement Schedule: How can you remove or reduce or remedy the cause and by when? Indicate where additional resources will be needed.	Until remedied, how will you know when this is actually causing deterioration towards unsafe drinking water?	What contingency management plan is in place until the cause is removed, reduced or remedied? Who needs to know and how quickly? Who can help?
1. Residual Chlorine levels in distribution, too high or too low.	Develop a regular (weekly) monitoring schedule for residual chlorine.	Increase in Public dissent about taste, appearance or smell of water. Increase regular monitoring.	As in 1 above
2. Treatment facilities/storage tank/reservoir is damaged by natural disasters .i.e. flooding, landslide, earthquakes.	Establish and follow emergency/contingency plans for all natural disaster events. I.e. earthquakes. Have a standby treatment system incase of emergencies. Switch to manual dosing treatment if no other option permits. Follow the maintenance schedules for all repair works and ensure all maintenance is up to date. i.e. cyclone season.	Inspection after natural disaster Cannot rely on other testing services during disaster. Water-borne diseases on the rise.	As in 1 above
3. People drinking alternative sources which are potentially unsafe .i.e. water from rainwater catchments, because of the aesthetic qualities of the water.	Soften water using appropriate technology	Generally known that urban population will intermittently use their rain tanks. Potential for random illness across supply. Difficult to quantify extent of any illness. Urban consumers may switch to rainwater for other reasons including loss of pressure, chlorine issues and related costs	Must relay to urban consumers that piped water is safer than poorly harvested rain water sources. Use water quality tests as evidence and ensure a robust public information programe.

Distribution

Risks that 'Needs Urgent Attention'	Improvement Schedule: How can you remove or reduce or remedy the cause and by when? Indicate where additional resources will be needed.	Until remedied, how will you know when this is actually causing deterioration towards unsafe drinking water?	What contingency management plan is in place until the cause is removed, reduced or remedied? Who needs to know and how quickly? Who can help?
1. There is not enough contact time with chlorine before the first consumer, resulting in water not properly disinfected.	Contact storage tank(s) needs to be installed to give appropriate contact time for first consumers.	Assume that contact time for first consumers may not occur.	There is no current contingency.
2. Illegal connections could lead to cross-contamination	A regular monitoring / surveillance schedule for illegal connections. Allocate wardens in each zone/area/community.	Public complaints	The residual chlorine will provide protection (provided the levels of contaminants are low) until repairs are complete.
3. Cross-connection of Rainwater system with the reticulated supply could lead to cross-contamination and backflow risks.	A regular monitoring / surveillance schedule for inspection of household rainwater systems. Allocate wardens in each zone/area/community. Write a National Guideline for Rainwater System Installation.	Public complaints and a constant drop in FAC levels	The residual chlorine will provide protection (provided the levels of contaminants are low) until repairs are complete. Advise the public against cross-connecting rainwater and reticulated systems by having a public health awareness programme.
4. Low Pressure could result in some communities being deprived of water.	Install a booster pump where low pressure could be a problem or alternative engineering solutions to increase network pressure	Households complain of low pressure or no water.	Advise on collecting water. Make arrangements for water distribution (i.e. by a water truck).

5. Breakages in underground pipeline from other activities such as digging for electrical/ telephone cables, construction etc. allowing contaminants to enter the supply.	Engineers responsible for the distribution system are trained in main flushing, disinfection etc. Refer to previous section comments (how urgent is this risk) as control could be based around other agencies contact TWB if pipe work is damaged	Drop in the localized pressure for the zone of works. Public reports and complaints of contaminated water.	The residual chlorine will provide protection (provided the levels of contaminants are low) until repairs are complete.
6. Free available chlorine levels in the distribution system could be too low.	Ensure consistency in water treatment by establishing a minimum standards.i.e. Chlorine residual to stay between 0.2mg/L and 2.5mg/L. Check for possible leakages in the system where water quality is contaminated.	Minimum standards for FAC are not achieved regularly. Rise in water borne diseases.	As in 1 above until minimum standards are achieved.
7. Vandalism/sabotage	Ensure locking and safe guarding of sections and equipments that is possible.i.e. water mains meters, stop valves etc. also use relevant legislation to guide against such risk.	Vandalism of fittings and equipments will almost allow seepage of contaminants through loose joints and poor/weak materials. Water smells, taste and looks abnormal.	Make arrangements for emergency repair works and maintenance before water is consumed by the public. Isolate affected area of the network by shutting the immediate area using the gate valves. Inform and update the public on major emergency works by stop drinking of water until further advised.
8. Damages to the distribution network from natural disasters .i.e. floods, landslides, and earthquakes.	Establish and follow emergency/contingency plans for all natural disaster events. Have standby crews working around the cloak to ensure availability of safe drinking water.	Inspection of system following significant disaster and Public reports and complaints. Damaged pipelines and leakages. Drop in water pressure.	As in 1 above until further noticed. Follow emergency/contingency procedures.
10.			

Step 4: Water Safety Plan -Catchment and Intake

Hazard event	Cause	Level of Risk	Control Measure	Critical Limits		Monitoring			Corrective Action	Verification
				Target	Action	What	When	Who		
1. Contamination of aquifer from household wastewater and sewage.	Household septic tanks seep into aquifer.	Moderate ? only a few houses adjacent to the bore field therefore a low risk? (may change with additional knowledge regarding the water lens)	Develop policy/building code for septic tanks. Review existing legislations and policies.	Restrict building of septic tanks near underground water lens and aquifer.	Positive result of faecal coliform i.e. H2S tests. Outbreaks and epidemics i.e. typhoid and diarrhoea. Reports and data from Health department.	Sanitary inspection of septic tanks and sanitary facilities in immediate vicinity of bore field.	Twice a year.	MOH, TWB	Awareness and education of sanitary facilities. Fix leaks, faults etc. Propose other toilet alternatives e.g. Organic/compost toilet.	Sanitary inspection reports.
2. Contamination of aquifer from agricultural chemicals.	Chemicals applied to farms seep into aquifer.	Moderate	Introduce organic farming. Extend existing awareness programmes i.e. Tonga trust. Training and legislation.	Reduce contamination.	Use dye tests to detect sources. Treat contaminated water and patients from agrichemical poisoning.	Target chemicals being used that would be likely to have residual in water. Chemicals present in agrichemical products. Medical illnesses.	Twice a year. At peak time of usage	MOH, TWB, MOE	Banning of agrichemical usage around underground water aquifers.	Results.
3. Contamination from Diesel	Diesel Leaks & Spills.	Likely	Switch to electricity pumps. Training of technicians/work practices. Provide spill kits and fix faulty	Prevent contamination of well from diesel spills.	Fix and repair damages, cracks and caps to prevent diesel contamination.	Hygienic inspection of pump sheds and engine setups. Monitor wells with worst visible spillage now.	Monthly.Check at refueling and report by exception. Following	TWB-Pump operators to report to Principal Production Officer	Review work practices	. Results and spillage reports

			pumps.				spillage			
4. Electrical pumps stop operating.	Power outage.	Moderate Currently only 3 electric pumps dependent on duration of power outage	Water level not to drop.	Establish a stand by generator and a back up pump.	Obtain and maintain a fully functional back up generator and standby pump.	Water pressure and water level.	Continuously monitor non stop. Also watch out for power surges and power failure.	TWB	Automatic operation of standby pump and generator.	Increase in water level and higher water pressure.
5. Intentional contamination or damage to pump or well.	Sabotage / Vandalism	Low (health risk wise) currently problems with stealing fuel?	Secure safe site for pump sheds.	To ensure the safety and integrity of the site.	Secure the compound by fencing, locking and warning signs. Also establish some monitoring i.e. security guards.	Safety and security of pump site and well area.	Daily 24hrs monitoring.	TWB, Security personnel.	Report and investigate	Report from security re exception
6. Level of Freshwater in the aquifer decreases.	Prolonged drought.	Unlikely/Catastrophic	Maintain good dialogue between all parties involved	Maintain the sustainable rate of extraction.	Laws and policies to control the usage. Applies to island as a whole	Underground water reserves.	Monthly	TWB & Geology Department	Restrict water use, and banning of certain activities.	report on long term trending
7. Poor workmanship/construction of well casing, leading to corrosion of the casing.	Poor workmanship/construction.	Low	Well casing is kept in good condition and free of corrosion	Well casing is well maintained and show no visible sign of corrosion	Visible signs of damage or corrosion	Standard of construction and materials used. Ensure adherence to building code.	Quarterly –after initial prioritisation	TWB engineers.	Replace and repair damaged and corroded well casings	Evidence of Prioritied list of repairs and actions taken
8. Shallower	Contaminated shallow	Low	Safe pumping rate	Maintain safe pumping rate	Conduct tests to obtain safe	Quality of water and	Monthly	TWB and engineers	Either reduce water usage and or	Quality testing

ground water that is contaminated is drawn into the well. Include with (1)	ground water.		from the well.	from the well	maximum pumping rate and do not exceed this rate.	safe pumping rate		after have received more info regarding lens	pumping rate	and monitoring
9. Well head poorly designed/constructed. Include with (7)	Poor design/construction of well head.	Medium	State of the seals around the well head	Ensure proper seal around the well head	Well head is in poor condition.	Quality of well head	Yearly – after initial prioritization	TWB, engineers, MOW	.Use the drilling code to construct and build the correct wellhead and is properly sealed	Inspection
10. Damaged well head. Include with (7)	Poor design/construction of well head.	Medium	Well head in good condition	Maintain well head in good condition	Well head is damaged and in need of repairs	State of the well head	Yearly – after initial prioritization	TWB, engineers	Construct protection around the well head. Conduct repair works.	Inspection
11. Well is too close to contamination sources. Include with (1)	Close proximity of well to contamination site(s).	Low to Medium	Protect well from the contamination sources	Ensure proper protection of the well from the contamination sources	Concentration of the contaminant exceeds the Maximum Allowable Levels.	Concentration of contaminant sources	Daily	TWB, Lab technicians, MOH After receiving more info regarding the lens	Obtain correct advice on treating the water to remove contaminants.	Testing and Monitoring
12. Low ground wells. Not applicable to Urban	Well location too low in elevation.	Low	Locate and avoid low ground level wells.	Maintain a high ground level well if possible.	Pooling of water around well head after rain	Quality of water in low ground level water.	Yearly	TWB, engineers, builders, MOW	Put drains in place, and avoid low ground for location	Testing and monitoring

bore field										
13. Animal damage to well head and pumps. Urban field kept free of grazing animals	Unsecured well head and pump facilities.	Low	Keep well head and pumps safe and secure	Maintain safe and secure site for the pump and well	Provide fencing to protect the well head and pump from animals	Safety and security of well head and pumps	Yearly	TWB,	Start regular inspection and erect a fence line.	Inspection
14. Well head, pump and engine is damaged by natural disasters .i.e. floods, landslides and earthquakes.	Natural disasters.	Low	Protection for well head, engine and pumps from all natural disasters.	Maintain all appropriate and alternative measures to protect the well head, engine and pumps	Low or no flow, and damages to well head, engine and pumps	Resistance and resilience of the well head, engine and pumps to natural disasters	Yearly	TWB, engineers, MOW	Regular inspection of the well, especially after a natural event. Extra precautions to reduce damages under extreme weather would be advisable such as…efficient designs	Evidence of Inspection after natural events.
15. A pump does not work.	Damaged pumps.	Low	Keep pumps in operation	Maintain pumps in operation	Maintenance failing behind schedule – create proactive schedules resulting in low or no flow.	Maintenance schedule	Monthly	TWB, engineers.	Prepare maintenance schedule. Fix and repair pump.	Evidence each month of proactive maintenance being undertaken Inspection
16. Oil spillage in the pump	Poor design.	High	Prevent oil spillages from entering	Stop oil spillages on top of the	Design a fall or containment/safe area for	Maintenance schedule	Daily	TWB operating staffs/mana	Activate and follow emergency spill containment	Evidence of maintena

engine base due to poor design.			the well from poor design. Have spill kits purchased and available	engine base.	absorption of the contaminant.			gement staffs.	procedures – write procedures.	nce being undertaken
17. Old borehole is not sealed properly.	Lack of funding and resources.	High			Provide appropriate coverage and seal for the old borehole	Original prioritise list should identify these	One off - once existing ones sealed	Operating staffs.	Provide a safe secure area by erecting fence and safety barriers.	Inspection.
18. Agricultural activities and chemical usages. see (2) above	No laws and policies to protect water sources.	High	Provide protection to water sources from agriculture and chemical activities.	Maintain and ensure the water source is protected	Establish and enforce protective measures for safeguarding the water source.	Harmful activities which affects the water quality.	Monthly	Water committees and town officers	Stop consuming the water, use alternative water supply until quality is safe	Monitoring and testing.
19. Pit toilet. Survey for (1) above will identify if these are in bore field/village ?	Same as above.	High	Same as above but for protection of water source from pit toilet.	Same as above	Same as above	Same as above	Daily	Same as above	Same as above	Sanitary inspection.
20. Inappropriate pump engine selection. Does this apply to the village	Lack of Technical know how and expertise.	low – little direct health risk	Provide for appropriate and efficient selection of pump engine	Reduce and minimize money and time wastage from inappropriate selection	Use expert help from appropriate personnel in selecting the right pump engine.	Efficient selection of pump engines	Monthly	Same as above	Same as above	Monitoring and testing.

situation only?										

Step: 4 Water Safety Plans – Storage and Treatment

Hazard event	Cause	Risk	Control Measure	Critical Limits		Monitoring			Corrective Action	Verification
				Target	Action	What	When	Who		
21. Chlorine dosing failure due to power outage.	Power outage/black out.	Moderate.	Efficient non stop chlorination of water.	Continuous chlorine dosing of water.	Provide back up power from generator.	Chlorine level in water.	24 hrs, daily.	TWB, TEPB.	Manual chlorine dosing. Follow a manual chlorine dosing procedure	Monitoring chlorine levels.
22. Chlorine supply may run out, resulting in untreated water being distributed to the communities **Means of ensuring each new batch received is consistent quality**	Run out of supply/out of stock. Careless work practices.	Moderate	To achieve sufficient chlorine supply and stock.	Sufficient supply of chlorine for treatment.	Stocking sufficient supply of chlorine. Spare container of chlorine on site. Accurate data records for correct estimates of supply required.	Supply of chlorine.	Monthly monitoring	TWB.	Ordering system for when supplies are low	Evidence of sufficient supply available and good stock rotation
23. Residual chlorine levels in distribution, too high or too low.	Damaged chlorinator. Inefficient and ineffective	Moderate.	To achieve and maintain correct	To achieve correct dosing level of chlorine in	Monitor and adjust for correct dosing amount in	Correct level of chlorine in water .i.e.	Preferably 24hrs monitoring. – but	TWB. More specific responsibili	Monitor and adjust for correct levels of chlorine.	Evidence of corrections being made when out of

	chlorination of water.		level of chlorinated water.	water between 0.3 – 0.7 Reference to relevant Std/Guideline	water.	0.3 – 0.7	until available - daily across distribution zone but require field testing equipment	ty within TWB – Treatment section/Head Chemist		spec water is discovered
25. There is no treatment/barrier for protozoa, so it could be assumed that they are present in water. – see (1) and (6) above	Poor protection of source. .	Low.	Sanitation inspection and proper resources to tackle the problem of protozoa.	Treatment of protozoa	Establish funding and resources for the treatment of protozoa.	System of treatment for protozoa type bacterium.		TWB, MOH.	Immediate treatment for protozoa.	Positive tests for elimination of protozoa.
26. Chlorine dosing system does not operate properly .i.e. dosing pump not working, tubing blocked and inefficient dosing by the pump. See (23)above	Damaged dosing system.	Moderate to High	Efficient non stop operation of the chlorination system.	Establish and enforce a dosing policy and all related activities ensuring smooth non stop operation of the dosing system.	Have a back up dosing system in standby for any damages and breakdowns.	Chlorine levels and FAC levels.	Preferably a 24hrs monitoring system.	TWB, Operating staff and dosing technicians	Manual dosing system	E.coli, Faecal streptococci.
27. Chlorine	Inefficient	Moderate.	Smart	Ensure	A drop in water	Chlorine	Daily	Lab	Adjust and	E.coli, Faecal

dosing rate does not counteract fluctuation in water quality accordingly. See 23 and 26	dosing rate/ineffective treatment.		dosing system to counteract fluctuating water quality.	efficient dosing system to vary accordingly.	quality from monitoring tests.	levels/microbial levels.		technicians, TWB and MOH	manual dose for correct rate accordingly	streptococci.
28. FAC samples taken incorrectly.	Poor sampling practices	Moderate	Correct sampling procedures	Establish and follow correct sampling procedures.	Enforce and adhere to strict protocols ensuring correct sampling procedures.	Correct procedures and strict adherence to the protocols.	Weekly	TWB, MOH.	Provide training to appropriate staffs regarding the correct sampling procedures.	Evidence of training of samplers
29. Chlorine level in dosing solution is too high because of spillage of chlorine into dosing solution and supplied batch concentration is too high. see 23 and 26	Poor work practices and lack of training.	Low	Minimize accidental spillage and poor work practices in dosing work.	Stop unnecessary spillages and accidents.	Establish and enforce a correct policy of dosing procedures.	System of work practices and efficient dosing procedures.	Daily.	TWB, MOH	Same as above.	E.coli, Faecal streptococci.
30. /Condition of storage tank/reservoir.	Leaks in the storage tank.	Low	Water stays in the storage tank	Ensure the physical integrity of the storage tank.	Visual inspection and water leaking from the tank	Physical damages and breaks to the storage tank.	wkly	TWB, Operating staffs.	Fix and carry out necessary repair works.	Evidence of Inspection/assessments.
31. Animals and birds getting into storage tank. See	Animal access to storage tank.	Low	Inspection covers and hatches	Inspection hatches and covers show	Visible signs of damage or corrosion.	Sanitary Inspection	wkly	Operating staff.	Replace damaged or corroded	Inspection

(30)			are kept in good conditions.	no visible signs of damage or corrosion.					covers and hatches.	
32. Accumulation of sediments in storage tank. See (30)	No sedimentation process.	Low to Moderate.	Regular cleaning of service reservoir, drain-down of reservoir and clear sediment	Interior of reservoir is clean and sediment is minimized and undisturbed.	Biofilm develops, increase in chlorine consumption	Sanitary inspection, chlorine residuals, turbidity.	wkly	Operating staff/TWB	Tank reservoir off-line and cleaned	Aeromonas
33.Vandalism/sabotage	Vandalism/theft /sabotage.	Low	Water is safe and not stolen	Protect and provide secure the premises for water storage.	Erect security barriers/fences to provide a safe area/zone for water storage.	Safe and secure site/area for water storage.	Quarterly	Management, TWB	Report and use the law and policies to prosecute offenders. Post warning signs to act as deterrent for offenders.	Physical Inspection
35. Treatment facilities/storage tank/reservoir is damaged by natural disasters .i.e. flooding, landslide, earthquakes.	Natural disasters.	Low (low frequency	Minimal damage to facilities in natural disasters.	Ensure structural integrity of the facilities	Build and construct structural features resistant to natural disasters.	Structural performance and resilience to natural disasters.	Quarterly /Seasonal	Engineers and operating staffs, TWB.	Design and construct safe and resilient structures to withstand natural disasters.	Physical/Visual inspection of structures.
36. Inadequate staff training.	Lack of staff training.	Moderate to High	Ensure appropriate staff training for	Set target goals for training and skill	Yearly planning and training needs assessments	Training needs and skill levels	Quarterly	Management and Leadership chain, TWB	Provide appropriate training.	Evidence of Performance assessments and skill levels

			all operating personnel.	upgrades.	good. Enforce and monitor proper training schemes.					of all staffs.
37. Inadequate safety/protective apparatus/tools and training .i.e. breathing mask, safety gloves, safety footwear etc.	Lack of safety tools/equipments and knowledge/training.	Moderate to High	Sufficient and appropriate safety equipments and apparatus.	Proper safety tools is in place for safe and efficient treatment works	. Provide equipment and training	Safety issues and hazard prevention procedures	New staff as part of induction.	Engineering Department-Chief Engineer overlooks the whole operation while each Head of Section takes responsibility for their own.	Cease operation until all safety concerns are addressed.	Evidence of accident records Safety records, hazard identification and inspection.
39. No treatment for calcium (water hardness) – risk/event = drinking alternative sources	Excess calcium content in water.	moderate	Acceptable level of calcium content in water	Establish water hardness treatment programme	Ensure calcium content of water is controlled for good aesthetics quality	Water hardness	Daily	Operating staff	Until treatment is preceded there is no inherent health risk in hard water.	Inspections and monitoring.

Step 4: Water Safety Plan - Distribution

Hazard event	Cause	Risk	Control Measure	Critical Limits		Monitoring			Corrective Action	Verification
				Target	Action	What	When	Who		
40. Illegal connections could lead to cross-contamination.	Damage backflow systems. Illegal connections.	Moderate.	Reduction of cross contamination from illegal connections.	Non contamination of water by illegal connections.	Reporting, legislate and ban illegal connections.	Cross contamination from illegal connections.	Preferably 24hrs a day non stop monitoring.	TWB	Disconnect illegal connections and prosecute.	Positive tests for contaminants. Monitoring.
41. Cross connection of Rainwater system with the reticulated supply could lead to cross-contamination.	Connection of rainwater and tap water supply	Moderate.	Separate the two supply's	Maintain water quality and free of contamination. Backflow control	Separate or disconnect the two supplies.	Water quality and cross contamination.	Preferably daily.	TWB and water rate payer.	Disconnect and separate the supplies.	Evidence of backflow prevention installed and teted.
42. Low pressure could result in some communities being deprived of water.	Low level in reservoir. Too much water leaks in mainline and distribution mains.	Low	To achieve a constant high pressure to gravity feed all communities.	To achieve sufficient water level hence creating enough pressure to feed low pressure areas.	Repair leaking mains and fix distribution leakages. Increase pressure by raising water level on reservoir.	Establish and maintain a constant high water level for the storage reservoir.	Preferably a 24hrs a day monitoring.	TWB.	Raise water level on reservoir by repairing leaks and fixing mains leaking.	A constant high pressure in low pressure areas.
43. Leakages within the distribution	Earthquakes, poor workmanship	Moderate to high.	Establish a system to minimize	Reduction and minimization of contamination	Mobilize the Leak Detection	Leaking distribution lines.	Preferably 24hrs a day.	TWB Leak Detection	Repairs and routine maintenance	Less frequent leakages.

network could result in cross-contamination. Put all backflow issues together see 41	and low quality equipments and materials.		cross contaminatio n from leaking distribution lines.	from leaking distribution lines.	team and counteract the leaking distribution lines.			team.	of distribution lines.	
44. Breakages in underground pipelines from other activities such as digging for electrical/telepho ne cables, construction etc.	Careless/poor workmanship and inefficient work practices.	Low to Moderate .	Have policy that ensures minimal damages to underground mains from other services/utilit y activities. Encourage good signage/ communicati ons between services. Ensure maps available	Ensure efficient operation of policy to prosecute and protect underground pipelines from other service activities.	Practice and enforce laws and policies to protect underground services from damage from other utility activities.	Damages of underground services from digging/construc ction activities.	24 monitorin g system	TWB, Leak Detection team.	Perform repair works/fixing damages. Repair leaks, bury pies and reinforce joints.	Evidence of breakage s when other services are excavatin g roads etc
45. Free available chlorine levels in the distribution system could be too low. See 23,26, 29 above	Inefficient dosing system for treatment. accounts for increase in microbial levels.	Moderate to High.	Control level of FAC in the distribution system.	Establish a more efficient dosing system of chlorination. .	Establish and enforce a policy that ensures a controlled FAC level in the distribution system.	FAC levels, Turbidity, and Chlorine residuals.	24hrs monitorin g system.	Leak Detection team, Treatmen t officers and Chemists /Lab techs	Train staff in best practices and efficient treatment works.	E.coli, Faecal streptoco cci

5. Conclusion

The Water Safety Plan was finalised during the follow up mission 1 and improvement schedules was also compiled. Since the engineer Mr Roly Hayes was available during the mission it was easier to finalised the two documents on time. The draft documents were presented to the Steering Committee who initially endorsed them as the final document. It was realised that these two documents were very important for the countries to divert further funding in this area. The completed Water Safety Plan is an ideal document for donor agencies for implementation of water programmes.

ANNEX: 1

Drinking water Risk Assessment Table

Judging Priorities – systematic risk assessment

i. For each hazard event, decide on the likelihood of the event happening

Liklihood Score	Possible Descriptions
Almost Certain	• Occurs like clockwork • Occurs every week, month or season
Likely	• Has occurred more than once before • Expected to occur every year
Possible	• Has occurred before • Expected to occur every 2-5 years
Unlikely	• Has occurred before • Expected to occur every 5-10 years
Rare	• Has never occurred before and unlikely to occur less than every 10 years

ii. *For each hazard event, decide on the consequence to people's health if it did happen*.

Consequence Score	Possible Descriptions
Insignificant	• No illness expected in the community or interruption to water availability
Minor	• Very few of the community ill, or some interruption to water availability
Moderate	• Some of the community ill
Major	• Most of the community ill
Catastrophic	• Most (or all) of the community ill with anticipation of some deaths

iii. *For each hazard event, look up the likelihood and consequence scores in this table to find the corresponding priority (very low, low, medium, high, very high)*

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	medium	medium	high	high	very high
Likely	medium	medium	medium	high	high
Possible	very low	low	medium	high	high
Unlikely	very low	very low	low	medium	high
Rare	very low	very low	low	medium	medium

(Adapted from NZ MoH, 2007)

Instruction: Using either of the methods outlined above, consider each of the hazard events separately and determine the priority for each. Enter the priority rating into the third column of the DWSP matrix.

Reference:

1. PPK Consultants Pty Ltd 1992, Water Resources and Assessment-Tonga
2. Ministry of Health, 2005, Small Drinking Water Supplies- Preparing a Public Health Risk Management Plan. Wellington, New Zealand.
3. Water Supply Plans Books 1&2 -2004, WEDC Publication-Loughborough University, UK
4. Engineering Section Report-January 2007-Tonga Water Board