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Integrated Catchment Management in ‘Eua, Kingdom of Tonga.

by

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Abbreviations

EC	electrical conductivity (a measure of water salinity)
mg/L	milligrams per litre
m?/d	cubic mitre per day
L/p/d	Litres per person per day
TWB	Tonga Water Board
MLSNR	Ministry of Survey and Natural Resource
WHO	World Health Organisation
?S/cm	microsiemens per centimetre (also shown as ?mhos/cm or micromhos/cm): measure of EC
MOH	Ministry of Health
CPD	Central Planning Department

1. Purpose of the Case Study

This case study was prepared to provide details of surface water catchments practices in the island of ‘Eua, Kingdom of Tonga. It provides historical data and details of improve measures to alleviate the impact of natural and human activities on the water supply catchment.

2. Introduction

2.1 Physical features

‘Eua lies to the south east of the main island of Tongatapu and is geologically one of the oldest island in the Tongan archipelago. ‘Eua island has an area of 54 km? and comprises two administrative districts made up of a total of 14 villages. These villages are located in a ribbon like development adjacent to the main north – south road on the western side of the island. ‘Eua has a maximum elevation of 312 metres, sloping gently to the east west in a series of three terraces and then plunging in a series of cliffs to the eastern side. The island is uplifted limestone with a basaltic base extending almost to the surface of the eastern ridge. Most of the coastline comprises of weathered limestone. The eastern ridge on ‘Eua has not been divided into land parcels (‘api’s) and large stands of secondary native forest existed there in the past. An area along the southeast cliffs has been allocated as a National Forest Preserve. Most of the accessible native hardwood forest resources on ‘Eua have been logged and the cleared land is being encroached upon by subdivision into tax ‘api’s (tax allotment for farming). The island is supplied with services such as power, water, telephone, a hospital, churches, and schools.

‘Eua is a lush rural island with highly productive soils suited to agriculture. The island lifestyle is rural with a high dependence on income from agricultural produce. Generally the villages are well cared for and gardens are well managed. There is little litter, although there are areas of obvious rubbish disposal. Population density is low with many vacant lots and houses.

Figure 1. Location map of Tongatapu and ‘Eua

2.2 Population

'Eua comprises of two administrative districts – 'Eua proper and 'Eua Fo'ou. The total population of both districts was established in the 1996 census as 4934. The district of 'Eua Proper comprises of 6 villages and 'Eua Fo'ou comprises of 9 villages, with respective populations recorded in the 1996 census as detail in Table 2.1. The number of households and total population of villages has been updated to 2002 figures in consultation with staff of the Niu'eiki Hospital 'Eua. All villages except Houma to the northern part of the island, which has a separate water supply, are serviced by the 'Ohonua – Ha'atu'a ('Eua) water supply system. The average number of people per household in 1996 was six.

The 2002 population is based on the number of households recorded by Niu'eiki Hospital multiplied by the number of people per household (6) calculated from the 1996 Census.

A summary of the population trends on 'Eua provided by the Tongan Government National census and the annual census undertaken by the Niu'eiki Hospital 'Eua is provided in Table 2.1. Records held by the hospital indicate that the population is growing at a much slower rate than projected by the 1996 national census which established a growth rate for 'Eua of 1.2%. 'Eua's growth rate seems to have slowed to the national population of 0.3% faster than predicted for 'Eua by the Tongan Statistics Department. Staff at the Niu'eiki Hospital suggests that the declining growth rate is caused by a large number of young women leaving the island in search of work. Young men seem to be more willing to remain on 'Eua to work in agriculture. Net migration in 2001 was 82 men and 114 women departing the island. The disproportion of male to females on 'Eua is also attributed to these factors.

Table 2.1: 'Eua population by household 1996 and 2002

District and Village	Male 1996	Female 1996	H'holds 1996	Total Pop'n 1996	H'hold 2002	Total Pop'n 2002
'Eua Proper						
'Ohonua	710	601	208	1311	229	1374
Tufuvai	95	64	26	159	34	204
Pangai	150	137	47	287	61	366
Houma	146	148	49	294	50	300
Ha'atu'a	277	246	85	523	86	516
Ta'anga	114	78	40	192	31	186
'Eua Fo'ou						
Angaha	224	194	69	418	68	408
Futu	137	125	45	262	44	264
Esia	103	83	33	186	31	186
Sapa'ata	85	69	27	154	24	144
Fata'ulua	122	99	33	221	28	168
Mu'a	78	84	27	162	27	162
Tongamamao	100	116	33	216	29	174
Petani	127	116	84	243	28	228
Mata'aho	156	150	50	306	30	180
Total	**2624**	**2310**	**820**	**4934**	**810**	**4860**

Source: 1996 Census and Niu'eiki Hospital records,'Eua

Table 2.2. Population Projections

	Population by Year									
Data Source	**1986**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2010**	**2015**
Statistic Dept	4393	4934	4975	5009	5037	5060	5080	5096	5262	5313
Niu'eiki Hospital		4912	4951	4939	4917	5115	5023	4860	4972	5047

Source: National Census 1986,1996 and projected estimates

Niu'eiki Hospital data 'Eua (1996-2002) and projection base on an annual growth of 3%

2.3 Land Tenure System and Use

The Kingdom of Tonga has a unique land tenure system. Land is owned by the Monarchy, Government and the nobles. The patrilineal line of descent is through the male and only male children inherit family land. Under the Constitution, every male over the age of 18 years is entitled to an 8 acre piece of land for his cultivation and a town allotment of ?/? acre. Men can acquire land through applying to the Minister of Lands. Recently, legislation regarding female ownership of land has been modified permitting women to acquire land through leasing.

'Eua is primarily a subsistence agricultural economy so land allocation (tax allotments or tax 'api's) for farming is important. The community on 'Eua is composite, with migrants from the islands of 'Ata and Niuafo'ou being allocated town allotment but not necessarily tax allotments for farming. Under a cabinet directive, the government allocated tax allotments for people who migrate from Niuafo'ou. Some of these lands are within the forestry and water catchments creating a potential conflict of use scenario.

2.4 Brief outline of catchment management issues.

The main catchment management issue on 'Eua is water quality degradation caused by activities within the catchment. The majority of the existing 'Eua water quality problems are caused by impurities entering the water in the catchment area. The limestone covering most of 'Eua contains interconnected cavities which allow rapid flow of water both horizontally and vertically. The surface soil horizons cover steep catchment surfaces and significant transport of eroded soil, vegetation and rock occurs during heavy rainfall. The combination of limestone and soil produces rapid detoriation of water quality during wet weather periods.

Clearing of trees and increase farming and stock raising has contributed to a progressive reduction in the water quality. This is because loss of vegetation from farming activities and stock raising promotes soil erosion.

Currently land ownership of the catchment lies with the Ministry of Lands, Survey and Natural Resources (MLSNR). Management of the catchment should be the responsibility of those who are operating the water supply system to ensure that they are well managed and that they are link with the guideline to be adopted by the propose catchment management committee.

3. WATER RESOURCES AND WATER USE

3.1 Water Resources

The original water supply in 'Eua was based on rainwater collection, typically in ferrocement tanks. Earlier water supply systems consisted of water from hand-dug wells or from springs and caves located around the island. The main centralized water supply was constructed in the mid – 1970's under the auspices of the Ministry of Health (MOH). This system utilized the two sources, the Heke stream and the Hafu stream located to the north of the existing intake at Kolomaile (refer Fig 2). Both these sources suffered from water quality and quantity problems and subsequently alternatives sources (surface water) were developed in the Kolomaile area.

These systems were further improved with additional construction and upgrading of rainwater collection tank as part of MOH or Central Planning Department (CPD) initiatives during the early 1990s (PPK 1992). Over 300, 22000-litre tanks were constructed during these programmes. This system was manage by MOH and the 'Eua Village Water Committee until 1984, when the control passed to the Tonga Water Board (TWB).

Figure 2. Location map of water sources and reticulation system of 'Eua.

3.1.1 Intake Structures

The Kolomaile intake system utilizes four principle sources: Saoa Cave, Fern Gully Stream, Matavai Cave and 'Ana Peke Peka Cave. Figure 1 shows the location of each source. At each source has a small concrete weir has been placed across the stream way with one 150 mm PVC pipe embedded with it, approximately 500mm below water level. A description of each of these sources follows:

a). Matavai Cave Source: Historical low pressure within the reticulation system requires moving the intakes at Matavai Cave upstream to its present location to increase system pressure. This was achieved by blasting a hole through the roof of the cave to allow access to the stream for the construction of a new weir at a higher elevation.

b). 'Ana Peke Peka cave source: The 'Ana Peke Peka cave system is inhibited by numerous swifts and bats, resulting in extensive deposits of dropping in the cave. To reduce the risk of contamination, TWB has moved the weir into the cave approximately 350 metres from the entrance. This is under the assumption that the water entering the cave upstream has not been contaminated from other sources. Investigations indicate however, that the source of water that enters the cave is via a surface depression only 25 metres upstream of the of the current weir locations.

Access to this weir is difficult and requires climbing two waterfalls and passing through two low roof sections of the cave where the roof is within 100mm of the water surface.

c). Fern Gully Cave Source: The Fern Gully Source utilizes a large weir with a high flow bypass constructed in October 2001. This stream source is the most susceptible to increase turbidity as the streambeds accumulates large volumes of sediment from the watershed above. This stream acts as a surficial collection pathway for large number of small flows and is apparently the most affected by drought.

d). Saoa Cave Source: Immediately below the Fern Gully weir is the Saoa Cave source. This cave stream has the most constant flow of all the four sources and is currently disconnected from the reticulation system (since 1996). Reconnection of this source is required if it is to be used in the future.

The 'Ana Peke Peka and Matavai PVC pipelines are interconnected at a 'Y' Junction; Immediately downstream of junction, the Fern Gully pipeline connects to the main. Pressure problem within the reticulation system relate to the fact that all four sources are at different elevations. In particular, two of the sources are too low to provide adequate system pressures to some of the higher parts of the supply located in Ha'atu'a village at approximately a reduced level (RL of 117m) under the present system configuration (refer Table 3.1).

Table 3.1 Summary of previous reported elevations of 'Eua water supply weirs.

Water Source	Caving Report	MLSNR Barometric Survey	PPK Report	MLSNR Survey
'Ana Peke Peka	163 m	155 m	159 m	159 m
Matavai Cave	155 m	………	145 m	123.0 m
Fern Gully	………	165 m	145 m	133.68 m
Saoa Cave	183 m	157 m	140 m	128.9 m

3.1.2 Groundwater Bores

The 'Eua Water Supply has in the past utilized groundwater sources. The former groundwater bore system consisted of two bores with diesel operated pumps located at 'Ohonua and west of Ha'atu'a. The Ha'atu'a bore was pumped to into a 100 mm PVC rising main to an elevated storage tank. This elevated storage tank fed into the main during the peak demand periods that typically required two hours of groundwater pumping per day. This bore was also utilized to supplement the supply from the four cave sources during dry periods. The bore at 'Ohonua directly inject water to a break pressure tank and feed the reticulation system of 'Ohonua and Ta'anga area.

The bore at Ha'atu'a provides slightly saline water, which was mixed with the main reticulation system to reduce salt content to palatable levels. This bore was decommissioned in 1998 due to a collapse in the uncase section of the bore at approximately 80 metres. The bore at 'Ohonua was decommissioned in 1992, also due to a collapse inside the bore. The salinity levels at this bore were low. The average electrical conductivity or EC measurement was 950 ? S/cm.

3.2 Water Use

Historical Water Use

The reticulated water supply from the 'Eua system is currently delivered to about 530 (68% of total) households in the area. The number of registered connections in December 1995 was 890, of which 516 were connected and 374 were disconnected. In February 1995 the situation was reasonably similar, with a total of 877 registered connections (554 connected and 323 disconnected). The proportion of disconnections to the total registered connections increased in 1995 from 37% to 42%. By comparison, there were 550 connections in 1991 (PPK Consultants, 1992). In 1998 there was a total of 560 connections, which is similar to the current number of connections.

In February 1995, total water usage based on consumer meter readings was approximately 4,770 m?. This represents about 160 m?/day. Using the estimated population of 4,000 consumers, the averaged water consumption in February 1995 was about 42 litres per person per day (L/p/d). In 1991, the estimated consumption was 40 L/p/d. The total water usage for May 2002 was 5989 m?. This was equated to 41 litres per person per day at the current population of 4860 consumers.

About 82% of households also have a 3000 – gallon (approximately 13,500 L) cement rain water tank These tanks have been funded and supplied from a variety of sources including the resident family, remittances from family overseas and bilateral donors such as NZODA, AUSAID and the Canada Fund. Household without rainwater tank are usually able to use water from a neighbor's tank or the nearby church. Sharing water (although not practiced by everyone) is common especially when water becomes scarce in the dry season.

Reticulated water is primarily used for bathing, cooking, water for animals and gardens. It is often dirty after rainfall events and has reportedly caused skin rashes in children. Rainwater is used for drinking, bathing babies and washing clothes. There seems to be a cultural and historic precedence for this as well as reasons of water quality.

Consumption

As indicated above the consumption rates for 'Eua are very low, in the order of 40 L/p/d. This is due to several factors including the preference of rainwater for consumption, the perceived dirty nature of the reticulated water supply and low quantity and pressures often experienced by consumers. Analysis of the bulk water records indicates that the averaged current monthly (Jan – May, 2002) production is in the order of 15000 m?/month while the consumption figures supplied an average of only 5,400 m?. This indicates that between 64% of water collected is lost as system leakage. The Burke report (1998) also calculated similar system leakage values indicating wide scope for demand management and leak detection investigations/implementation, which are critical to the sustainability of the surface water source in the future. Future domestic demand will quickly rise if the water supply system is upgraded and water quality improves: it will slowly rise due to natural population increases. Various reports (SMEC, 1999 and PPK, 1992) have examined the degree by which the consumption is artificially suppressed by the low quantity and quality of water from the existing system.

3.3 Current Water Problems

3.3.1 Water Quantity

As noted in Section 3.1.1, the current water supply is largely derived from three small streams flowing from caves in the higher parts of 'Eua. These sources are:

- Fern Gully;
- 'Ana Peke Peka Cave;
- Matavai Cave; and
- Saoa Cave (currently disconnected from the system)

The safe, sustainable yields from each of these sources are unknown. The cave sources are reported (PPK 1992) to flow continuously during extended periods of dry weather but exact low flow rates are not known for each one. The estimated total flow from the connected surface sources during a dry period (e.g. in February 1998) was about 3.2L/sec. The flow in the connected source (Saoa Cave) was measured at approx. 2.2 L/sec in February 1998 and at 2.1 L/sec in 1999 (using bucket and stopwatch). By comparison, the flow at this weir in May 1996 was measured at14 L/sec. The difference in flows is attributable to different rainfall conditions preceding the two measurements.

Table 3.1 Flow measurements at surface sources, 'Eua

			Flow at Water Source (L/s)				
Date	**Ana Peke Peka**	**Matavai Cave**	**Fern Gully**	**Combine Developed Source**	**Saoa Cave**	**Flow Meter**	**Reference& Comments**
1/3/90				6.7		6.7	PPK Consultant (1992)
30/7/91	1.9				2.0		PPK Consultant (1992)
14/9/91		3.0					PPK Consultant (1992)
Oct 91		Trickle					PPK Consultant (1992)
10/5/96					14.2		V-Notch Weir by Falkland/Bencke
4-5/2/98	1.3	1.1-1.7	2.0	4.4-5.0	2.2	3.2-3.6	Burke 1998
20/7/98					2.1		Tonga Water Board

The total flow rate of the currently connected surface sources in February 1998 (Both measured at flow meter site) was about 3.6 L/s. The flow rate doest not account for the disconnected Saoa Cave source or the 'Ana Peke Peka source, which were not contributing to the flow. It is considered that the reconnection of Saoa Cave and the removal of pipe restrictions within the 'Ana Peke Peka main will greatly increase the available flow to an average rate of approximately 8 L/sec.

For a total estimated system design population of 5,000 people, this is equivalent to about 110 Litres per person per day (L/p/d) with a leakage rate of 20%. The severe lack of source flow data is a serious constraint in determining potential minimum flows. Anecdotal evidence indicates that the Saoa Cave source is the least affected by low rainfall periods and that Fern Gully is the most rapidly affected.

Although there is a lack of individual source flow data, reasonable consumer consumption data is available, which indicates that in 1992 the minimum and maximum consumption was 60 m?/day and a maximum of 200 m?/day. Currently the 2002 consumption rate is 250 m?/day with an average production rate of 500 m?/day. This production rate has been achieved without the Saoa and the 'Ana Peke Peka source severely restricted due to reticulation problems. Also, due to the differing elevation of each source, a pressure differential exists with the stream supply pipe where they intersect with the bulk 150mm main. This would reduce the potential available flow from the lower elevation source (Matavai Cave). Therefore, if each source was connected to a common storage tank, no pressure differential would exist and the maximum flow from each source could be collected. During extended periods of low rainfall, the use of supplementary sources such as groundwater will be required.

Rainfall statistics indicate high levels of rainfall with a long-term mean of 1899mm/year (SMEC 1999). For water resources purposes the minimum rainfall levels are important, as is the duration of rainfall periods. The lowest recorded annual rainfall was 838mm/year in 1983 (due to the 1982-83 El Nino) and the longest consecutive low rainfall period (below 40mm/month) was for four months (PPK, 1992). This indicates that while surface water resources could be limited during extended periods of low rainfall, surface water would not completely dry up (according to local knowledge, 1983 drought) and that the recharge to the ground-water system would easily be of sufficient magnitude to sustainably supply the required daily volumes.

3.3.2 Water Quality

The major problem of water quality as identified by the community (as consumers of the reticulated water supply system), relates to dirty water following rain events. Comments were also made about nutrients and pesticides entering the water system and their potential impact on consumers of the water.

Observations during rainfall events both at the water supply intake positions and from the reticulation system indicated that the material causing pollution problems is a dark reddish brown fine silt/clay. Checks of toilets systems and bulk meter strainers, as depositional areas within the water supply network, further confirmed this.

There is a lack of reported water quality data from the 'Eua surface water sources. Measurements previously taken by some consultants indicate pH values between 7.1 and 7.3 and very low salinity values. This indicates a neutral pH and suggest that the water has had limited contact time with the limestone aquifer (the longer the contact time the higher the pH). Electrical conductivity measurement undertaken by previous consultants and myself indicate that the cave waters have very low conductivity. Similarly calcium and magnesium concentrations are also very low (PPK, 1992), further supporting the short residence time within the limestone aquifer.

Generally the water quality analyses previously undertaken indicate that the quality of the surface water is very high during periods of dry weather. However, during rainfall events high concentration of suspended solids greatly reduce the quality. Settling tank would remove most suspended sediment and organic material. Bacteriological analyses performed by the Tonga Water Board on a monthly basis indicate that, after rainfall events, bacteria counts greatly exceed the WHO drinking water guidelines (WHO, 1993). Data showing bacteriological contamination of the surface water supplies is shown in Table 3.2:

Table 3.2. Bacteriological analysis result of the 'Eua water supply system

Date Sampled	Bacteriological Count (Faecal per 100 ml)
29/10/99	20
24/02/99	18
29/10/99	20
11/01/99	8
15/11/99	9
15/10/98	31
30/09/98	9
17/9/98	38
6/07/98	23
24/03/98	218

Source: Tonga Water Board

The bacteriological contamination requires that water be disinfected prior to consumption. Chlorination is the most appropriate method of disinfections for the 'Eua system. Previous reports by the Tonga Water Board have determined that gaseous chlorine is the most effective technology for use in Tonga, although there are serious health and safety issues that require specialist training of staff in gaseous chlorine handling. This paper concurs with this. At this stage no protozoan contamination has been reported within water sources on 'Eua. Any design of disinfections technology in 'Eua should allow for inclusion of UV disinfections systems in the future, if protozoa are detected in the water supply system.

The Tonga Water Board had designed and constructed a filter bed at the Fern Gully Stream adjacent to the weir but repeated clogging and poor maintenance has lead to its abandonment. The filter bed at its early stages was proved successful at normal flow except high flows (flooding), where it was frequently damage.

4. Water catchments issues

4.1 Brief history of past event.

The water quality degradation of the 'Eua water catchments area commenced with the relocation of the 'Eua Fo'ou people from the last volcanic eruption at Niuafo'ou (a volcanic island to the north of the Tonga group). Lands within the water catchments was distributed among these people for farming.

Within the water catchments on 'Eua, the water catchment, there are already a number of activities occurring including forest harvesting, gardening, tourism and roading. As indicated earlier, the quality of water supply at its source is already comprised by sediment discharge derived from those activities such as cropping and roads. Further, there is the potential for other contaminants to enter the water sources, which, in the long term, have the potential to cause severe problems to the general health of the community.

4.2 Description of current catchments condition

The UNDP (2000) Report provides an initial delineation of a catchment boundary for the existing surface stream water sources, and this is reproduced in Fig. 3. It indicates that an area of approximately 2.77 km? forms the water supply catchment. The definition of the surface water supply catchments boundary within within this report (catchment) relates to those catchments, covering water sources contributing to the Saoa, 'Ana Peke Peka and Matavai cave system and Fern Gully Stream. The need for this delineation is to establish the areal basis for catchment management guidelines.

4.3 Guidelines

The following guideline will need to set:

- ?? Management approaches to various activities within the watershed to maintain appropriate downstream water quality, and
- ?? Suitable monitoring system to assure these approaches are effective and being implemented

Field investigation was undertaken with consultants from New Zealand to validate the previously identified watershed boundary following the initial studies of the various water intake areas and structure. The field program fell into three parts as outline below:

Southern boundary

The conclusion drawn is that the original southern watershed boundary mapped is appropriate in terms of surface hydrology.

Eastern boundary

The conclusion drawn is that the original watershed eastern boundary mapped is appropriate in terms of surface hydrology.

Northern boundary

The conclusion drawn is that the original northern watershed boundary mapped needed to be extended to the north as indicated in Figure 3.1 to ensure all of the catchments draining to Fern Gully were included.

Reviewing the above information in terms of surface flows and also considering information gained from cave systems, the adjusted topographic boundaries for the catchment are illustrated in Fig. 3.

Figure 3. Map of catchment boundary (UNDP 2000 & revised extension)

4.4 Origin of sediments

Natural Processes

On analysis of the local geology, intake locations and various environmental conditions, the red brown sediment entering the water supply clearly originate from the Miocene volcanic sandstone. The main factors that support this ascertain are direct observations of:

?? Accumulated sediment at or near the intake structure within Saoa, Matavai, and 'Ana Peke Peka caves, and

?? The extensive erosion of the weathered sandstone creating the typical stream channel topography of the area.

?? In-stream sediment character immediately upstream of the Fern Gully intake and material directly entering the pipe system.

Human influence

Discussions held with a number of groups suggest that the sediment inputs may be occurring due to more recent extensive cropping and forest harvesting activities within the 'Eua Water Supply Catchment (EWSC). Certainly these activities have the potential to increase erosion and sediment discharge into stream channels.

Factors that influence soil erosion and therefore increased sediment discharge into streams are:

?? Slope

?? Soil type and moisture content

?? Vegetation cover

?? Rainfall including intensity

?? Land use activities.

Sediment loads in surface runoff increases from the following land uses if not controlled:

?? Forestry

?? Stream works

?? Earth works

?? Vegetation removal

?? Unsealed roads, tracks and trenches

Any of these land uses or activities that occur within the catchment will therefore have the potential to increase the sediment discharge during rain events. To what degree this will happen under natural conditions is hard to predict. Considering the current land use in the catchments appears to have already highly modified them from a natural bush environment, it is clear that increased erosion is occurring now.

4.5 Potential for other pollutants to occur

Field investigation within the water supply catchment indicated a number of sources of pollution likely to impact on water quality. Several plastic oil containers were noted along roads and within 'api. Dumped domestic garbage was also observed with a variety of mixed containers and product. The soil within the catchment is deficient in nutrients and susceptible to erosion particularly those on the western dipping terraces. Cropping, to be effective, will therefore need to include nutrient addition. Pollutants associated with heavy machinery, both for cultivation and forestry management, are also potential sources of problems. Continued access to the water supply catchment by the general population, or the ever-increasing tourist ventures could also result in pollution in a number of ways, including increased litter, invasive plants, chemical spills and disposal of human waste associated with tourism.

Land use controls that can be put in place to avoid these potential problems include:

?? Restriction of roadway access: this would reduce illegal dumping, pollutants from vehicles and local erosion.

?? Banning of agricultural practices and/or the use of various chemicals: This would reduce the potential for nutrients and pesticides being used and also reduce local erosion and sediment discharge to streams.

?? Development of guidelines for land use and chemical use: This would assist in reducing all problems but have certainty of outcome.

?? Education on pollution problems and the link with water: This would assist in reducing all problems but have limited certainty of outcome.

In considering the likelihood of various pollutants entering the stream and cave waters the water quality information discussed in Section 3.3.2 clearly indicates the residence time of water is short. Therefore highly mobile pollutants (soluble) would be expected to enter waterways rapidly, and they would be hard and expensive to remove. Less mobile pollutants may be trapped in the soil matrix or other solid phases and unable to reach waterways. Alternatively they may take more time to reach waterways, in which case they may also take extended periods to flush out.

In terms of risk, certainly nutrients and pesticides do pose problems to human health and it is better to avoid their entry into the hydrological cycle. Experience internationally is that removing them from a water system may be more onerous to the community than using avoidance methods to start with.

The various controls outlined above to manage or avoid chemical contamination of the water supply catchment must therefore be considered in terms of their ability to exclude any recognized chemical pollutants. Given the complexity of identifying long-term impacts of different activities and potential pollutants, it is considered best to target those activities most likely to create problems, or risks, and use simple and effective techniques to avoid these.

4.6 Impact on Water Resources

In terms of catchment management, it is very important to consider how they will be impacted by the activities within the water supply catchment. An examination of the key problems that can occur within the area against the effects they have, or the long-term costs/impact to the community is provided simply in Table 4.1

Table 4.1 Problems and their impact in the Watershed

Problem	Effect on Watershed	Effect on Reticulation	Effect on Community
Suspended sediments	Infilling of stream bases, reduce water quality, loss to habitat	Increase clogging of filters, higher operational cost and maintenance	Increase costs of water supply, and customer dissatisfaction
Pesticides/nutrients or other soluble pollutant	Ecosystem potential degraded, water quality reduction	Reduce quality of water supply, higher costs if removal required, perceived failure of project, reduce use by customers.	Increased costs of water supply, health hazard, alternative source sought, and customer dissatisfaction
Loss of habitat and ecosystem	Infilling of streams, reduced water quality, lower ecological value	Increase clogging of filters, higher cost and maintenance	Increase costs of water supply, dissatisfaction

Table 4.1 indicates that the management of suspended sediments is possible through reticulation system controls and the impact on the community is basically related to costs of water. For

pesticides, nutrients or other soluble pollutants the impacts are considerably greater, including potential health hazards and potential loss of customer's use and revenue. Should land-use activities fail to protect the local habitat and ecosystems the consequence will likely be increased costs to the community.

The Tonga Water Board and Government of Tonga has initiated further steps by revising the Tonga Water Board Act of 1966 to alleviate the impact of human activities on water resources and its assets. Given that the management of the catchment can be achieved through the Tonga Water Board Act (section 45 and 61), the Tonga Water Board may be able to implement the management guidelines.

The revised Tonga Water Board Act – 32 of 2000 section 61 states:

61. (1) Any person who without the Board's consent, causes or allows –

(a) Any structure to be built or any filling to be placed on land in which the Board has and interest of any type whatsoever, or

(b) Any soil, rock or other matter that supports, protects or covers any works of the Board to be removed,

Commits an offence.

The intent of the Tonga Water Board Act 2000 is for this very purpose and, it is considered the appropriate legislation to use

The Government of Tonga has also initiated steps to address this issue and to relocate the farmers out of the area.

Interestingly, land allocation, potential relocation and/or compensation did not emerge as issues of concern during a public meeting held in 'Eua, to relocate farmers from the water supply catchment area. The consultants assume that recent discussions, promised resolution and the new Tonga Water Board Act, meet the needs of affected parties.

4. CURRENT PROJECT

5.1 Objectives and description

The New Zealand Government had been approving through its NZODA/TONGA bi-lateral aid a $1.7 million project for the improvement of the 'Eua Water Supply System. The project will provides a comprehensive review and analysis of an earlier report (SMEC, 1999) and proposes a project design consistent with the Tongan Government Policies and Plans and NZODA Guiding Principles. It addresses the key issues and constraints faced by the beneficiary communities and the Government implementing agencies in upgrading the water supply facilities on 'Eua in order to provide a safe, reliable water supply in the long-term.

The Project objectives are:

?? Develop appropriate watershed management guidelines to ensure the required quantity and quality of water available to the current and future reticulated system demands

?? Develop a project management structure and provide an outline of management and administrative procedures appropriate for the 'Eua water supply.

?? Determine the potential economic, social, environmental and political benefits, costs, risks and constraint for project activities and outputs.

?? Provide a detail design for the 'Eua Water Supply Improvement Project that will achieves the desired objectives, have a positive development impact and be consistent with NZODA Guiding Principles and Policy Statements.

5.2 Community education, awareness and participation

There is an increasing need for effective community education and awareness about water resource management issues in 'Eua. This aspect will be addressed by the project by undertaking community awareness program in collaboration with various NGO's. Training programmes will be provided by a suitably qualified community trainer (CDT). However, this aspect will be addressed along with the many other factors that impact on sustainable water resources management.

It is important that the communities of 'Eua, especially the more populated ones, are encouraged to become more involved in water supply planning and management issues. The need for water conservation is above all a community issue. Only with the support and participation of the community at large, especially women and children, will the people of 'Eua be able to reduce wastage and move towards sustainable development of their water resources. Appropriate community information and education in this regard are most important and can be provided through public meetings, school presentations and radio broadcasts. It is essential that governments and water agencies recognise the need for community participation in water resources conservation, planning and management in order to protect the water resources for the future generations of 'Eua.

6. Future Strategies

6.1 Protection of the area

Legislation in Tonga does not provide a simple method of managing land use, particularly in regard to the water supply catchment. What is required is the ability to 'zone' the catchment, and then manage land use practices to avoid erosion and sediment generation's problems, and other types of pollution problem.

In regard to zoning of the catchment, the Tonga Water Board Act 2000 provides for protection of land adjacent or overlying water sources by prohibiting activities (Part II section 45 and 61). Through such a process the Watershed can be define and declared and land-use practices that can cause problems prohibited. While other legislation may exist, the Tonga Water Board Act has been formulated to provide an appropriate tool for water source areas, and should be used for this purpose. Other legislation may have different purposes and will not be suitable for implementation.

The management objectives are as follows:

Without clear local legislative direction on how to established watershed management guidelines and Objectives, the following objectives is considered appropriate:

✍✍To maintain water flows and quality sufficient to ensure:

- the existing and long-term supply needs of 'Eua are met; and
- both habitat and ecosystem diversity are maintained or enhanced

To achieve this objective it is clear, that the main issue will be land use within the water supply catchment, in terms of creating sediment discharge, and maintaining the environmental conditions that sustain the high quality of water. **Policies** aimed at addressing these factors in relation to the objective are outlined below.

1. Land use

Land-use activities that affect the quantity and quality of water contributed to stream, wetlands, aquifers shall be controlled so as to:

a. protect the quantity and quality of water

b. avoid or mitigate flooding and erosion

c. enhance water quality; and

d. maintain or enhance habitat and ecosystem diversity

2. Environmental Conditions

Environmental conditions within the Watershed shall be monitored both on a regular and project specific basis to:

a. establish existing diversity

b. ensure degradation is not occurring; and

c. identify ways to maintain and enhance habitat and ecosystem diversity.

The types of methods that can be used to meet these policies revolve around understanding the Watershed in terms of environmental conditions as they are today and also as they may change over time, and controlling activities to maintain or enhance them.

a. Land-use Zoning and Activities

Establish the following two zones in the water supply catchment within which the following activities are either allowed or prohibited:

Eastern Highlands

?? Forestry and associated private roading should be allowed, but with rules for vegetation clearance and road construction. Rules are to include guidelines for road building and management covering location, timing and storm water runoff control, leaving undergrowth in place during logging in the wet season or drought periods.

?? Tourism should be allowed, but with access protocol in place. Rules are to include timing, access roads, prohibited products and activities, together with monitoring and reporting processes.

?? Cultivation of crops should be prohibited. Uncontrolled use of nutrients and pesticides, together with the increase potential for generation of sediments in runoff, threatens water quality and quantity.

Western Highlands

?? Forestry, cultivation of crops and roading should be prohibited. Uncontrolled use of nutrients and pesticide, together with the increase potential for generation of sediments in runoff, threatens water quality and quantity.

?? Tourism should be prohibited. The potential for discharge of pollutants and infectious protozoan or other biological diseases threatens water quality and quantity.

?? Access by those managing the Watershed (and their vehicles) should be allowed to monitor the state of the environment and the presence of any prohibited activities.

?? Natural regeneration of the area should be allowed

b. Environmental Conditions

Undertake both a baseline review and a long-term monitoring program of the Watershed covering habitat, ecosystem, and land use and water quality. This information is to be used for determining:

i. Changes in the Watershed character and the reason for these changes

ii. Changes to objectives, policies and methods being used in the management of the Watershed

iii. Establishing ecological corridors to link vegetation from western dipping terraces with National Forest

Based on the proposed guidelines for objectives, policies and methods identified above it is considered the Watershed can be managed well for its use as the source of water supply systems.

6.2 Management of the Watershed

Currently ownership of the water supply catchment lies with MLSNR. Management of the catchment however, should be the responsibility of those who are operating the water supply system to ensure the objectives are met and that they are linked with other operational issues.

Given that a number of key stakeholders have different interests in the management of the catchment (e.g. TWB, Ministry of Agriculture and Forestry (MAF), MLSNR, 'Eua Development Committee and the local community) it will be important to clarify each group's needs. It is considered that, a catchment management committee with representative from the above key stakeholder and chaired by the TWB, should be establish to manage the catchment.

Given that the management of the catchment can be achieved through the Tonga Water Board Act (Section 45 and 61), the TWB may be able to implement the management guidelines. Other arrangements may also be possible through land use controls already use on the National Park and buffer areas, however given the intend of the Tonga Water Board Act 2000 is for this very purpose, it is considered the appropriate legislation to use.

Summary and Conclusion

There is no neat alternative or a short cut solution for the improvement of the surface water resources in 'Eua. However, the Government of Tonga and its related parties (TWB, MLSNR, MOH, EDC and local community) should prioritize its works and try to alleviate the problem of water catchment management problems at 'Eua. The recent approval of the NZODA/TONGA bi-lateral aid project for the improvement of water supply in 'Eua, will supply a much better quality water for the people of 'Eua.

Water is a limiting resource, especially in an island like 'Eua. The need for adequate land zoning and guidelines covering acceptable activities in the water supply catchment area is the most fundamental element in the improvement of water supply in 'Eua. Community education, awareness and participation will be the supporting tools and an approach of policing the whole catchment area with a catchment management committee will no doubt improve the quality of water for the future generations of 'Eua. The quantity and quality of water available can be the limiting factors in regard to sustainable population levels. Quality of life will also be improved, or limited, by water purity and availability.

Water supply catchment management is critical in all aspects of water supply, whether it be in planning, sourcing (including catchment management and groundwater protection), treatment, pumping and reticulation, monitoring, and management of demand. A systematic approach to catchment management is necessary to ensure that there is a comprehensive environmental care across at all levels, and that catchment policies and objectives are achieved.

It is imperative that Government of Tonga, TWB, MLSNR, 'Eua Development Committee, Aid donors and the local community of 'Eua make a long-term investment to be implemented for the management of the water supply catchment in 'Eua. This investment will ensure that the water supply catchment will develop and fulfill its benefit to the people of 'Eua in many years to come.

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