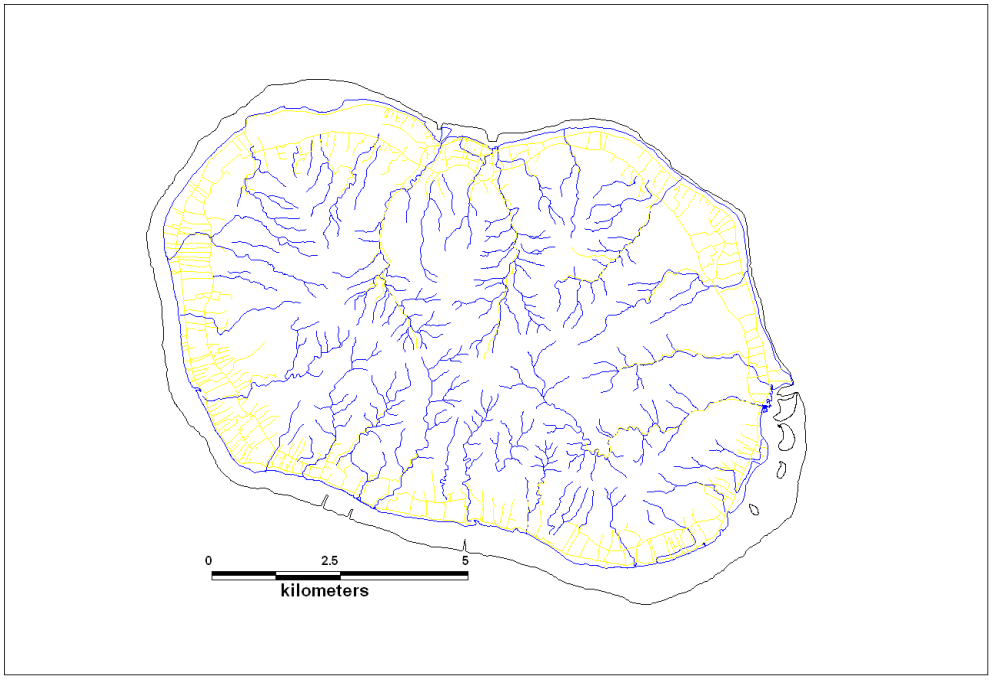
RAROTONGA WATER QUALITY ANNUAL REPORT 2007



September 2009

NGERETEINA GEORGE

TEINA TUATAI

TUAINE TURUA

DOROTHY SOLOMONA

Annual Report 2007

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Contents

Executive Summary

The water quality monitoring programme was started to provide baseline water quality data for Rarotonga in September 2004 and was modified and expanded in 2006. Initially the Takitumu area was a concern due to the occurrence of the syndrome that occurred in Titikaveka. The syndrome affected people who swam or spent time in the Titikaveka lagoon area at the end of 2003 and as a result developed eye, nose, throat and skin irritations.

In 2007 samples were collected on a monthly basis from 14 lagoon and 8 stream sites. The water samples were analysed for nutrients, physical parameters, total and volatile suspended solids, chlorophyll *a* and bacteria. Nutrient samples were sent to the National Institute of Water and Atmospheric Research Ltd (NIWA) for analyses, the physical parameters were measured at each site and bacteria, total and volatile suspended solids and chlorophyll *a* were analysed at the Ministry of Marine Resources (MMR) laboratory.

The results showed that the Eco-Tours site had the lowest lagoon water quality, with concentrations above those recommended for the protection of coral reefs, for dissolved reactive phosphorus (DRP), chlorophyll *a* and total suspended solids. The Eco-Tours site also had the highest ammonia and nitrate concentrations and the bacteria concentrations were in category D on three sampling occasions. Club Raro had the best lagoon water quality with all nutrient and chlorophyll *a* concentrations below the guidelines recommended for the protection of coral reefs and with bacteria concentrations below the World Health Organisation (WHO) standards for contact recreation. The lowest water quality occurred in March with most of the sites having elevated bacteria, total suspended solids and volatile suspended solids.

The Akapuao stream had the lowest stream water quality with the lowest dissolved oxygen (DO) concentration and high concentrations of total suspended solids, volatile suspended solids, bacteria, DRP, ammonia and nitrate. The North Airport Drain had the best water quality where, except for two sampling occasions, all samples were in the A and B category for bacteria concentrations and had the highest number of samplings that were below the DRP concentrations recommended for the protection of coral reefs.

The results from this report can be used to compare the state of the water quality in the lagoon and streams with those in the past and can be used to evaluate future developments.

1. Introduction

Rarotonga is the capital of the Cook Islands and is rapidly developing, hence it is vital that the health of the lagoon is monitored and action is taken to protect the health of the lagoon, the reef and most importantly human health. Human activities for example farming pigs, deforestation and farming of crops close to streams are known to decrease the water quality in the streams and the lagoon. Results of the water quality monitoring programme give information on the state of the streams and the lagoon and if a low water quality is detected, human activities close to the streams can be investigated.

Rainfall can influence the health status of the lagoon and streams, and on Rarotonga the rainfall and weather patterns vary between the wet and dry season. The dry season begins in April/May to September/October and the wet season begins in November and ends in March. During the dry season the prevailing wind direction is from the east and southeast shifting to the northeast during the rainy season with occasional tropical storms especially from the north west.

The measurement of basic physical and chemical parameters (temperature, DO, pH and salinity) is important for establishing long term changes in water quality of the lagoons and streams. Temperature and DO influences the occurrence and growth of aquatic plants, and animals. The solubility of DO in water is regulated by temperature, however other factors also affect DO saturations. In the water, DO is either absorbed directly from the atmosphere or is produced by plants or algae by photosynthesis and is removed by respiration and decomposition of organic matter. The recommended minimum for DO (Department of Health, Clean Water Branch Hawaii 1994) is not less than 75% saturation for oceanic waters, embayments, open coastal waters and estuaries and not less than 80% for streams. There is little variation in salinity in most marine environments and it is normally between 34ppt and 36ppt (Smith 2004).

Mosely et al. (2004) in the water quality guidelines developed for Pacific Countries by the Pacific Islands Applied Geoscience Commission (SOPAC) suggested that pH should be between 8.0 and 8.4 in lagoon type environments which is similar to the ANZECC (2000) standards for tropical Australia. The Department of Health, Clean Water Branch Hawaii (1994) pH standard for open coastal waters is between 7.6 and 8.6 and can be as low as 7.0 in areas influenced by freshwater inputs.

Nutrients such as nitrate and phosphate are naturally present in seawater and are essential for the growth of phytoplankton and other algae, which form the base of the food web. Naturally occurring nutrient concentrations in the tropical Pacific Ocean are generally very low, as is productivity. If elevated concentrations of nutrients are added to the water, algae and aquatic plant biomass will increase. In coral reef areas, this can have detrimental impacts on the coral reef.

The guidelines for nutrient concentrations for the protection of coral reef health are 14µg/L for dissolved inorganic nitrogen (DIN), which is made up of nitrate and ammonia (NO_3-N + NH_4-N), and 2.6µg/L for dissolved reactive phosphorus (DRP) (Bell 1992). The ANZECC guideline values for streams or lowland rivers of concern in Australian tropical areas are 10µg/L for nitrate (NO_3-N) and ammonia (NH_4-N), and 4µg/L for DRP (ANZECC 2000). All physical and chemical measurements made are indicative of lagoon health and provide a baseline for water quality for lagoons and streams around Rarotonga.

Chlorophyll *a* is used to measure phytoplankton biomass which increases when nutrient concentrations in the water column increase. Chlorophyll *a* concentrations above 0.5µg/L have been shown to impact coral reef health (Bell 1992). Total suspended solids measures the inorganic and organic particulate material in the water column, like chlorophyll *a*, elevated total suspended solids have been shown to impact negatively on coral reef health above concentration of 4-5mg/L (Bell 1992).

The organic particulate material in the water, particularly of animal origin, can be related to bacteria concentrations in the water; the higher the particulate material the higher the concentration of bacteria. Enterococci are a group of bacteria commonly used to indicate the potential presence of human pathogens in the marine and freshwater environment. Guidelines have been developed by the World Health Organisation for contact recreation using Enterococci numbers in the marine environment (Table 1). This guideline is also used for freshwater to evaluate the water quality of the streams as they flow directly into the lagoon and are likely to impact the bacterial counts in the lagoon.

The results from this report are compared with the guidelines for the protection of coral reefs and the guidelines for swimming and overall findings are presented.

Table 1. WHO Standards for Bathing Water Quality (WHO 2001).

Category	Indicator Counts	Microbiological Assessment
A.	≤ 40 Enterococci /100ml	Suitable for swimming
B.	≥ 41 to ≤ 200 Enterococci /100ml	Suitable for swimming but requires surveillance
C.	≥ 201 to ≥ 500 Enterococci /100ml	Not suitable for swimming, requires assessment
D.	> 500 Enterococci /100ml	Not suitable for swimming, public warnings

2. Methods

2.1 Sampling Sites and Sampling

Fourteen lagoon and 8 stream sites were sampled monthly (Fig 1, Table 2 and 3). All the lagoon sites were sampled for total and volatile suspended solids however the data from May and June were removed because of inadequate rinsing of the filters. The total and volatile suspended solids data for the sites Pou'ara Ra'ui, Avana Mudflats, Eco-Tours, Tikioki Packing Shed, Kent Hall, Totokoitu Research Station, Sheraton and Kaena Restaurant in February were also removed for the same reason. There were no volatile suspended solids for January as the filters were not processed for this parameter. There were no chlorophyll *a* data available for the first 3 months of the year. All lagoon physical parameter data were missing for August. The lagoon DO data in August 2007 were missing. For lagoon samples salinity data for August and September and pH data for February, April, May, and September were deleted because of instrument calibration problems. All stream physical parameter data were missing for June and October; pH data were deleted for January, February, April and May because of instrument calibration problems. Rutaki stream was dry in August.

2.2 Physical Parameters

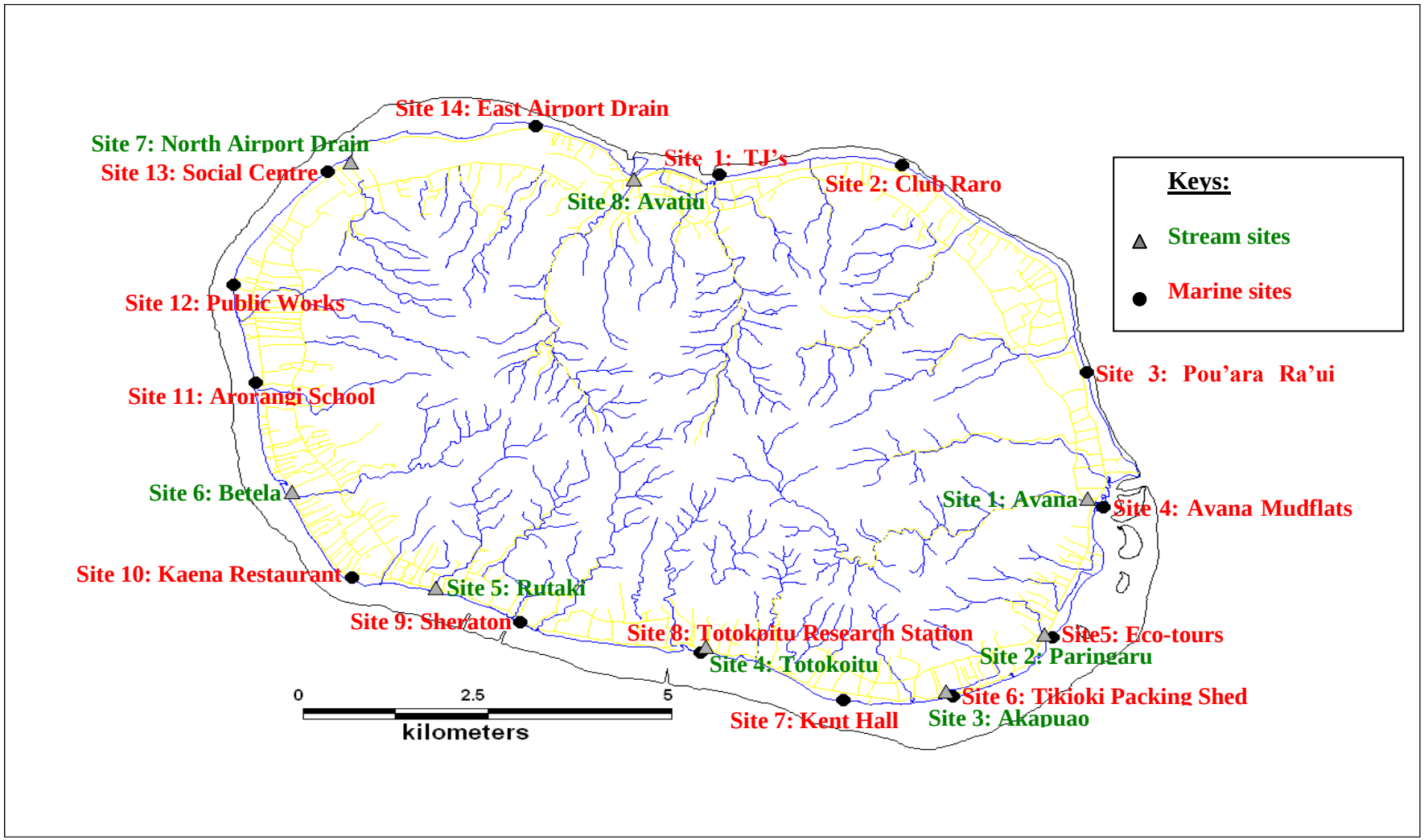
At each site temperature (ºC), dissolved oxygen (DO) % saturation and concentration, pH and salinity (‰) were measured using a YSI 556 Probe. The individual probes were calibrated before use in the field (Hall et al., 2007). Measurements were made at each site at the time of water sampling (Hall et al., 2007).

Table 2. Rarotonga Lagoon sampling sites.

SITE NUMBER	LOCATION	LATITUDE	LONGITUDE
1	TJ's	S21 12.308	W159 46.441
2	Club Raro	S21 04.417	W159 45.304
3	Pou'ara Ra'ui	S21 13.821	W159 43.842
4	Avana Mudflat	S21 14.864	W159 43.730
5	Eco-Tours	S21 15.856	W159 44.089
6	Tikioki Packing Shed	S21 16.314	W159 44.788
7	Kent Hall	S21 16.195	W159 45.335
8	Totokoitu Research Station	S21 15.976	W159 46.570
9	Sheraton	S21 15.744	W159 47.851
10	Kaena Restaurant	S21 15.401	W159 49.036
11	Arorangi School	S21 13.903	W159 49.723
12	Public Works	S21 13.149	W159 49.873
13	Social Centre	S21 12.285	W159 49.205
14	East Airport Drain	S21 11.932	W159 47.737

Table 3: Rarotonga Stream sampling sites.

SITE NUMBER	LOCATION	LATITUDE	LONGITUDE
1	Avana	S21 14.794	W159 43.835
2	Paringaru	S21 15.838	W159 44.135
3	Akapuao	S21 16.274	W159 44.836
4	Totokoitu	S21 15.938	W159 46.535
5	Rutaki	S21 15.481	W159 48.442
6	Betela	S21 14.739	W159 49.462
7	North Airport Drain	S21 12.214	W159 49.043
8	Avatiu	S21 12.342	W159 47.047


Site 14: East Airport Drain
Site 7: North Airport Drain
Site 13: Social Centre
Site 1: TJ's
Site 2: Club Raro
Site 8: Avatiu
Site 12: Public Works
Site 11: Arorangi School
Site 3: Pou'ara Ra'ui
Site 6: Betela
Site 1: Avana
Site 4: Avana Mudflats
Site 10: Kaena Restaurant
Site 5: Rutaki
Site 9: Sheraton
Site 8: Totokoitu Research Station
Site5: Eco-tours
Site 4: Totokoitu
Site 2: Paringaru
Site 6: Tikioki Packing Shed
Site 7: Kent Hall
Site 3: Akapuao
0
2.5
5
kilometers
Keys:
Stream sites
Marine sites

2.3 Nutrients

All water samples for nutrient analysis were collected, stored on ice and processed within eight hours. Samples for nutrients were filtered through a Whatman GF/F glass fibre filter into a 250ml acid washed plastic bottle. These samples were stored frozen until they were shipped on ice in chilly bins to NIWA for analysis. All nutrient analysis were conducted using an Astoria Pacific autoanalyser 300 series with methods from the Astoria Pacific International Methods Manual (A 6/00). NO_3-N was analysed by the cadmium column reduction method (Astoria 305-A177), DRP by the molybdenum blue method (Astoria 305-A204) and NH_4-N by the indophenol blue method (Astoria 305-A026).

2.4 Chlorophyll *a* and Suspended Solids

Samples for total and volatile suspended solids and chlorophyll *a* analysis were collected and stored in the dark on ice for a maximum of 8 hours. Known volumes of samples were filtered on to GF/F filters for total and volatile suspended solids, placed on a labeled aluminum cup and dried in an oven at 104°C for 6 hours (Hall et al., 2007).

For chlorophyll *a* the filters were analysed by acetone extraction and fluorometry (APHA 1998).

2.5 Bacteria

Water samples collected were stored on ice and analysed for Enterococci within 5 hours of sample collection. Samples were analysed in duplicate using a membrane filtration method and placed on Enterococci agar (Hall et al., 2007). The volumes filtered differed depending on how clean the water was and on previous results (Hall et al., 2007). Enterococci plates were incubated at 37^0C for 24 hours after which Enterococci per 100ml were calculated (Hall et al., 2007).

3. Results

3.1 Physical Parameters

Lagoon

The water temperature in the lagoon has a strong seasonal variation with highest mean temperature in February and April and lowest in July. Mean air temperature ranged from 27.1ºC in February to 23.2ºC in July/September. The lagoon water temperatures showed similar trends to the air temperature. The cooler months were from June to September and the warmer months from October to May. The mean lagoon temperature in 2007 ranged from 22.6ºC in July to 27.9ºC in February and April, compared to 2006 when the range was 23.8 to 29.1ºC (Fig. 2).

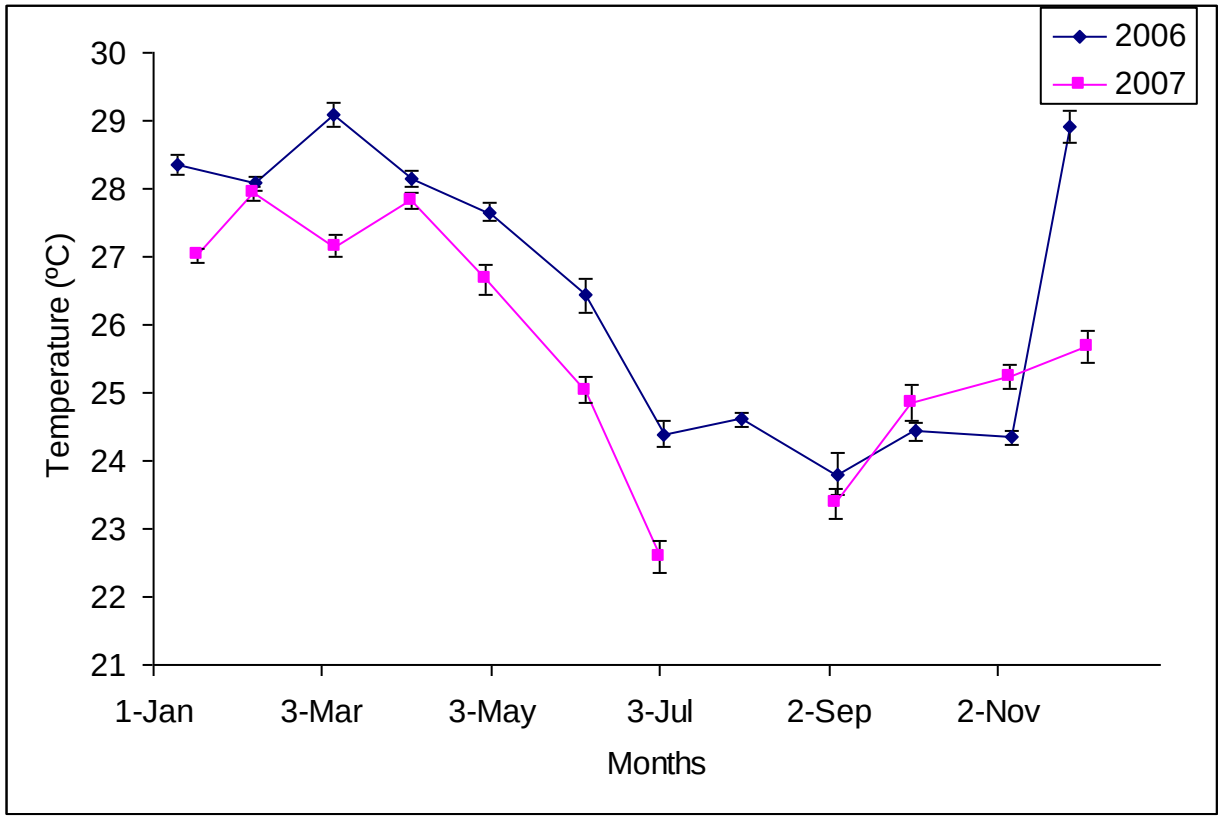


Figure 2. Lagoon annual mean temperature (ºC) in Rarotonga from January to December 2007 and 2006.

In 2007 the East Airport Drain site had the highest temperature of 29.0ºC in April and the lowest was 21.2ºC at Totokoitu Research Station in July.

The pH of the lagoon ranged from 8.0 at Eco-Tours in December to 8.9 at Arorangi School in March (Appendix 3). The highest pH recorded in 2007 exceeded the Department of Health Clean Water Branch (1994) guideline of between 7.6 and 8.6 for open coastal waters.

Salinity ranged from 27.5‰ at Eco-Tours in March to 37.6‰ at Social Centre in February (Appendix 3). The Eco-Tours site is influenced by stream inflows resulting in lower salinities at certain tides and stream flows. The March salinity was consistently low across all sites due to high rainfall in the 3 days prior to sampling. Salinity is site specific; sites with freshwater influence have a wide range of salinity compared to sites with no or little freshwater influence (Tuatai et al., 2006).

In Tuatai et al 2006 DO was reported as DO concentrations and in this report percent (%) saturation is used. DO saturations range from 75.8% (4.9mg/L) at Eco-Tours in February to 150.8% (9.7mg/L) at Arorangi School in April (Appendix 3). All DO saturations in 2007 were above the guidelines of ≤75% for the Department of Health Clean Water Branch (1994).

Streams

The temperatures for the stream sites showed a strong seasonal variation with higher temperatures in the summer months and lower temperatures in the cooler months. The stream temperature follows the air temperature trends in 2007 but overall air temperatures were cooler. The temperature ranged from 19.8ºC at Totokoitu in September to 32.7 ºC in April and is narrower than the range of 21.1 to 33.9ºC recorded in 2006. The sites had similar mean temperatures except for the North Airport Drain which showed consistently higher temperatures in both 2006 and 2007 (Fig. 3).

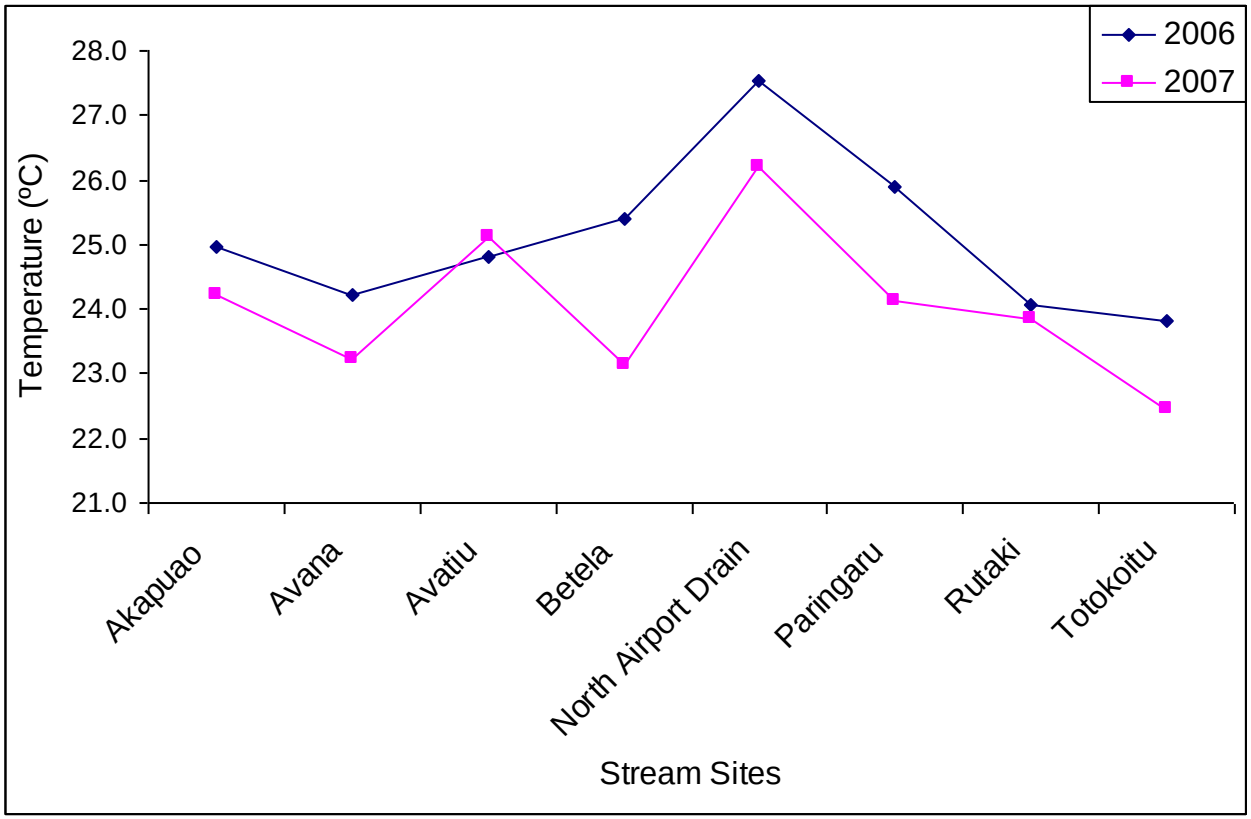


Figure 3. Stream mean temperature (ºC) in Rarotonga from January to December in 2007 and 2006.

The pH of the streams ranged from 5.3 at the North Airport Drain to 10.2 in Avatiu in July with the upper pH range above Department of Health Clean Water Branch (1994) guidelines.

Salinity in the streams ranged from 0.04‰ at Totokoitu in September to 13.1‰ at Avana in November 2007 (Appendix 3). In 2007 Betela and Totokoitu consistently had the lowest mean salinity (0.1‰) and Akapuao, Avana, Avatiu and North Airport Drain occasionally had elevated salinities due to tidal influences. Avana and Akapuao salinities were higher due to high seas in November in the Takitumu area.

Dissolved oxygen (DO) saturations in the streams ranged from 11.1% (0.9 mg/L) at Akapuao in February to 199.6 % (14mg/L) at Avatiu in December 2007 (Table 4). Akapuao consistently had the lowest DO saturations followed by Paringaru and both were consistently below the Clean Water Branch standard for stream waters. Avatiu and the North Airport Drain were consistently over the standard except in January when the North Airport Drain was slightly below.

Table 4. **Dissolved Oxygen (DO) saturations (%) recorded in the Rarotonga streams from January to December in 2007. The recommended minimum for DO (Department of Health, Clean Water Branch Hawaii 1994) is not less than 80% for streams. Green indicates results within the guideline and red indicates results above the guideline.**

Date	Avana	Paringaru	Akapuao	Totokoitu	Rutaki	Betela	North Airport Drain	Avatiu
17-Jan-07	111.7	59	31.3	91.8	112.9	95	78.4	117.4
6-Feb-07	91.7	48.8	11.1	82.9	71.8		113.5	107.9
8-Mar-07	98.3	90.7	76.8	99.1	96.6	90	126.1	96.5
4-Apr-07	91	54.2	46.2	91.6	90.3		177.2	90.9
1-May-07	92.8	54.3	22.6	84.1	88.4	118.2	159.2	167.8
6-Jun-07								
3-Jul-07	77.6	56.4		83.6	72.6	67.1	103.1	143.9
7-Aug-07	80.3	88.2	19.1	79.4		68.4	132.5	97.1
4-Sep-07	95.2	44.6	27.6	89.2	101.8	90.7	116.4	101.4
2-Oct-07								
6-Nov-07	84.2	113.2	17	83.4	135.5	79.9	118	108.5
4-Dec-07	125.1	66.1	51.8	117.2	114.5	98.7	110.1	199.6

3.2 Nutrients

Lagoon

DRP concentrations ranged from 0.5 to 49µg/L (Table 5). At Eco-Tours, Kent Hall and Totokoitu Research Station sites, the DRP concentrations exceeded the Bell (1992) guideline of 2.6µg/L for the protection of coral reef health on all sampling occasions. The TJ's and Club Raro sites had five occasions that were below the guideline. In August, eight out of fifteen sites were below the recommended guideline whereas the months of January, February and September all sites exceeded the guideline (Bell 1992) (Table 5).

The guideline concentration for DIN (NO_3-N + NH_4-N) for the protection of coral reef health is 14µg/L (Bell 1992). The Kent Hall site exceeded the Bell (1992) guideline on ten out of twelve sampling occasions and Tikioki Packing Shed exceeded it on eight occasions (Table 6). Club Raro and Social Centre were the only two sites that were below the Bell (1992) guideline on all sampling occasions. In February, only one out of the fourteen sites exceeded the Bell (1992) guideline whereas in September and December, there were seven sites above the guideline (Table 6).

Ammonia (NH_4-N) concentrations ranged from 0.5 to 47µg/L. Club Raro had the lowest concentration with all results ≤6µg/L, whereas Eco-Tours recorded the highest concentration ranging from 3 to 47µg/L. In November the lowest ammonia concentrations of 0.5 to 8µg/L were recorded at all sites. In September four sites had high ammonia concentration ranging from 9 to 47µg/L (Appendix 3).

Table 5. Dissolved reactive phosphorus (DRP) concentrations (µg/L) for Rarotonga lagoon 2007. The DRP guideline for the protection of reef health is 2.6 µg/L (Bell 1992). Green indicates concentrations equal to and below the guideline, red indicates concentrations above the guideline.

Date	TJ's	Club Raro	Pou'ara Ra'ui	Avana Mudflat	Eco-Tours	Tikioki Packing Shed	Kent Hall	Totokoitu Research Station	Sheraton	Kaena Restaurant	Arorangi School	Public Works	Social Centre	East Airport Drain
17-Jan-07	11	4	6	4	7	4	5	4	4	4	6	4	4	6
6-Feb-07	7	5	7	4	6	4	7	4	7	6	9	4	5	5
8-Mar-07	1	0.5	8	25	49	10	26	11	4	2	6	3	4	9
4-Apr-07	3	3	2	2	4	2.5	5	5	10	1	4	1	1	4
1-May-07	3	5	4	2	4	2	7	3	4	3	8	2	0.5	3
6-Jun-07	3	3	2	6	24	7	9	16	6	10	4	3	2	10
3-Jul-07	0.5	2	0.5	2	7	3	4	8	2	2	7	6	4	3
9-Aug-07	0.5	2	1	3	3	5	3	4	5	2.5	2	0.5	2	1
4-Sep-07	4	3	3	6	6	5	3	4	6	3	9	7	3	4
2-Oct-07	2	2.5	3	11	5	5	4	3	4	5	9	7	3	4
6-Nov-07	2	0.5	3	4	4	1	5	3	3	5	8	6	6	4
4-Dec-07	7	4	4	7	6	2.5	3	8	6	4	2	7	4	4

Table 6. Dissolved inorganic nitrogen (DIN) concentrations (µg/L) for Rarotonga lagoon 2007. The DIN guideline for the protection of reef health is 14µg/L (Bell 1992). Green indicates concentrations equal to and below the guideline, red indicates concentrations above the guideline.

Date	TJ's	Club Raro	Pou'ara Ra'ui	Avana Mudflat	Eco-Tours	Tikioki Packing Shed	Kent Hall	Totokoitu Research Station	Sheraton	Kaena Restaurant	Arorangi School	Public Works	Social Centre	East Airport Drain
17-Jan-07	18	7	9	9	8	20	19.5	6	8	10	17	13	7	13
6-Feb-07	15	3	5.5	10	10	14	14	5	12	12	9	7	4	3.5
8-Mar-07	8	6	16	78	82	34	40	11	8	9	13	13	7	14
4-Apr-07	6	6	8	10	19	17.5	22	14	12.5	7	21	12	6	16
1-May-07	7	4	8.5	6	9	10	24	4	6.5	16	19	7	7	6.5
6-Jun-07	6	4	13	9	224	38	30	24	14	23	12	8.5	11	20.5
3-Jul-07	8	6	18	8.5	20	14	20.5	14	6	7.5	16	37	8	10
9-Aug-07	7	9	10	14	11	24	33	11	25.5	8.5	9	15	9	5
4-Sep-07	34.5	4	5	66	60	20	11	8	15	7	23	27	13	12
2-Oct-07	4	7	8.5	29	14	23	17	4	14	9	18	33	7	8
6-Nov-07	2.5	3	11	8.5	8	7	15.5	18	4.5	7	24	26	6	5
4-Dec-07	7	6	5	16	32	39	33	15	38	11	8	42	14	5

Nitrate (NO_3-N) concentrations ranged from 0.5 to 188µg/L. Club Raro recorded the lowest nitrate concentrations ranging from 1 to 3µg/L on all sampling occasions. Eco-Tours had high concentrations ranging from 10 to 188µg/L. Low nitrate concentration, 0.5 to 11µg/L, were recorded at all sites in February, compared to the month of September and October that had seven occasions with nitrate concentrations over 10µg/L (Appendix 3).

Streams

Concentrations of DRP ranged from 2 to 410µg/L (Table 7). All streams except for North Airport Drain had consistently high DRP concentrations. North Airport Drain had five sampling occasions with DRP concentrations below the ANZECC (2000) guideline for lowland rivers in tropical areas of 4µg/L. Avana, Akapuao, Totokoitu, Rutaki, Betela and Avatiu streams exceeded the ANZECC guideline on all sampling occasions. Samples collected in March had the highest DRP concentration ranging from 51 to 410µg/L compared to May, which had the lowest, 2.5 to 54µg/L (Table 7).

Table 7. **Dissolved reactive phosphorus (DRP) concentrations (µg/L) for Rarotonga streams 2007. The DRP guideline for lowland rivers in tropical areas is 4µg/L (ANZECC 2000). Green indicates concentrations equal to and below the guideline, red indicates concentrations above the guideline.**

Date	Avana	Paringaru	Akapuao	Totokoitu	Rutaki	Betela	North Airport Drain	Avatiu
17-Jan-07	29	9	10	49	68	40	7	70
6-Feb-07	42	13	6	46	66	42	4	51
8-Mar-07	104	201	410	80	87	64	51	89
4-Apr-07	32	12	12	47	79	45	17	77
1-May-07	38	3	10	24	36	25	2.5	54
6-Jun-07	40	14	7	32	53	53	7	79
3-Jul-07	40	11	10	26	37	45	5	70
9-Aug-07	39	12	176	197		69	3	92
4-Sep-07	80	5	79	70	107	53	20	167
2-Oct-07	41	10	115	20	32	29	2	40
6-Nov-07	29	9	272	46	33	39	4	77
4-Dec-07	45	17	12	59	75	14	11	96

Ammonia (NH_4-N) concentrations ranged from 0.5 to 2200µg/L. The Akapuao stream had consistently high ammonia concentrations throughout the year ranging from 45 to 2200µg/L. In contrast the Avana and Avatiu streams had ammonia concentrations below the ANZECC (2000) guideline except in November. In the months of February, July, October and November, five out of eight streams had ammonia concentrations above the 10µg/L, which is above the guideline for lowland rivers in tropical areas (ANZECC 2000). Only two streams were above the guideline in May (Table 8).

Table 8. **Ammonia (NH_4-N) concentrations (µg/L) for Rarotonga streams 2007. The NH_4 guideline for lowland rivers in tropical areas is 10 µg/L (ANZECC 2000). Green indicates concentrations equal to and below the guideline, red indicates concentrations above the guideline.**

Date	Avana	Paringaru	Akapuao	Totokoitu	Rutaki	Betela	North Airport Drain	Avatiu
17-Jan-07	3	10	45	11	3	9	64	3
6-Feb-07	8	35	438	14	9	19	26	3
8-Mar-07	7	13	65	6	3	11	53	5
4-Apr-07	6	25	86	9	7	9	18	7
1-May-07	3	38	83	10	0.5	0.5	1	1
6-Jun-07	4	32	71	6	6	7	21	7
3-Jul-07	7	40	107	25	16	11	4	6
9-Aug-07	7	14	2200	18		21	5	7
4-Sep-07	3	44	155	10	4	6	111	3
2-Oct-07	8	60	490	16	14	11	2	6
6-Nov-07	12	62	164	22	2	7	6	12
4-Dec-07	5	25	66	9	3	11	49	7

Nitrate (NO_3-N) concentrations ranged from 0.5 to 396µg/L (Table 9). Paringaru stream had consistently high nitrate concentrations except in February. Nitrate in the Totokoitu stream was above the guideline on all sampling occasions with concentrations ranging from 11 to 82µg/L. North Airport Drain and Avatiu had five and six out of eight sampling occasions, respectively when nitrate concentrations were below the ANZECC (2000) guideline of 10µg/L for lowland rivers in tropical areas. High nitrate concentrations were recorded in June and December ranging from 14 to 396µg/L. In comparison, low concentrations were recorded in October ranging from 1 to 25µg/L (Table 9).

Table 9. **Nitrate ($N0_3$-N) concentrations (µg/L) for Rarotonga streams 2007. The nitrate guideline for lowland rivers in tropical areas is 10µg/L (ANZECC 2000). Green indicates concentrations equal to and below the guideline, red indicates concentrations above the guideline.**

Date	Avana	Paringaru	Akapuao	Totokoitu	Rutaki	Betela	North Airport Drain	Avatiu
17-Jan-07	3	61	66	14	2	14	114	4
6-Feb-07	11	8	25	24	17	11	54	2
8-Mar-07	72	347	374	11	6	126	312	70
4-Apr-07	58	184	77	14	70	124	266	197
1-May-07	13	218	27	30	31	2	0.5	6
6-Jun-07	54	396	146	17	84	121	223	124
3-Jul-07	31	378	65	28	64	51	2	17
9-Aug-07	29	127	23	82		127	2	6
4-Sep-07	11	41	229	19	14	96	186	94
2-Oct-07	15	22	3	25	11	17	1	5
6-Nov-07	11	45	20	15	29	3	5	6
4-Dec-07	103	395	119	14	100	99	189	163

3.3 Chlorophyll *a* and Total Suspended Solids

Lagoon

The chlorophyll *a* concentrations in the lagoon ranged from <0.1 to 1.5µg/L (Table 10). All the sites were below the concentration of 0.5µg/L recommended for the protection of coral reefs except for Eco-Tours, Tikioki Packing Shed, Kent Hall and Totokoitu Research Station. In August all these sites were over the guideline and the Eco-Tours site exceeded the guideline on five out of nine sampling occasions.

Table 10. Chlorophyll *a* concentrations (µg/L) for the Rarotonga lagoon. The red colours indicate concentrations above 0.5µg/L which is the concentrations recommended for the protection of coral reef health (Bell 1992).

Date	TJ's	Club Raro	Pou'ara Ra'ui	Avana Mudflat	Eco-Tours	Tikioki Packing Shed	Kent Hall	Totokoitu Research Station	Sheraton	Kaena Restaurant	Arorangi school	Public works	Social Centre	East Airport Drain
4-Apr-07	0.2	0.1	0.1	<0.1	0.4	0.2	0.1	0.2	<0.1	<0.1	0.1	0.1	<0.1	0.4
1-May-07	<0.1	<0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.1	<0.1	0.1	0.1	<0.1	0.2
6-Jun-07	<0.1	0.2	0.4	0.2	0.4	0.1	0.1	0.2	0.3	<0.1	0.1	<0.1	<0.1	0.3
3-Jul-07	0.1	0.1	0.2	0.1	0.7	0.1	0.1	0.4	0.2	<0.1	0.1	<0.1	<0.1	0.3
9-Aug-07	<0.1	<0.1	0.1	0.3	0.7	0.6	0.6	0.9	0.2	0.1	0.2	0.2	0.3	0.3
4-Sep-07	0.1	0.1	0.1	0.1	0.7	0.2	0.2	0.6	0.1	0.1	0.1	0.1	0.2	0.3
2-Oct-07	0.1	0.2	0.2	0.2	1.1	0.2	0.3	0.1	0.2	0.1	0.1	0.1	<0.1	0.2
7-Nov-07	0.1	0.1	0.2	0.2	0.3	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2
4-Dec-07	<0.1	0.1	0.3	0.3	1.5	0.8	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1

The total suspended solids concentrations ranged from 0.3 to 216.0mg/L (Table 11). The Ecotours and the Club Raro sites were over the guideline of 5.0mg/L (Bell 1992) on four out of twelve sampling occasions. In January and March, eight and seven sites respectively were over the guideline for the protection of coral reefs. All samples collected from Pou'ara Ra'ui, Sheraton, Kaena Restaurant and Arorangi School sites did not exceed the guideline for protection of coral health. None of the sites exceeded the guidelines in November and December.

The volatile suspended solids ranged from 0 to 17.7mg/L. The highest volatile suspended solids concentrations were recorded in March at all sites except Pou'ara Raui, Arorangi School, Public Works and East Airport Drain (Appendix 3).

Table 11. Total suspended solids (mg/L) for Rarotonga lagoon. The red colours indicate concentrations above 5.0mg/L which is the concentration recommended for the protection of coral reef health (Bell 1992).

Date	TJ's	Club Raro	Pou'ara Ra'ui	Avana Mudflat	Eco-Tours	Tikioki Packing Shed	Kent Hall	Totokoitu Research Station	Sheraton	Kaena Restaurant	Arorangi School	Public Works	Social Centre	East Airport Drain
17-Jan-07	5.7	37.8	4.2	47.3	216.0	29.1	3.2	0.9		2.1	2.8	33.1	44.1	123.0
6-Feb-07	7.2	8.4									3.6	4.0	2.4	2.9
8-Mar-07	2.3	11.2	0.9	60.9	23.9	5.7	34.0	16.2	2.5	1.4	2.8	7.4	4.0	3.5
4-Apr-07	0.8	1.6	1.9	0.9	2.9	1.5	1.3	15.4	0.4	0.3	2.9	0.8	0.3	4.2
1-May-07														
6-Jun-07														
3-Jul-07	0.7	0.7	0.3	6.0	2.4	2.1	0.7	1.1	0.3	0.3	0.7	0.6	0.9	8.3
9-Aug-07	1.0	5.9	0.3	0.8	1.4	1.8	0.3	3.9	4.5	0.6	0.3	0.3	1.8	1.1
4-Sep-07	0.5	1.4	0.8	0.3	9.3	1.0	0.9	33.7	0.3	0.7	1.7	0.6	1.5	4.9
2-Oct-07	0.3	1.7	0.8	0.7	6.2	1.1	0.9	0.3	0.5	0.3	0.3	0.8	2.2	2.1
7-Nov-07	1.3	4.9	2.3	2.3	4.1	2.0	0.9	1.2	1.1	0.5	0.5	0.7	1.4	1.7
4-Dec-07	1.3	2.1	1.0	0.6	3.5	1.0	0.3	0.5	0.3	0.3	0.3	0.3	1.5	2.7

Streams

The total suspended solids concentrations for the streams ranged from 0.3 to 99.2 mg/L (Table 12). The total suspended solids concentrations at the Akapuao stream and North Airport Drain were within the guideline for the slightly disturbed ecosystems in tropical Australia (ANZEC 2000) of 2 to 15mg/L on nine and seven out of twelve sampling occasions respectively. The Betela stream was within the same range on ten sampling occasions. Rutaki and Paringaru streams were below the range on ten sampling occasions. In March, five out of eight streams were below or within the range for a slightly disturbed ecosystem and three streams above the range. In September all streams were within the slightly disturbed range except for Avatiu which was above and Paringaru which was below.

The volatile suspended solids ranged from 0 to 31.1mg/L. The highest volatile suspended solids occurred in March at Avana, Paringaru, Akapuao and Rutaki (Appendix 3).

Table 12. Total suspended solids (mg/L) for Rarotonga streams. The green colour indicates concentrations below the range of 2 to 15mg/L which represent concentrations for slightly disturbed ecosystems in tropical Australia (ANZECC 2000). The orange and red colour indicates concentrations within and above this range respectively.

Date	Avana	Paringaru	Akapuao	Totokoitu	Rutaki	Betela	North Airport Drain	Avatiu
17-Jan-07	2.6	0.4	8.7	1.4	0.7	1.5	6.8	1.2
6-Feb-07	1.5	0.7	2.0	1.2	0.5	2.5	10.8	4.6
8-Mar-07	99.2	60.1	63.8	9.1	1.7	5.7	13.4	2.1
4-Apr-07	1.6	0.3	2.1	3.2	1.2	3.2	2.3	1.6
1-May-07	0.3	0.3	1.1	1.0	1.0	0.9	0.9	0.1
6-Jun-07	0.3	1.0	4.3	1.2	1.3	2.0	5.2	0.7
3-Jul-07	0.6	1.7	3.2	1.1	1.4	11.4	0.8	0.8
9-Aug-07	0.3	2.1	46.3	33.9		8.5	4.7	1.0
4-Sep-07	3.6	0.7	14.0	6.2	2.3	2.1	6.7	16.5
2-Oct-07	0.8	1.3	12.5	2.6	1.2	4.0	35.6	0.3
7-Nov-07	3.3	1.5	6.6	0.3	1.4	2.0	17.4	2.6
4-Dec-07	0.3	0.3	6.1	0.3	0.3	2.8	1.9	1.7

3.4 Bacteria

Lagoon

From January to December, 93% of the sampling sites and days showed that the lagoon water was safe for swimming with bacterial concentration falling in the A and B categories (Table 13). In the month of March at Avana, Eco-Tours, Tikioki Packing Shed and Kent Hall sites, the water was not suitable for swimming. The bacterial numbers from these sites ranged between 625 to 5050 per 100ml (category D). In February and June at Eco-Tours, bacterial counts were 570 and 660 per 100ml respectively (category D). Category D is not recommended as safe for swimming or other contact recreation based on WHO standards. Rainfall is often considered to be a contributing factor to the elevated Enterococci numbers in the water. Correlation of Enterococci and rainfall in the 3 days prior to sampling date showed a strong relationship ($r^2 = 0.92$) at Avana Mudflats, Eco-Tours, Tikioki Packing Shed and Kent Hall sites indicating that run off from land is potentially increasing bacterial numbers in the lagoon.

Table 13. Summary of 2007 Enterococci numbers (per 100ml) from lagoon sites. There are 4 color codes used in the table which represents WHO standards (Table 1). Green represents category A, Yellow category B, Orange category C and Red category D.

Date	TJ's	Club Raro	Pou'ara Ra'ui	Avana Mudflat	Eco-Tours	Tikioki Packing Shed	Kent Hall	Totokoitu Research Station	Sheraton	Kaena Restaurant	Arorangi School	Public Works	Social Centre	East Airport Drain
17-Jan-07	41	34	1	5	23	4	0	10	2	2	3	4	18	24
06-Feb-07	67	1	97	111	570	59	70	63	62	26	54	78	52	92
08-Mar-07	18	8	308	625	5000	1760	5050	168	32	0	26	6	465	162
04-Apr-07	1	4	1	9	20	3	3	19	133	1	27	3	1	72
01-May-07	1	5	8	7	4	32	2	15	4	2	2	3	2	4
05-Jun-07	0	0	230	2	660	2	10	248	42	0	0	0	2	58
03-Jul-07	0	12	0	1	6	2	4	55	0	18	10	0	0	3
09-Aug-07	1	1	1	6	10	6	8	303	1	5	1	0	2	8
04-Sep-07	31	0	2	92	2	2	0	200	155	0	7	3	7	14
02-Oct-07	0	2	2	6	4	1	1	1	17	0	1	10	5	11
06-Nov-07	0	0	3	24	56	11	0	0	0	0	0	7	9	16
04-Dec-07	1	11	1	12	2	4	0	23	9	1	1	0	4	7

Streams

Enterococci numbers were in the C and D categories, not recommended for swimming (Table 14). At Avana and Akapuao streams from January to December, all Enterococci numbers were in the D category. In the month of January at Paringaru, Totokoitu, Rutaki, North Airport Drain and Avatiu streams, bacterial numbers were lower and in categories A and B. In the months of March and September, there were high counts of Enterococci at all sampling sites. North Airport Drain was in category A or B on ten out of twelve sampling occasions. Rainfall is often considered to be a contributing factor to the elevated Enterococci numbers in streams. Correlation of Enterococci numbers in the stream and rainfall data in the 3 days prior to the sampling date showed a relationship ($r^2 = 0.92$) at the Paringaru and Akapuao sites.

Table 14. **Summary of 2007 Enterococci numbers per 100ml for stream sites. There are 4 color codes used in the table which represents WHO standards (Table 1). Green represents category A, Yellow category B, Orange category C and Red category D.**

Date	Avana	Paringaru	Akapuao	Totokoitu	Rutaki	Betela	North Airport Drain	Avatiu
17-Jan-07	870	143	790	65	63	460	93	31
06-Feb-07	1585	695	4800	1180	9200	9550	25	1295
08-Mar-07	22000	66500	143500	1600	1430	1365	890	1505
04-Apr-07	1475	630	3000	1588	1160	1025	107	195
01-May-07	1480	410	9400	4400	915	1130	60	425
05-Jun-07	4250	4600	10250	1345	705	1690	93	1105
03-Jul-07	1450	1230	7900	6550	1480	1260	50	465
09-Aug-07	1150	1800	13600	5000		5000	61	825
04-Sep-07	9200	4600	5000	10750	6300	6400	5000	78500
02-Oct-07	695	2000	8450	6300	533	690	88	765
06-Nov-07	990	1100	17650	1640	645	815	28	455
04-Dec-07	800	228	930	710	570	780	156	308

4. Discussion

4.1 Lagoon

Anderson et al. (2004) reported that water and air temperatures follow similar trends with air temperature generally cooler than the lagoon water temperature. In 2007 the cooler months were from June to September and the warmer months from October. The range for lagoon temperature for 2007 was 21.2ºC at Totokoitu Research Station in July to 29.0ºC at East Airport Drain in April and is similar to the last three years of data (George et al., 2007, Hall et al., 2006). The lagoon temperatures showed strong seasonal trends and varied slightly between years.

Elevated pH levels when DO levels were high as reported by Anderson et al. (2004) were not observed in the last two years. The highest pH recorded in 2007 was 8.9, which was over the Department of Health Clean Water Branch (1994) guideline.

In 2007 the Eco-Tours site was influenced by stream inflows at certain tides. The mean salinities at East Airport Drain, Arorangi School and Public Works in 2007 were higher than those recorded in 2006 as the sampling site were shifted away from the influence of freshwater and underground springs. In March 2007 rainfall affected the salinity levels in the lagoon. Salinity levels in both 2007 and 2006 are site specific with some sites influenced by freshwater inflows.

DO saturations were generally within the guidelines for the Department of Health Clean Water Branch (1994). The results for 2007 showed that the south/south-western side of Rarotonga continues to have low DO saturation (Appendix 3) as reported by Tuatai et al., (2006), Anderson et al., (2004) and Hall et al., (2006).

The Club Raro site had the highest water quality and with all samples within the Bell guideline of 2.6µg/L and 14µg/L for DRP and DIN respectively for the protection of coral reef health. This may be due to the absence of streams near this

site and its close proximity to the open ocean, approximately 60m from the reef. The Eco-Tours and Kent Hall sites continue to exceed the Bell guideline for DRP and DIN concentration, which is consistent with Hall et al. (2006) and George et al. (2007). These data suggests that adverse impacts on the coral reefs may be occurring. The Redfield ratio (the ratio of DIN to DRP) (Redfield 1958) for the overall marine lagoon sites is 3, which indicates that the concentration of nitrogen in the water is limiting the growth of phytoplankton and macro algae in the lagoon. This was a similar result found by Hall et al. (2006) and George et al. (2007).

The chlorophyll *a* concentrations in the lagoon ranged from <0.1 to 1.5µg/L which was lower than the reported range of 0.1 to 5.1µg/L in 2006 (George et al., 2007) and 0.1 to 2.9µg/L in 2005 (Hall et al., 2006). Chlorophyll *a* at Eco-Tours site was above 0.5µg/L in 2007 and 2006 on five and four out of nine sampling occasions respectively (George ., 2007).

The total suspended solids concentrations for 2007 range from 0.3 to 216.0mg/L and is larger than the range of 0.15 to 29.76mg/L in 2006 (George et al., 2007) and 0.5 to 36mg/L in 2005 (Hall et al., 2006).

Eco-Tours had high total suspended solids in 2007 and four out of nine sampling occasions were over the 5.0mg/L concentration recommended for the protection of coral reefs. These results were consistent with the past two years data where half of the sampling occasions were over the guidelines for the protection of coral reefs (George et al., 2007 and Hall et al., 2006). The Sheraton site did not exceed the guideline for the protection of coral reefs in 2007 and 2006 compared with three out of eighteen sampling occasions in 2005 (Hall et al., 2006). The total and volatile suspended solids, bacteria and nutrients were elevated in March. The rainfall data was compared to the total and volatile suspended solids data and showed that the average rainfall for 3 days before the sampling date were the highest for the year. The rainfall event was likely to have contributed to the high concentration of total and volatile suspended solids at this time.

In March, bacterial counts above those recommended for swimming were measured at six out of fourteen sites. All those six sites have streams running into the lagoon in close proximity. These elevated bacterial numbers are also likely to be linked to the high rainfall event. In comparing the data from Rarotonga lagoon between 2005 to 2007, the overall percentage of sampling occasions in categories A and B did not change significantly between these years (Appendix 1). This suggests that the water quality in the lagoon of Rarotonga from 2005 to 2007 was similar over the three years.

Overall the Eco-Tours site had the lowest lagoon water quality and was routinely over the concentration recommended for the protection of coral reefs for DRP, chlorophyll *a* and total suspended solids. The Eco-Tours site also had the highest ammonia and nitrate concentrations and the bacteria concentrations were in Category D on three of the sampling occasions. This is consistent with previous years (George et al., 2007 and Hall et al., 2006). Club Raro had the highest water quality with all samples for nutrient and chlorophyll *a* concentrations below the guidelines recommended for good coral growth and with bacterial concentrations suitable for contact recreation. The lowest water quality occurred in March with most of the sites having elevated bacteria, TSS and VSS concentrations. The low water quality coincided with the highest rainfalls of the year.

4.2 Streams

The temperatures for the stream sites showed a strong seasonal variation with higher temperatures in the summer months and lower in the cooler months. In 2007 the highest temperatures were recorded in April and lowest in September compared with 2006 when the highest temperatures were recorded in November and lowest in July. The sites had similar mean temperatures except for the North Airport Drain which showed consistently higher temperatures in both 2006 and 2007. The range and mean stream temperatures in 2007 were lower than those recorded in 2006 and 2005 (George et al., 2007 and Hall et al., 2006). In 2007 the DO saturation range was larger than recorded in 2005 and 2006 (George et al., 2007 and Hall et al., 2006). In 2007 Paringaru and Akapuao streams had consistently low DO saturations which is consistent with those recorded in 2005 and 2006 as reported by Hall et al. (2006) and Tuatai et al. (2006). The water quality in these two streams is potentially influenced by land based activities such as agriculture, piggeries and a rubbish dump, also the stream occasionally goes stagnant.

Akapuao stream recorded the highest nutrient concentration (exceeding the ANZECC guideline) for DRP, ammonia and nitrate concentration for all occasions, which is consistent with data collected in 2005 (Hall et al., 2006 and 2006 George et al., 2007). The ammonia concentration of 2200µg/L on the 9th of August 2007 at Akapuao was below the lower LC_{50} (Lethal Concentration to 50% of organisms) concentration of 3944 µg/L ammonia provided for freshwater fish in the ANZECC guidelines (ANZECC 2000), however, was above the lower concentration of 1450 µg/L for a chronic NOEC (No Effect Concentration) for a range of nine for freshwater fish species (ANZECC 2000).

The North Airport Drain site had five out of twelve sampling occasions below the ANZECC guideline for DRP concentration, while Avana and Avatiu had eleven out of twelve occasions below the ANZECC guideline for ammonia concentration. On five and six out of twelve sampling occasions, North Airport Drain and Avatiu

respectively had nitrate concentrations below the ANZECC guideline. Totokoitu had the lowest mean and range of nitrate concentrations even though on all occasions these were above the ANZECC guideline.

The total suspended solids concentrations in the streams in 2007 ranged from 0.1 to 99.2mg/L and is higher than the 0.39 to 28.1mg/L recorded in 2006 (George et al., 2007) and lower than <0.5 to 490mg/L recorded in 2005 (Hall et al., 2006). Akapuao stream had total suspended solids concentrations that were within the range for the slightly disturbed ecosystems in tropical Australia (ANZECC 2000) on nine out of twelve sampling occasions in 2007 and nine out of ten sampling occasions in 2006 (George et al., 2007). This stream also had concentrations that were over this range on two occasions in 2007, once in 2006 (George et al., 2007) and on six out of seventeen sampling occasions in 2005 (Hall et al., 2006).

Analysis of bacterial numbers showed, that in the month of March, all sites were in category "D" – not fit for swimming. High rainfall may have contributed to these high bacterial count observed at all stream sampling sites. In contrast, if streams run low and there is limited water flow, this may lead to bacterial growth in streams and may explain high bacterial counts on some occasions. In comparison to data that has been collected between 2005 to 2007, for each year, over 80% of the samples collected were in the C and D category (water was not safe for swimming) (Appendix 2).

Overall the Akapuao stream had the lowest stream water quality with low DO concentrations and high concentrations of TSS, VSS, bacteria, DRP, ammonia and nitrates. The North Airport Drain had the highest water quality, except on two sampling occasions, all bacteria samples were in the A and B category and DRP concentration were consistently below those recommended for the protection of coral reefs. The lowest water quality in 2007 was in March with all streams having bacterial numbers in category D and most of the sites were within or above the TSS concentrations for slightly disturbed ecosystems in tropical Australia.

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7. Appendices

7.1 Appendix 1: Comparison of Annual Bacterial Counts between Years in the Rarotonga Lagoon.

	Category	
Year	A & B (%)	C & D (%)
2005	89	11
2006	97	3
2007	93	7

7.2 Appendix 2: Comparison of Annual Bacterial Counts between Years in the Rarotonga Streams.

	Category	
Year	A & B (%)	C & D (%)
2005	11	89
2006	8	92
2007	16	84

7.3 Appendix 3: Water quality data lagoon sites.

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
1	TJ's	17-Jan-07	26.7	37.4	100.6	6.5	8.2	11	3	14		5.7		41
1	TJ's	17-Jan-07						11	5	14				
1	TJ's	6-Feb-07	27.6	36.1	104.3	6.7		7	4	11		7.2	2.1	67
1	TJ's	8-Mar-07	27.5	35.3	110.9	7.2	8.2	1	3	5		2.3	0.4	18
1	TJ's	4-Apr-07	27.5	35.4	111.6	7.2		3	4	2	0.2	0.8	0.1	1
1	TJ's	1-May-07	26.8	34.6	115.8	7.6		3	3	4	0.05			1
1	TJ's	5-Jun-07	25.4	35.5	110.1	7.4	8.2	3	3	3	0.05			0
1	TJ's	3-Jul-07	22.9	34.5	120.3	8.5	8.7	0.5	5	3	0.1	0.7	0.7	0
1	TJ's	9-Aug-07						0.5	5	2	0.05	1.0	0.3	1
1A	TJ's	4-Sep-07	22.5		86.8	4.6		4	49	16	0.1	0.4	0.1	34
1B	TJ's	4-Sep-07						4	2	2		0.7	0.3	27
1	TJ's	2-Oct-07	24.8	35.8	124.3	8.4	8.1	2	1	3	0.1	0.3	0.3	0
1	TJ's	7-Nov-07	24.9	36	118.6	8	8.0	2	2	0.5	0.1	1.3	0.2	0
1A	TJ's	4-Dec-07	25.3	35.8	108.4	7.3	8.1	7	4	4	0.05	1.6	0.6	0
1B	TJ's	4-Dec-07						7	3	3		1.0	0.3	1
2	Club Raro	17-Jan-07	26.8	37.5	101.1	6.6	8.3	4	4	3		37.8		34
2	Club Raro	6-Feb-07	27.9	37.5	107.9	6.9		5	2	1		8.4	1.4	1
2	Club Raro	8-Mar-07	27.6	35.4	106.2	6.9	8.7	0.5	4	2		11.2	2.8	8
2	Club Raro	4-Apr-07	27.6	35.3	113.3	7.3		3	4	2	0.1	1.6	0.5	4
2	Club Raro	1-May-07	26.7	34.6	118.5	7.8		5	2	2	0.05			5
2	Club Raro	5-Jun-07	25.2	35.5	109.5	7.4	8.2	3	2	2	0.2			0
2	Club Raro	3-Jul-07	22.7	34.9	108.2	7.6	8.7	2	4	2	0.1	0.7	0.2	12
2	Club Raro	9-Aug-07						2	6	3	0.05	5.9	2.3	1
2	Club Raro	4-Sep-07	23.1		89.1	4.7		3	3	1	0.1	1.4	0.2	0
2A	Club Raro	2-Oct-07	23.9	35.9	131.1	9	8.2	2	3	3	0.2	3.2	0.9	1
2B	Club Raro	2-Oct-07						3	5	3		0.4	0.3	2
2	Club Raro	7-Nov-07	25	36.1	123.8	8.3	8.1	0.5	2	1	0.1	4.9	0.4	0
2	Club Raro	4-Dec-07	25	35.8	113.6	7.7	8.1	4	3	3	0.1	2.1	0.6	11
3	Pou'ara Ra'ui	17-Jan-07	27.1	37.5	111.5	7.2	8.5	6	5	4		4.2		1

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
3	Pou'ara Ra'ui	6-Feb-07	27.8	37.5	117.8	7.5		9	4	1				97
3	Pou'ara Ra'ui	6-Feb-07						4	4	2				
3	Pou'ara Ra'ui	8-Mar-07	27.2	34.4	113.3	7.4	8.8	8	7	9		0.9	0.3	308
3	Pou'ara Ra'ui	4-Apr-07	27.8	35.4	110.1	7.1		2	4	4	0.1	1.9	0.2	1
3A	Pou'ara Ra'ui	1-May-07	27.1	34.5	107.3	7		2	0.5	0.5	0.1			0
3B	Pou'ara Ra'ui	1-May-07						5	1	15				15
3	Pou'ara Ra'ui	5-Jun-07	24.9	35.5	108	7.3	8.2	2	8	5	0.4			230
3	Pou'ara Ra'ui	3-Jul-07	23.9	35	115.4	8	8.7	0.5	7	11	0.2	0.4	0.4	0
3	Pou'ara Ra'ui	9-Aug-07						1	5	5	0.1	0.3	0.3	1
3	Pou'ara Ra'ui	4-Sep-07	22.7		82.2	4.4		3	3	2	0.1	0.8	0.5	2
3A	Pou'ara Ra'ui	2-Oct-07	24.9	36.1	139.2	9.4	8.3	2	4	3	0.2	0.8	0.4	1
3B	Pou'ara Ra'ui	2-Oct-07						4	4	6		0.8	0.6	2
3	Pou'ara Ra'ui	7-Nov-07	25.4	36.1	119	8	8.2	3	4	7	0.2	2.3	0.1	3
3	Pou'ara Ra'ui	4-Dec-07	25.2	35.7	122.6	8.2	8.3	4	4	1	0.3	1.0	0.6	1
4	Avana Mudflat	17-Jan-07	26.3	37.2	92.7	6.1	8.4	4	5	4		47.3		5
4	Avana Mudflat	6-Feb-07	28.1	36.2	101.1	6.5		4	5	5				111
4A	Avana Mudflat	8-Mar-07	26.7	31.4	100.6	6.8	8.5	45	16	127		120.6	34.8	665
4B	Avana Mudflat	8-Mar-07						5	7	6		1.3	0.6	585
4	Avana Mudflat	4-Apr-07	27.7	35.2	93.7	6.1		2	7	3	0.05	0.9	0.0	9
4	Avana Mudflat	1-May-07	25.8	34	93	6.3		2	1	5	0.1			7
4	Avana Mudflat	5-Jun-07	24.6	35.3	110	7.5	8.2	6	6	3	0.2			2
4A	Avana Mudflat	3-Jul-07	22.3	33.3	132.1	9.5	8.8	2	6	3	0.1	1.0	0.6	1
4B	Avana Mudflat	3-Jul-07						2	6	2		11.0	5.3	1
4	Avana Mudflat	9-Aug-07						3	6	8	0.3	0.8	0.2	6
4	Avana Mudflat	4-Sep-07	22.5		82.1	4.3		6	40	26	0.1	0.3	0.2	92

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
4	Avana Mudflat	2-Oct-07	25.7	31.8	125.4	8.6	8.2	11	12	17	0.2	0.7	0.1	6
4A	Avana Mudflat	7-Nov-07	24.2	35.9	108.8	7.4	8.1	3	4	5	0.2	2.2	0.9	34
4B	Avana Mudflat	7-Nov-07						4	4	4		2.4	0.4	14
4	Avana Mudflat	4-Dec-07	24.6	34.3	105	7.2	8.1	7	3	13	0.3	0.6	0.2	12
5	Eco-Tours	17-Jan-07	26.9	36.2	96.9	6.3	8.3	7	4	4		216		23
5	Eco-Tours	6-Feb-07	27.6	36.4	75.8	4.9		6	7	3				570
5A	Eco-Tours	8-Mar-07	26	27.5	85.2	5.9	8.4	52	17	69		21.8	7.3	5000
5B	Eco-Tours	8-Mar-07						46	16	62		26.0	9.0	5000
5	Eco-Tours	4-Apr-07	27.5	34.1				4	10	9	0.4	2.9	0.9	20
5A	Eco-Tours	1-May-07	25.7	33.8	92.8	6.3		4	7	4	0.4			2
5B	Eco-Tours	1-May-07						4	1	6				5
5	Eco-Tours	5-Jun-07	24	27.6	90.3	6.5	8.0	24	36	188	0.4			660
5	Eco-Tours	3-Jul-07	21.4	33.4	107.3	7.8	8.6	7	10	10	0.7	2.4	0.9	6
5	Eco-Tours	9-Aug-07						3	8	3	0.7	1.4	0.5	10
5	Eco-Tours	4-Sep-07	22.7		81.6	4.4		6	47	13	0.7	9.3	2.0	2
5A	Eco-Tours	2-Oct-07	25.4	35.3	129	8.7	8.2	6	2	11	1.1	4.4	0.8	5
5B	Eco-Tours	2-Oct-07						4	3	12		8.0	2.3	2
5	Eco-Tours	7-Nov-07	24.6	36	107	7.3	8.0	4	3	5	0.3	4.1	0.6	56
5	Eco-Tours	4-Dec-07	24.8	34.5	102.8	7	8.0	6	7	25	1.5	3.5	1.2	2
6	Tikioki Packing Shed	17-Jan-07	26.8	36.8	95.5	6.2	8.3	4	5	15		29.1		4
6	Tikioki Packing Shed	6-Feb-07	27.7	37.2	94.6	6.1		4	8	6				59
6	Tikioki Packing Shed	8-Mar-07	26.5	31.8	93.5	6.3	8.7	10	8	26		5.7	1.6	1760
6A	Tikioki Packing Shed	4-Apr-07	27.5	35.2	89	5.8		2	7	10	0.2	1.5	0.4	1
6B	Tikioki Packing	4-Apr-07						3	8	10		1.4	0.4	4

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
	Shed													
6	Tikioki Packing Shed	1-May-07	25.9	34	101.4	6.8		2	3	7	0.1			32
6	Tikioki Packing Shed	5-Jun-07	24.4	33.1	93.5	6.5	8.1	7	11	27	0.1			2
6	Tikioki Packing Shed	3-Jul-07	21.5	33.2	106.6	7.8	8.6	3	7	7	0.1	2.1	0.6	2
6	Tikioki Packing Shed	9-Aug-07						5	7	17	0.6	1.8	0.7	6
6	Tikioki Packing Shed	4-Sep-07	22.5		78.9	4.3		5	4	16	0.2	1.0	0.2	2
6	Tikioki Packing Shed	2-Oct-07	24	34.8	120	8.3	8.1	5	3	20	0.2	1.1	0.5	1
6	Tikioki Packing Shed	7-Nov-07	24.5	36.1	122.8	8.3	8.1	1	4	3	0.3	2.0	0.5	11
6A	Tikioki Packing Shed	4-Dec-07	25.2	33.9	111.5	7.6	8.1	2	3	32	0.8	1.2	0.5	6
6B	Tikioki Packing Shed	4-Dec-07						3	5	38		0.8	0.2	1
7	Kent Hall	17-Jan-07	26.6	36.7	88.8	5.8	8.2	5	5	14		3.2		0
7	Kent Hall	17-Jan-07						5	8	12				
7	Kent Hall	6-Feb-07	27.5	37.2	88.3	5.7		7	6	8				70
7	Kent Hall	8-Mar-07	26.5	30.5	88.2	6	8.6	26	10	30		34.0	10.7	5050
7	Kent Hall	4-Apr-07	27.5	35	88	5.7		5	8	14	0.1	1.3	0.4	3
7	Kent Hall	1-May-07	25.5	33.9	95.5	6.5		7	6	18	0.1			2
7	Kent Hall	5-Jun-07	24.4	34.1	88.4	6.1	8.2	9	9	21	0.1			10
7A	Kent Hall	3-Jul-07	21.8	34.4	101.3	7.3	8.6	4	9	13	0.1	0.6	0.6	5
7B	Kent Hall	3-Jul-07						4	7	12		0.7	0.3	3
7	Kent Hall	9-Aug-07						3	6	27	0.6	0.4	0.1	8

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
7	Kent Hall	4-Sep-07						3	1	10	0.2	0.9	0.4	0
7	Kent Hall	2-Oct-07	23.5	35.4	114.4	7.9	8.1	4	4	13	0.3	0.9	0.0	1
7A	Kent Hall	7-Nov-07	24.5	36	111.7	7.6	8.0	4	10	9	0.2	1.5	0.1	0
7B	Kent Hall	7-Nov-07						5	5	7		0.3	0.3	0
7	Kent Hall	4-Dec-07	25	34.6	106.8	7.3	8.1	3	4	29	0.4	0.4	0.2	0
8	Totokoitu Research Station	17-Jan-07	27.1	37	112.2	7.3	8.4	4	3	3		0.9		10
8	Totokoitu Research Station	6-Feb-07	27.5	37.3	96.8	6.2		4	4	1				63
8	Totokoitu Research Station	8-Mar-07	26.7	31.8	90.1	6	8.5	11	5	6		16.2	7.3	168
8	Totokoitu Research Station	4-Apr-07	27.6	32.5				5	9	5	0.2	15.4	2.8	19
8	Totokoitu Research Station	1-May-07	26	34.3	91.3	6.1		3	1	3	0.1			15
8A	Totokoitu Research Station	5-Jun-07	23.9	28.8	89.1	6.4	8.1	17	12	19	0.2			225
8B	Totokoitu Research Station	5-Jun-07						14	7	10				270
8	Totokoitu Research Station	3-Jul-07	21.2	33	110.5	8.1	8.6	8	8	6	0.4	1.1	0.1	55
8A	Totokoitu Research Station	9-Aug-07						4	6	4	0.9	2.2	0.8	305
8B	Totokoitu Research Station	9-Aug-07						3	8	4		5.6	1.9	300
8	Totokoitu Research Station	4-Sep-07	22.9		99.8	5.3		4	3	5	0.6	33.7	2.3	200
8	Totokoitu	2-Oct-07	23.8	35.6	117.3	8.1	8.2	3	3	1	0.1	0.4	0.0	1

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
	Research Station													
8	Totokoitu Research Station	7-Nov-07	25.6	36.1	116	7.7	8.1	3	1	17	0.2	1.2	0.1	0
8	Totokoitu Research Station	4-Dec-07	25.6	33	113.3	7.7	8.1	8	6	9	0.4	0.5	0.3	23
9	Sheraton	17-Jan-07	27	36.6	108.6	7.1	8.4	4	3	5				2
9	Sheraton	17-Jan-07						4	3	5				
9	Sheraton	6-Feb-07	27.8	37.4	114.4	7.3		8	9	5				62
9	Sheraton	6-Feb-07						6	6	4				
9	Sheraton	8-Mar-07	27.5	34.7	106.4	6.9	8.9	4	4	4		2.5	1.0	32
9A	Sheraton	4-Apr-07	27.6	34.2	106.3	6.9		2	5	3	0.05	0.5	0.5	104
9B	Sheraton	4-Apr-07						17	12	5		0.3	0.1	162
9A	Sheraton	1-May-07	26.7	34.3	105.6	7		4	3	3	0.1			3
9B	Sheraton	1-May-07						3	5	2				5
9	Sheraton	5-Jun-07	24.8	34.2	94	6.4	8.2	6	6	8	0.3			42
9	Sheraton	3-Jul-07	22.9	32	127.7	9.1	8.8	2	4	2	0.2	0.3	0.1	0
9A	Sheraton	9-Aug-07						5	5	15	0.2	0.3	0.1	0
9B	Sheraton	9-Aug-07						5	6	25		8.8	1.6	2
9	Sheraton	4-Sep-07	24.1		89.1	4.8		6	5	10	0.1	0.3	0.1	155
9	Sheraton	2-Oct-07	23.8	35.4	121.9	8.4	8.2	4	3	11	0.2	0.5	0.2	17
9	Sheraton	7-Nov-07	25.2	36	116.7	7.8	8.1	3	0.5	4	0.1	1.1	0.4	0
9	Sheraton	4-Dec-07	25.6	33	114.5	7.8	8.2	6	5	33	0.1	0.3	0.0	9
10	Kaena Restaurant	17-Jan-07	27.2	37.4	109.6	7.1	8.4	4	5	5		2.1		2
10	Kaena Restaurant	6-Feb-07	28	37.4	112.3	7.1		6	9	3				26
10A	Kaena Restaurant	8-Mar-07	27.6	35.3	109.5	7.1	8.6	2	5	4		1.4	0.7	0
10B	Kaena Restaurant	8-Mar-07						2	5	4		1.5	0.7	0
10	Kaena Restaurant	4-Apr-07	27.8	35.4	125.1	8.1		1	5	2	0.05	0.4	0.0	1
10	Kaena	1-May-07	26.8	34.6	104.1	6.9		3	10	6	0.05			2

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
	Restaurant													
10	Kaena Restaurant	5-Jun-07	25.3	35.6	93.3	6.3	8.2	10	14	9	0.05			0
10A	Kaena Restaurant	3-Jul-07	23.3	35	123.6	8.6	8.8	2	4	3	0.05	0.3	0.1	20
10B	Kaena Restaurant	3-Jul-07						2	5	3		0.3	0.2	15
10A	Kaena Restaurant	9-Aug-07						3	5	4	0.1	0.5	0.2	6
10B	Kaena Restaurant	9-Aug-07						2	5	3		0.7	0.6	3
10	Kaena Restaurant	4-Sep-07	24.1		89.7	4.6		3	4	3	0.1	0.7	0.3	0
10	Kaena Restaurant	2-Oct-07	24	35.8	112.2	7.7	8.1	5	6	3	0.1	0.3	0.0	0
10	Kaena Restaurant	7-Nov-07	25.5	35.6	114.1	7.6	8.1	5	1	6	0.1	0.5	0.5	0
10A	Kaena Restaurant	4-Dec-07	25.7	35.4	113.8	7.6	8.2	4	5	8	0.1	0.4	0.3	0
10B	Kaena Restaurant	4-Dec-07						3	4	5		0.4	0.0	1
11	Arorangi School	17-Jan-07	27.3	36.3	126.8	8.2	8.4	6	6	11		2.8		3
11	Arorangi School	6-Feb-07	28.4	36.5	128.3	8.1		9	3	6		3.6	1.5	54
11	Arorangi School	8-Mar-07	27.6	34.3	121.9	7.9	8.8	6	3	10		2.8	1.2	26
11	Arorangi School	4-Apr-07	28.4	33.9	150.8	9.7		4	8	13	0.1	2.9	0.6	27
11	Arorangi School	1-May-07	27.1	33.9	132.7	8.7		8	7	12	0.1			2
11	Arorangi School	5-Jun-07	25.7	34.8	110.1	7.4	8.2	4	5	7	0.1			0
11	Arorangi School	3-Jul-07	22.6	32.9	139	9.9	8.7	7	6	10	0.1	0.7	0.2	10
11	Arorangi School	9-Aug-07						2	5	4	0.2	0.4	0.3	1
11A	Arorangi School	4-Sep-07	24		96.8	5.2		8	4	18	0.1	1.0	0.6	6
11B	Arorangi	4-Sep-07						9	5	19		2.4	0.9	8

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
	School													
11	Arorangi School	2-Oct-07	26.1	34.3	139.7	9.3	8.2	9	5	13	0.1	0.4	0.4	1
11	Arorangi School	7-Nov-07	25.9	35	130.4	8.7	8.2	8	4	20	0.2	0.5	0.5	0
11	Arorangi School	4-Dec-07	26.3	35.5	123.8	8.2	8.2	2	3	5	0.1	0.3	0.1	1
12	Public Works	17-Jan-07	27.3	37.2	112.8	7.3	8.5	4	2	11		33.1		4
12	Public Works	6-Feb-07	28.4	37.5	112.1	7.1		4	5	2		4.0	1.6	78
12	Public Works	8-Mar-07	27.8	35.3	112	7.2	8.5	3	2	11		7.4	1.2	6
12	Public Works	4-Apr-07	28.2	34.6	141.7	9.1		1	6	6	0.1	0.8	0.0	3
12	Public Works	1-May-07	27.7	34.5	129	8.4		2	4	3	0.05			3
12A	Public Works	5-Jun-07	26.3	35.5	109.1	7.2	8.2	3	5	3	0.05			0
12B	Public Works	5-Jun-07						3	6	3				0
12	Public Works	3-Jul-07	23.4	34.3	120.2	8.4	8.7	6	5	32	0.05	0.6	0.4	0
12	Public Works	9-Aug-07						0.5	7	8	0.2	0.4	0.0	0
12A	Public Works	4-Sep-07	24		84.5	4.5		5	12	12	0.1	1.0	1.6	2
12B	Public Works	4-Sep-07						9	5	25		0.3	0.0	3
12	Public Works	2-Oct-07	26	34	129.5	8.7	8.2	7	5	28	0.1	0.8	0.0	10
12	Public Works	7-Nov-07	25.5	35.5	121.3	8.1	8.2	6	3	23	0.2	0.7	0.0	7
12	Public Works	4-Dec-07	26.4	34.8	112.8	7.5	8.2	7	3	39	0.1	0.4	0.4	0
13	Social Centre	17-Jan-07	27.6	37.5	103.2	6.6	8.4	4	5	2		44.1		18
13	Social Centre	6-Feb-07	28	37.6	108.2	6.9		3	3	1		2.4	1.1	52
13	Social Centre	6-Feb-07						6	3	1				
13	Social Centre	8-Mar-07	27.6	35.4	111.7	7.2	8.5	4	5	2		4.0	1.8	465
13A	Social Centre	4-Apr-07	27.8	35.5	113.8	7.3		0.5	4	2	0.05	0.3	0.3	0
13B	Social Centre	4-Apr-07						2	4	2		0.3	0.1	1
13	Social Centre	1-May-07	27.4	34.7	109.3	7.1		0.5	5	2	0.05			2
13	Social	5-Jun-07	25.8	35.6	85.5	5.7	8.2	2	8	3	0.05			2

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
	Centre													
13	Social Centre	3-Jul-07	23	34.1	108.2	7.6	8.6	4	6	2	0.05	0.9	0.2	0
13	Social Centre	9-Aug-07						2	6	3	0.3	1.8	0.7	2
13	Social Centre	4-Sep-07	23.9		86.4	4.5		3	5	8	0.2	1.5	0.7	7
13	Social Centre	2-Oct-07	25.7	36.1	120.4	8	8.2	3	5	2	0.05	2.2	1.2	5
13A	Social Centre	7-Nov-07	26.1	36.1	117	7.7	8.2	5	3	4	0.2	1.5	0.1	0
13B	Social Centre	7-Nov-07						6	2	3		1.2	0.2	17
13	Social Centre	4-Dec-07	27.2	35.9	112.8	7.3	8.2	4	6	8	0.1	1.5	0.4	4
14	East Airport Drain	17-Jan-07	27.8	36.6	116.6	7.5	8.4	6	3	10		123		24
14	East Airport Drain	6-Feb-07	28.7	37.4	116	7.3		5	3	0.5		2.9	1.3	92
14	East Airport Drain	8-Mar-07	27.6	33.3	112.3	7.4	8.5	9	4	10		3.5	0.5	162
14	East Airport Drain	4-Apr-07	29	34.1	132.9	8.5		4	7	9	0.4	4.2	0.9	72
14	East Airport Drain	1-May-07	28.4	33.1	145.9	9.4		3	6	0.5	0.2			4
14A	East Airport Drain	5-Jun-07	25.9	34	109.5	7.3	8.3	8	10	10	0.3			20
14B	East Airport Drain	5-Jun-07						11	11	10				95
14	East Airport Drain	3-Jul-07	23.5	34.5	132	9.2	8.8	3	7	3	0.3	8.3	2.1	3
14	East Airport Drain	9-Aug-07						1	3	2	0.3	1.1	0.5	8
14	East Airport Drain	4-Sep-07	24.9		102.6	6		4	8	4	0.3	4.9	1.3	14
14	East Airport Drain	2-Oct-07	26.2	35.9	127.4	8.4	8.3	4	5	3	0.2	2.1	0.0	11
14	East Airport Drain	7-Nov-07	26.3	36	123.8	8.2	8.3	4	3	2	0.2	1.7	0.2	16
14	East Airport	4-Dec-07	27.6	33.9	118.7	7.7	8.3	4	3	2	0.1	2.7	0.6	7

Sample Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
	Drain													

7.4 Appendix 4: Water quality data stream sites.

Location	Site Number	Sampling Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
Avana	1	17-Jan-07	24.8	0.24	111.7	9.3		29	3	3	2.6		870
Avana	1A	06-Feb-07	25.3	0.72	91.7	7.5		41	6	7	1.7	0.7	1585
Avana	1B	06-Feb-07						43	10	14	1.3	0.6	
Avana	1	08-Mar-07	23.9	0.05	98.3	8.3	7.4	104	7	72	99.2	29.2	22000
Avana	1	04-Apr-07	23.6	0.07	91	7.7		32	6	58	1.6	1.6	1475
Avana	1	01-May-07	23.2	1.74	92.8	7.9		38	3	13	0.3	0.3	1480
Avana	1	06-Jun-07						40	4	54	0.3	0.1	4250
Avana	1	03-Jul-07	21.4	0.09	77.6	6.9	7.4	40	7	31	0.6	0.0	1450
Avana	1	09-Aug-07	22.4	3.23	80.3	6.8	6.9	39	7	29	0.4	0.3	1150
Avana	1A	04-Sep-07	20.2	0.64	95.2	8.6	6.5	80	3	12	3.4	1.4	10400
Avana	1B	04-Sep-07						79	3	9	3.8	1.3	8000
Avana	1	02-Oct-07						41	8	15	0.8	1.1	695
Avana	1	07-Nov-07	24.9	13.16	84.2	6.5	6.7	29	12	11	3.3	1.3	990
Avana	1	04-Dec-07	22.6	0.06	125.1	10.8	6.9	45	5	103	0.4	0.3	800
Paringaru	2A	17-Jan-07	25.6	0.2	59	4.8		8	10	61	0.5		143
Paringaru	2B	17-Jan-07						9	9	61	0.3		
Paringaru	2	06-Feb-07	25.5	0.2	48.8	4		13	35	8	0.7	0.7	695
Paringaru	2A	08-Mar-07	24.4	0.08	90.7	7.6	7.5	192	11	328	57.3	39.3	64000
Paringaru	2B	08-Mar-07						210	15	365	62.8	22.8	69000
Paringaru	2	04-Apr-07	25.3	0.17	54.2	4.5		12	25	184	0.3	0.6	630
Paringaru	2	01-May-07	25.3	0.2	54.3	4.5		3	38	218	0.3	0.8	410
Paringaru	2	06-Jun-07						14	32	396	1.0	0.0	4600
Paringaru	2A	03-Jul-07	23.7	0.17	56.4	4.8	9	11	41	369	2.1	0.6	1350
Paringaru	2B	03-Jul-07						10	39	386	1.4	1.4	1110

Location	Site Number	Sampling Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
Paringaru	2	09-Aug-07	23.1	0.21	88.2	7.6	7.6	12	14	127	2.1	1.5	1800
Paringaru	2	04-Sep-07	21.3	1	44.6	3.9	7.2	5	44	41	0.7	0.7	4600
Paringaru	2	02-Oct-07						10	60	22	1.3	1.1	2000
Paringaru	2	07-Nov-07	22.5	0.4	113.2	9.8	7.7	9	62	45	1.5	1.7	1100
Paringaru	2	04-Dec-07	24.6	0.21	66.1	5.5	7	17	25	395	0.3	0.2	228
Akapuao	3	17-Jan-07	27.2	0.17	31.3	2.5		10	45	66	8.7		790
Akapuao	3	06-Feb-07	25.9	0.19	11.1	0.9		6	438	25	2.0	1.0	4800
Akapuao	3	08-Mar-07	25	0.06	76.8	6.4	7.5	410	65	374	63.8	16.7	143500
Akapuao	3	04-Apr-07	26.1	0.16	46.2	3.7		12	86	77	2.1	0.1	3000
Akapuao	3	01-May-07	24.2	0.27	22.6	1.9		10	83	27	1.1	1.1	9400
Akapuao	3A	06-Jun-07						8	70	146	4.0	1.5	10550
Akapuao	3B	06-Jun-07						6	72	145	4.5	1.7	9950
Akapuao	3	03-Jul-07	21.6	0.83			9.2	10	107	65	3.2	0.6	7900
Akapuao	3A	09-Aug-07	21.5	0.52	19.1	1.7	7.7	177	2220	24	48.2	20.0	13100
Akapuao	3B	09-Aug-07						174	2180	22	44.4	18.8	14100
Akapuao	3	04-Sep-07	20.3	0.22	27.6	2.5	7.5	79	155	229	14.0	2.0	5000
Akapuao	3A	02-Oct-07						102	490	3	10.0	8.0	9000
Akapuao	3B	02-Oct-07						127	489	3	15.0	10.0	7900
Akapuao	3A	07-Nov-07	25.4	2.67	17	1.4	7.2	277	170	17	6.0	5.0	18250
Akapuao	3B	07-Nov-07						266	158	22	7.3	1.8	17050
Akapuao	3	04-Dec-07	25	0.21	51.8	4.3	7.2	12	66	119	6.1	0.4	930
Totokoitu	4	17-Jan-07	23.6	0.08	91.8	7.8		49	11	14	1.4		65
Totokoitu	4A	06-Feb-07	24.8	0.09	82.9	6.9		48	14	24	1.0	0.2	1180
Totokoitu	4B	06-Feb-07						44	14	23	1.4	0.4	
Totokoitu	4	08-Mar-07	23.6	0.06	99.1	8.4	8	80	6	11	9.1	6.0	1600
Totokoitu	4A	04-Apr-07	23.6	0.08	91.6	7.8		47	10	15	0.3	0.2	1680
Totokoitu	4B	04-Apr-07						46	8	12	6.1	1.6	1495
Totokoitu	4	01-May-07	22.6	0.13	84.1	7.3		24	10	30	1.0	0.8	4400
Totokoitu	4	06-Jun-07						32	6	17	1.2	0.2	1345
Totokoitu	4	03-Jul-07	20.7	0.12	83.6	7.5	8.7	26	25	28	1.1	0.5	6550
Totokoitu	4	09-Aug-07	21.1	0.07	79.4	7.1	7.5	197	18	82	33.9	16.7	5000
Totokoitu	4	04-Sep-07	19.8	0.04	89.2	8.2	7.9	70	10	19	6.2	2.3	10750

Location	Site Number	Sampling Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
Totokoitu	4	02-Oct-07						20	16	25	2.6	1.3	6300
Totokoitu	4	07-Nov-07	23.2	0.12	83.4	7.1	7.8	46	22	15	0.4	0.8	1640
Totokoitu	4	04-Dec-07	21.6	0.08	117.2	10.3	7.8				0.3	0.3	710
Rutaki	5A	17-Jan-07	24.5	0.1	112.9	9.4		62	3	2	0.6		63
Rutaki	5B	17-Jan-07						73	3	2	0.7		
Rutaki	5	06-Feb-07	25.3	0.14	71.8	5.9		66	9	17	0.5	0.0	9200
Rutaki	5	08-Mar-07	24.1	0.08	96.6	8.1	8.1	87	3	6	1.7	0.8	1430
Rutaki	5	04-Apr-07	24.3	0.09	90.3	7.6		79	7	70	1.2	0.2	1160
Rutaki	5	01-May-07	23.7	0.11	88.4	7.5		36	0.5	31	1.0	0.1	915
Rutaki	5	06-Jun-07						53	6	84	1.3	0.3	705
Rutaki	5	03-Jul-07	21.9	0.15	72.6	6.4	6.2	37	16	64	1.4	0.0	1480
Rutaki	5	09-Aug-07											
Rutaki	5A	04-Sep-07	20.2	0.08	101.8	9.2	7.7	107	4	13	2.3	0.6	5200
Rutaki	5B	04-Sep-07						107	4	15	2.4	0.9	7400
Rutaki	5A	02-Oct-07						25	14	11	1.2	0.9	550
Rutaki	5B	02-Oct-07						39	14	11	1.1	1.7	515
Rutaki	5	07-Nov-07	26.7	0.18	135.5	10.9	8.3	33	2	29	1.4	0.7	645
Rutaki	5	04-Dec-07	24.1	0.1	114.5	9.6	7.6	75	3	100	0.3	0.1	570
Betela	6	17-Jan-07	24	0.07	95	8		40	9	14	1.5		460
Betela	6	06-Feb-07	25.1	0.07				42	19	11	2.5	1.1	9550
Betela	6	08-Mar-07	24.4	0.07	90	7.5	7.8	64	11	126	5.7	3.0	1365
Betela	6	04-Apr-07	24.9	0.08				45	9	124	3.2	0.2	1025
Betela	6	01-May-07	23.5	0.08	118.2	10		25	0.5	2	0.9	0.9	1130
Betela	6	06-Jun-07						53	7	121	2.0	0.7	1690
Betela	6	03-Jul-07	20.5	0.09	67.1	6	8.8	45	11	51	11.4	3.3	1260
Betela	6	09-Aug-07	21.9	0.09	68.4	6	7.3	69	21	127	8.5	5.4	5000
Betela	6	04-Sep-07	20.4	0.08	90.7	8.2	7.7	53	6	96	2.1	0.7	6400
Betela	6	02-Oct-07						29	11	17	4.0	2.0	690
Betela	6	07-Nov-07	23.4	0.09	79.9	6.8	7.9	39	7	3	2.0	1.3	815
Betela	6	04-Dec-07	23.3	0.09	98.7	8.4	7.7	14	11	99	2.8	0.6	780
North Airport Drain	7	17-Jan-07	26.4	1.35	78.4	6.3		7	64	114	6.8		93

Location	Site Number	Sampling Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
North Airport Drain	7	06-Feb-07		0.31	113.5	8.5		4	26	54	10.8	5.4	25
North Airport Drain	7A	08-Mar-07	27.9	0.21	126.1	9.9	8.1	47	53	312	12.0	4.9	880
North Airport Drain	7B	08-Mar-07						54	53	312	14.8	4.0	900
North Airport Drain	7	04-Apr-07	32.7	0.23	177.2	12.8		17	18	266	2.3	0.6	107
North Airport Drain	7A	01-May-07	25.6	0.15	159.2	13		3	1	0.5	0.7	0.4	64
North Airport Drain	7B	01-May-07						2	0.5	0.5	1.2	0.7	55
North Airport Drain	7A	06-Jun-07						8	21	226	5.3	2.1	98
North Airport Drain	7B	06-Jun-07						5	21	220	5.0	1.5	88
North Airport Drain	7	03-Jul-07	22.2	0.14	103.1	9	5.3	5	4	2	0.8	0.2	50
North Airport Drain	7A	09-Aug-07	24.5	0.32	132.5	11	8	3	5	0.5	3.0	1.4	58
North Airport Drain	7B	09-Aug-07						3	5	3	6.5	2.8	63
North Airport Drain	7	04-Sep-07	21.9	0.15	116.4	10.2	8.4	20	111	186	6.7	2.4	5000
North Airport Drain	7	02-Oct-07						2	2	1	35.6	9.4	88
North Airport Drain	7A	07-Nov-07	30.1	0.32	118	8.9	8.6	4	6	6	17.2	5.6	30
North Airport Drain	7B	07-Nov-07						4	6	4	17.5	7.0	26
North Airport Drain	7A	04-Dec-07	24.7	0.15	110.1	9.1	7.9	9	49	199	2.2	0.6	148
North Airport Drain	7B	04-Dec-07						12	49	179	1.5	1.0	163
Avatiu	8	17-Jan-07	23.7	0.13	117.4	9.9	7.8	70	3	4	1.2		31
Avatiu	8	06-Feb-07	26.5	0.24	107.9	8.7		51	3	2	4.6	2.0	1295
Avatiu	8	08-Mar-07	24.3	0.11	96.5	8.1	7.9	89	5	70	2.1	1.0	1505
Avatiu	8A	04-Apr-07	25.6	0.13	90.9	7.4		78	8	232	2.3	2.3	193
Avatiu	8B	04-Apr-07						76	6	162	0.9	0.4	197

Location	Site Number	Sampling Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (cells/100mL)
Avatiu	8A	01-May-07	28.8	0.23	167.8	12.9		58	1	5	0.3	1.1	504
Avatiu	8B	01-May-07						49	1	6	0.3	0.0	345
Avatiu	8	06-Jun-07						79	7	124	0.7	0.1	1105
Avatiu	8A	03-Jul-07	26.5	0.25	143.9	11.6	10.2	63	6	16	0.5	0.1	460
Avatiu	8B	03-Jul-07						77	5	18	1.1	0.2	470
Avatiu	8	09-Aug-07	23.8	1.47	97.1	8.1	7.5	92	7	6	1.0	0.7	825
Avatiu	8	04-Sep-07	21.4	0.11	101.4	9	7.6	167	3	94	16.5	3.0	78500
Avatiu	8	02-Oct-07						40	6	5	0.4	1.1	765
Avatiu	8	07-Nov-07	25.6	0.16	108.5	8.9	7.9	77	12	6	2.6	0.7	455
Avatiu	8A	04-Dec-07		0.11	199.6	14	8.4	107	6	163	1.7	0.6	295
Avatiu	8B	04-Dec-07						85	7	163	1.7	0.6	320