COASTAL WATER QUALITY AND ECOLOGICAL STUDIES OF PROPOSED SITE FOR BUA BAY PORT DEVELOPMENT, WAIRIKI, BUA

Batiri Thaman, Akuila Cakacaka, Alifereti Naikatini, & Make Movono
Institute of Applied Sciences
University of the South Pacific

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EXECUTIVE SUMMARY

This report describes an environmental assessment of the coastal water quality, terrestrial ecology, and marine environment of the site proposed for the development of the Bua Bay Integrate Port at Wairiki, Vanua Levu. The study was commissioned by Erasito Consultants (Fiji) and carried out by the Institute of Applied Sciences. Fieldwork was carried out from the 21st to 23rd of December, 2004.

Water quality was sampled at five sites, four in the proximity of the development and one control site. On site measurements were taken for temperature, dissolved oxygen, salinity and conductivity and samples were taken for analysis for pH, total suspended solids, faecal coliforms, oil and grease, nitrate and phosphate. Two samplings were undertaken, one on the outgoing tide and one on the incoming tide. The current status of water quality at the site was found to be very good. All parameters, except dissolved oxygen levels were within the recommended guidelines for coastal waters and clarity was extremely good. The low dissolved oxygen levels during the early morning are probably not of a concern as levels increased later in the morning and are likely to be due to the calm shallow waters during the low tide in the early morning/ These levels could also be normal background levels for the area.

The terrestrial flora and fauna were assessed by trekking through the area to identify species and relative abundance. Birds were assessed by listening to birdcalls and sighting with binoculars. No rare or threatened plant species were found and the overall conclusion was that the site was of no special botanical significance. The vegetation was fairly disturbed and was largely dominated by grassland. Other vegetation types observed included coastal forest, vesi forest, mangrove forest, and dry lowland tropical forest. Of interest was the remnant pockets of dry forest and vesi forest which were probably the original vegetation of the area. Similar forest types, however, are found elsewhere in Vanua Levu. However, they are of local interest and should be protected as much as possible. The mangrove forest at the site formed a narrow margin along the coast and were in good condition. Larger stands are located to the south of the port site. All the bird and terrestrial animal species recorded are common throughout Fiji.

The marine environment comprised a fringing reef which extended approximately 200 meters offshore. The marine assessment consisted of a reconnaissance snorkel followed by ten 20 meter transects on the reef area. Along each transect substrate, fish and invertebrate abundance was recorded. In addition, lists of species present were also developed. The outer reef slope was found to be healthy as indicated by the high degree of live coral encountered on the transects in this zone of the reef. The outer reef flat was largely dominated by rubble with some presence of live coral. The inner reef area was dominated by algae, particularly the brown algae *Sargassum.* The abundance and diversity of marine invertebrates on the fringing reef was low with only five species being found and very few numbers of individual species in each transect. The abundance and diversity of reef fish of the area is fairly good for a small fringing reef. However most were juveniles and concentrated on the outer reef slope and outer reef flat of the reef where live coral cover was highest. Fifteen genera of fish were recorded with the most common being the butterflyfish, wrasses and damselfish. Commercial fish of importance that were common were the parrotfish, rabbitfish and surgeonfish

Significant impacts of the development of an access road and the port on the above environmental components that may result from construction activities include:

- Increased turbidity and silt in coastal waters from earthworks in road construction and drilling of piles for port which would have possible impact on the outer reef areas.
- Direct loss of large trees including mangroves on the coastal margin to clear area for road and access bridge.
- Destruction of marine habitat directly beneath pilings and impairment directly below access bridge as a result of shading.

Significant impacts that may result from the operation of the road and port include:

- Increase in nutrients and faecal coliforms in coastal waters if there is inappropriate discharge of sewage and other liquid waste from ships or port facilities. This would in turn affect marine habitats adapted to nutrient poor waters and lead to an increase in macroalgae.
- Oil and diesel spillage from port and ship operations.

Since the design and location of the access road and port structure has been chosen to minimise impacts on the environment the main recommendations to minimise impacts on the terrestrial and marine environment and water quality would be:

1. The use of silt retention structures and careful construction operations during construction
2. Minimise the removal of mangroves and large trees in road and port construction.
3. Undertake monitoring of coastal water quality during and after construction activities.
4. Ensure proper solid and liquid waste management facilities are provided at the port once it is in operation, and
5. Ensure oil spill kits are available for emergency use.

1.0 INTRODUCTION

The Institute of Applied Sciences of the University of the South Pacific was commissioned by Erasito Consultants (Fiji) to undertake an environmental assessment of the proposed site for the development of Bua Bay Port at Wairiki, in the province of Bua, Vanua Levu. The assessment provides baseline information on the marine and terrestrial environment at the site which can be used to guide planning of the development and against which future changes may be monitored.

Three main activities were undertaken as part of the assessment. These included:

- An assessment of the existing coastal water quality
- A survey of the terrestrial flora and fauna which includes a description of the mangroves
- A marine ecological study

These three components are described separately in this report together with a summary of the possible impacts of the development and mitigation measures .

The study team comprised of Batiri Thaman who carried out the water quality study, Alifereti Naikatini, who carried out the terrestrial flora and fauna survey and the mangrove assessment, and Akuila Cakacaka and Make Movono who carried out the marine study.

Fieldwork at Wairiki was undertaken from the 21st to 23rd of December 2004. The water quality work was carried out on the 22nd, the terrestrial flora and fauna work on the 22nd and 23rd and the marine assessment on the 22nd and 23rd. This was during the hot period of the year.

2.0 ENVIRONMENT & PROPOSED DEVELOPMENT

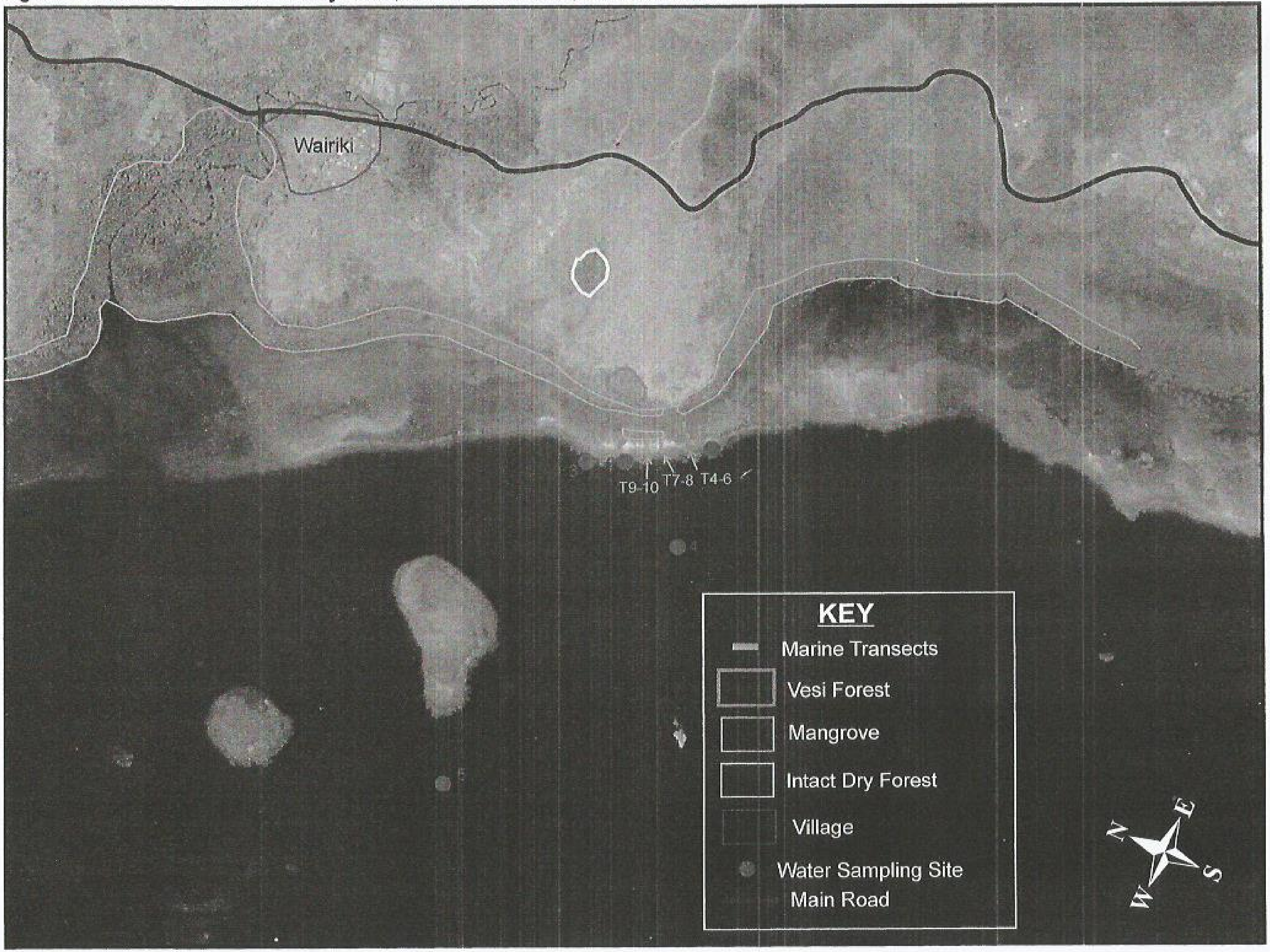
The topography of the site consists of hilly areas covered in grass. The area the port is to extend out from comprises of a hill that slopes steeply down to the coastline and is lined with a narrow belt of mangroves and has an opening at a rocky area where the access bridge will commence from (Appendix 3a Fig 1.). Along the base of the hill there is limited flat land between mangroves and grassy hill for the construction of the road. The marine environment comprises a narrow belt of mangroves, an intertidal area of macroalgae and rocks which is shallow at low tide, an exposed rocky/rubble area then the back reef area which includes live coral. The fringing reef extends about 200 meters offshore. There is also a small offshore mangrove island on the north part of the site (Figure 1).

The proposed development of the Bua Bay port at Wairiki will provide initially for woodchip export . The port development involves a number of different components of infrastructure. These include:

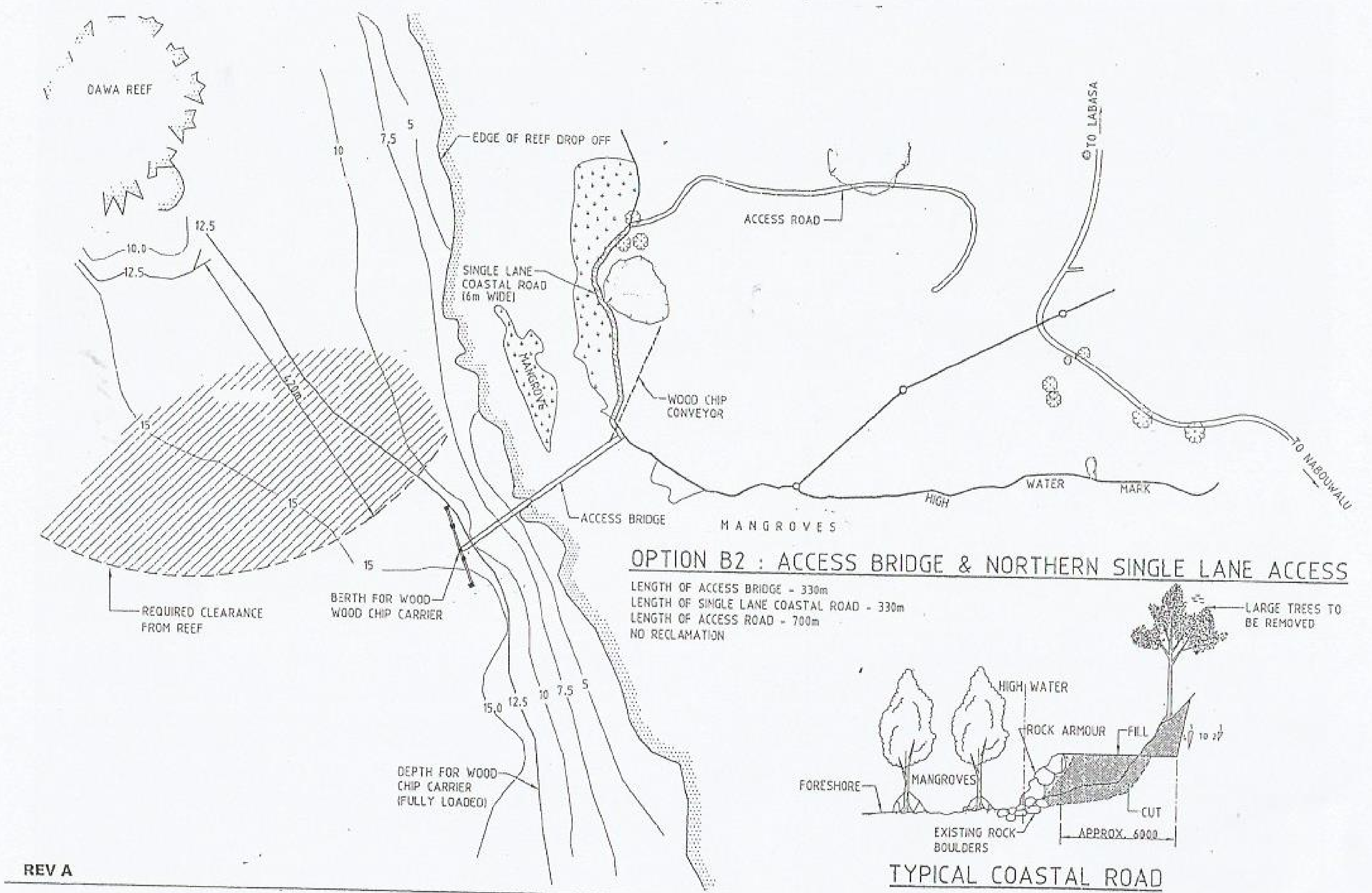
- Construction of port facility, pilings and access bridge
- The construction of an access road to the port
- Earthworks to clear the area for road and port

A single lane coastal road approximately 6 meters wide will be constructed on the periphery of the foreshore area on the landward side of the mangroves to connect the wharf structure to the working platforms to be developed on the headland. The port will comprise a dolphin jetty with 4 berthing dolphins supported on piles and connected by a suspended walkway, a central platform to support the ship loader and 2 mooring buoys. It will be a single use export facility. To avoid reclamation an access bridge which is elevated and supported by piles will connect the berthing structure to land. This is to link the port to the coastal road. (See Figure 2)

Figure 1. Location of Water Quality Sites, Marine Transects, and Forest Areas



[redacted] Proposed Site



REV A

MINISTRY OF FISHERIES AND FORESTS
GOVERNMENT OF FIJI

BUA INTEGRATED PORT PROJECT

ACCESS BRIDGE: OPTION B2

~~FIGURE 12~~

3.0 BACKGROUND

The proposed port project including the coastal access road will most likely have impacts on coastal water quality and the terrestrial and marine ecology of the area and the adjacent environment during their construction and operation. It is possible, however, to minimise or mitigate many of the effects through appropriate construction and operation practices and with regular monitoring.

Adverse effects on coastal water quality during the construction phase are likely to be from increased turbidity due to erosion of silt from earthworks and clearing involved in the construction of the coastal road and from the suspension of silt resulting from the drilling of piles for the port and access bridge. Oil and grease runoff from heavy construction vehicles may also affect water quality. Depending on the number of construction workers, impacts on water quality resulting from their disposal of their solid and sewage waste could also be a factor. Adverse effects on coastal water quality during the operation phase of the port are likely to be from increased turbidity as a result of vessels disturbing the seabed, the possibility of discharge of liquid waste such as sewerage and stormwater into the coastal waters from port facilities, disposal of solid waste into the coastal environment and possible spillages or discharge of fuel/oil and grease from boat operations and fuel storage facilities. If the coastal road is not properly resurfaced this could result in continuing silt runoff into the coastal waters during its use.

Adverse impacts on the terrestrial flora and fauna including the mangroves are largely restricted to the construction phase of the road and access bridge. These include the destruction of mature trees and other vegetation including mangroves. There may also be loss of related wildlife. Possible adverse impacts on mangroves may also result from the construction of the access bridge if coastal water circulation patterns are disrupted. A minor impact that the operation of the port may have on terrestrial flora is the inappropriate disposal of solid waste into adjacent areas.

Adverse impacts to the marine habitats in the vicinity of the port site and coastal road will be twofold, direct and indirect. Direct impacts would result from the construction of the dolphin structures and access bridge of the port where pilings will be drilled into the seabed, destroying the habitat directly beneath it whether it be seagrass or coral reef. Indirect impacts from the construction of the port would result from the shading effect of the central platform which would be around 15 meters wide. If there are adverse changes in the water quality such as increased turbidity and siltation or oil and grease this could result in impacts on the seagrass and reef communities adjacent to the port site. Adverse changes in water quality from construction of the access road could also adversely impact marine communities. Adverse impacts on the marine environment during the operation phase of the port and road would be most likely indirect as a result of changes in water quality such as increased turbidity from silt runoff from the road, spillage of oil from ships and port facilities, and increased nutrients resulting from inadequate liquid waste management facilities for sewage and stormwater. The improper disposal of solid waste may also impact the marine ecology.

4.0 COASTAL WATER QUALITY

4.1 Introduction

The water quality sampling to determine baseline coastal water quality at the site was carried out on Wednesday the 22nd of December, 2004. Two samplings were carried out, on the outgoing tide and on the incoming tide. Low tide was at 9:17 am thus the first sampling was conducted between 7:30 and 8:30 am. High tide was at 3:30 pm and second sampling conducted between 10:00 and 10:40 am. The weather was fine and cloudy with cloud cover at 5%. The water conditions were very clear and calm in the early morning becoming choppy later in the morning.

4.2 Water Quality Sites

Five sites were sampled, four in the proximity of the development and one control site a distance away from the proposed port which the results may be compared against as this site should not be impacted by the port. Sites 1 to 3 were chosen to indicate baseline water quality that may be affected by road and port construction and Site 4 would provided added information on effects of port operation (shipping) and Site 5 to provide a reference site which is assumed will not be affected by port construction and operation. The sites are described in relation to an iron rod which was placed offshore to indicate the positioning of the access bridge and port structure. These are listed below with details provided in Table 1 and Figure 1.

Site 1: Located about 200 meters to the southeast of the iron rod (on the left if looking from land) and approximately at the same distance from the shore off the iron rod, just off the edge of the fringing reef. Depth between 2 to 4 meters.

Site 2: Located about 200 meters to the northwest of the iron rod (on right if on the land) and same distance off shore as rod on edge of fringing reef. At the western edge of small offshore mangrove island. Depth between 4 and 6 meters.

Site 3: Located about 100 meters to the northwest of Site 2 off a small rocky outcrop with one mangrove tree. Also on the edge of the fringing reef. Depth between 2 to 4 meters.

Site 4: Located 400 to 500 meters directly offshore from iron rod in deep ocean. Depth around 16 to 20 meters.

Site 5: Control site located outside the patch reef also in deep water. Depth of more than 20 meters.

4.3 Water Quality Methods

A boat was used to undertake the water sampling. At each site, the GPS location and a description of the site were noted. On-site measurements for water temperature, dissolved oxygen, conductivity, and salinity were undertaken using a Horiba multimeter just below the surface (about 30 cm depth). Other characteristics of the site such as whether coral could be seen and any material floating on the surface was also recorded. A water sample was collected in bottles from the surface at each site for analysis in the IAS laboratory. Parameters analysed in the lab were ph, total suspended solids (TSS), faecal coliforms, oil and grease, nitrate and phosphate. Clarity and depth were also measured at each site using a Secchi disc. Sample bottles were stored in an eski with ice and transported back to the laboratory within 12 hours of sampling.

4.4 Water Quality Results

Results for the water quality sampling for the two sampling times are tabulated in Table 1 (outgoing tide) and Table 2 (incoming tide) and described below.

Outgoing Tide

Temperature at the five sites varied between 28.5 and 28.9 degrees Celsius which was relatively uniform. These were all within the recommended temperature for marine water which is 20 to 30 degrees Celsius. Results were fairly warm, however, measurements were taken during the hot time of the year.

Conductivity was also fairly constant between sites, ranging from 56.8 to 57.4 μS/cm and salinity varied between from 34.6 ppt at the control site to 35.2 ppt at Site 3. Conductivity is similar to salinity in that it measures the concentration of ionized substances dissolved in the water. The relation can be seen in the results with Site 3 which had the highest conductivity also having the highest salinity. The results were around the maximum expected range for salinity in marine water which is 35 ppt. The slightly high salinity at the inshore sites is probably due to it be shallower thus having a higher concentration of ions as a result of evaporation.

Dissolved oxygen varied between 3.07 and 4.63 mg/L at the five sites. Except for Site 5, the control site, these values are fairly low compared to the recommended level of >6 mg/L to support aquatic life and >4.5mg/L for port use. The low levels at the inshore sites could be a result of sampling being undertaken in the early morning which is following the main period of respiration for aquatic plants during the night when oxygen is used from the water and because it was nearly low tide thus the intertidal area being shallow with little water movement. High dissolved oxygen levels are required to support aquatic life which require oxygen for respiration.

The pH ranged from 7.9 to 8.2 and were within the acceptable range (7.7-8.5) at all sites.

Clarity was very good at all sites, all above the minimum requirement of more than 1.2 meters. The bottom was visible clearly at all three inshore sites and at Site 4 and 5 clarity was around 6 meters. Total suspended solids (TSS) which is also related to clarity as it measures the amount of suspended matter in the water was also at low levels (between 24 mg/L and 38 mg/L), although no specific guideline is given for this parameter. Total suspended solids and clarity are a measure of how clear the water is. This is important for survival of marine organisms. Increased silt may clog feeding and respiratory structures of coral and animals, reduce photosynthesis by reducing light penetration into the water column and smother organisms.

Oil and grease was detected in the lab analysis at Sites 2 and 3, (much higher than the limit of 0.01 mg/L), however no oil slick was seen and it is not evident what the source of this oil is. However, a surface slick of organic matter, probably originating from the mangroves was observed when the tide was receding which could be a source of natural hydrocarbons.

Faecal coliform levels ranged from <1 to 83 counts/100ml with the highest level recorded at Site 5, the control site in deep water. The source of faecal coliforms at Site 5 is not known. All values were below the maximum recommended level of 150 c/100ml required for swimming and 250 c/100ml required to sustain aquatic life. The measurement of faecal coliforms indicates the degree of pollution of water from animal or human faecal or sewage which if present at high levels could be health hazard for use of waters for swimming or for harvest of shellfish for consumption.

Nutrients (nitrates and phosphates) were not detected at all by laboratory analysis, however, small increases in nitrogen or phosphorus in coastal water could have negative impacts on corals which survive in low nutrient ocean waters.

Table 1. Water Quality Results for Sampling on Outgoing Tide

Site	1	2	3	4	5	**Guidelines***
Location	Offshore in line with rod, 200 m to east on reef edge	Offshore in line with rod 200m to west, just off edge.	100 m to west of Site 2. 80 m from rocky island with 1 mangrove on reef edge	400 m directly out from iron rod marking port	Control, outside of patch reef	
GPS	16°56.48 S 178°39.74E	16°56.23S 178° 39.60E	16°56.13S 178° 39.60E	16°56.43S 178° 39.55E	16°56.33S 178° 38.71E	
Time	7:37 am	7:52 am	8:03 am	8:15 am	8:30 am	
Depth (m)	3.75	4	2.8	16	>20	
Temperature (°C)	28.5	28.9	28.9	28.7	28.8	Marine water temperatures 20-30***
pH	7.9	8.2	8.1	8.2	8.2	7.7-8.5 8.0-8.4**
Conductivity (µS/cm)	57.2	57.3	57.4	57.1	56.8	
Dissolved Oxygen (mg/L)	3.12	4.07	3.07	3.49	4.63	>6 (AA waters) >4.5 (B waters >6***
Salinity (ppt)	34.8	35.1	35.2	35.1	34.6	None specified but expected range is 30 to 35 ppt for seawater
Clarity (m)	3.75 (b)	4 (b)	2.8 (b)	6.25	6.8	>1.2 m
Total Suspended Solids (mg/L)	24	33	31	38	36	None specified but sum of TSS and TDS <500 mg/L****
Oil and Grease (mg/L)	<2	19	3	<2	<2	No detectable surface slick. <0.01 mg/L
Faecal Coliforms c/100Ml)	4	<1	<1	1	83	<230c/100ml (AA waters) <400c/100ml (B waters) <150c/100ml**(swimming)
Nitrates (µg/L)	<34	<34	<34	<34	<34	2-8 µg/L**
Phosphates (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	5 µg/L**
Comments	Live corals on bottom	Live coral on bottom and organic matter on water surface (slick)	Live coral, bommies and sand	Floating mangrove leaves, froth and slick	Clear jelly fish aurelia.	

Fiji Draft Sustainable Development Bill – specific criteria for Class AA (Coastal Waters for Support of Marine Life) and B (Port Use)
** ANZECC (Australia and New Zealand Environment and Conservation Council) (2000)
ANZECC (1992) * ESCAP (Economic and Social Commission for Asia and the Pacific) (1994)

Incoming Tide

Temperature at the five sites varied between 29.3 and 29.8 degrees Celsius which was relatively uniform and slightly higher than the temperatures recorded in the early morning. They were again all within the recommended temperature for marine water which was 20 to 30 degrees Celsius.

Conductivity ranged from 54.6 to 58.4 µS/cm and salinity varied from 33.1 to 35.1 ppt. Conductivity is similar to salinity in that it measures the concentration of ionized substances dissolved in the water. The results were at or below the maximum expected range for salinity in marine water which is 35 ppt. The salinity was again highest at the inshore sites due to them being shallower.

Dissolved oxygen varied between 4.12 and 4.98 mg/L at the five sites. These values are still fairly low compared to the recommended level of >6 mg/L to support aquatic life and >4.5mg/L for port use. The values however are slightly higher than those in the morning sampling indicating that dissolved oxygen levels probably increase during the day, reaching highest levels at high tide which would have been in the afternoon.

The pH ranged from 8.0 to 8.2 and was within the acceptable range (7.7-8.5) at all sites.

Clarity was again very good at all sites, all above the minimum requirement of more than 1.2 meters. The bottom was visible clearly at all three inshore sites and at Site 4 and 5 clarity was around 7 to 8 meters. Total suspended solids (TSS) which measures the amount of suspended matter in the water was also low (between 34 mg/L and 49 mg/L), although no specific guideline is given for this parameter. Total suspended solids and clarity measure how clear the water is.

Oil and grease was not carried out for sampling of the incoming tide as traces or sources are land-based which would be detected in the outgoing tide and because of logistics in preserving samples of oil and grease.

Faecal coliform levels ranged from <1 to 4 counts/100ml. All values were below the maximum recommended level of 150 c/100ml required for swimming and 250 c/100ml required to sustain aquatic life indicating no pollution of coastal water from human or animal faecal waste.

Nutrients (nitrates and phosphates) were not detected at all by laboratory analysis.

Table 2. Water Quality Results of Sampling on Incoming Tide

Site	1	2	3	4	5	Guidelines*
Location	Offshore in line with rod, 200 m to east on reef edge	Offshore in line with rod 200m to west, just off edge.	100 m to west of Site 2. 80 m from rocky island with 1 mangrove on reef edge	400 m directly out from iron rod marking port	Control, outside of patch reef	
GPS	16° 56.46 S 178° 39.72E	16° 56.24S 178° 39.60E	16° 56.05S 178° 39.57E	16° 56.40S 178° 39.38E	16° 56.30S 178° 38.74E	
Time	10:39	10:28	10:18	10:00	10:08	
Depth (m)	2.2	5.6	3.75	>20	>20	
Temperature (°C)	29.3	29.8	29.6	29.5	29.4	Marine water temperatures 20-30***
pH	8	8.2	8.2	8.2	8.2	7.7-8.5 8.0-8.4**
Conductivity	57.8	58.4	55.4	54.6	57.3	
Dissolved Oxygen (mg/L)	4.12	4.52	4.62	4.98	4.69	>6 (AA waters) >4.5 (B waters >6***
Salinity (ppt)	35.1	35.1	33.2	33.1	34.7	None specified but expected range is 30 to 35 ppt for seawater
Clarity (m)	2.2	5.6	3.75	8.8	7	>1.2 m
Total Suspended Solids (mg/L)	34	49	55	47	48	None specified but sum of TSS and TDS <500 mg/L***8
Faecal Coliforms (c/100Ml)	2	2	4	<1	<1	No detectable surface slick. <0.01 mg/L
Nitrates (μg/L)	<34	<34	<34	<34	<34	<230c/100ml (AA waters) <400c/100ml (B waters) <150c/100ml***
Phosphates (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	2-8 μg/L**
Comments		Mangrove leaves and debris in water		Jellyfish and organic material	Waves from SE	5 μg/L**

Fiji Draft Sustainable Development Bill – specific criteria for Class AA (Coastal Waters for Support of Marine Life) and B (Port Use)
** ANZECC (Australia and New Zealand Environment and Conservation Council) (2000)
ANZECC (1992) * ESCAP (Economic and Social Commission for Asia and the Pacific) (1994)

4.5 Discussion and Proposed Impacts of the Development on Coastal Water Quality

The current status of water quality at the proposed development site is good to very good and serves as a baseline against which future water quality monitoring during construction and operation of the port and coastal road can be compared against. It should be noted that sampling was undertaken during fine weather, however, sampling should probably in future also be carried out following periods of rainy weather to see if water quality is similar.

During the outgoing tide, temperature, conductivity, salinity and pH were within the recommended guidelines for marine coastal waters at all five sites. Clarity was extremely good at all sites, with the live corals clearly seen at the inshore sites. Nutrients were not detected indicating low levels and faecal coliform levels were all well below the maximum recommended level. The only parameter of concern was the low dissolved oxygen levels at the inshore sites (all lower than the minimum level of 4.5 mg/L). This could have been due to the sampling time being early in the morning when dissolved oxygen levels are at the lowest during the day and warm calm waters. Low dissolved oxygen levels may affect marine life which require oxygen for respiration. Oil and grease was also detected at Sites 2 and 3, however this may be from a natural form of hydrocarbons.

During the incoming tide, temperature, conductivity, salinity, pH and faecal coliforms were all within recommended guidelines. Clarity was again very good at all sites and nutrients not detected. Again the only concern was the fairly low dissolved oxygen levels, however, they had increased as compared to the earlier sampling.

The coastal environment of and adjacent to the proposed port site is used for fishing by the nearby village of Wairiki. It is thus important that the water quality is maintained in its current good condition during construction and operation of the port and coastal road in order to protect the marine ecology of the area, human uses such as harvest of fisheries and swimming and the aesthetics of the area.

The key impacts that the proposed development (construction and operation of a port facility comprising of dolphins and an access bridge and a coastal access road) may have on coastal water quality and recommended mitigating measures include the following:

During construction:

Potential Impact	*Mitigation Measure/Recommendations*	*Possible Degree of Impact*
Coastal Road		
1. Increased turbidity and silt in coastal waters as a result of erosion and runoff from earthworks and unprotected excavated areas particularly in rainy weather due to steepness of slope on which road is to be built and because the road is to be built directly adjacent to the narrow mangrove belt.	• Have systems to control silt runoff such as holding ponds or silt bunds to trap silt • Ensure mangrove belt between road and coastal water is retained. • Careful construction operations	High
2. Spillage of hazardous material such as oil and grease from heavy construction vehicles	• Keeping spill cleanup kits on site and educating staff in their use. • Ensure vehicles do not leak oil and grease	Medium to Low
Port and Access Bridge		
1. Increased turbidity due to suspension of silt from the drilling of piles for port and access bridge structures.	• Silt curtains or fences around site of pile drilling to localize effect. • Undertake monitoring during and post construction of port and road	Medium
2. Improper disposal of solid and liquid waste from construction workers resulting in increased levels of nutrients and faecal coliforms.	• Ensure proper facilities are provided for disposal of rubbish and sewage effluent by construction workers. • Collecting construction debris and disposing of it in a suitable, approved disposal site.	Medium

During operation:

Potential Impact	*Mitigation Measures*	*Degree of Impact*
Coastal Road		
1. Increased turbidity due to continuing silt runoff if road is not properly resurfaced and areas left exposed	• Proper resurfacing of road and replanting of areas that are exposed and on steep slopes	Medium
Port and Access Bridge		
1. Increased turbidity as a result of vessels visiting the port stirring up sediment on the seabed	•	Low
2. Increase in nutrients and faecal coliforms from the inappropriate discharge of sewage and other liquid waste from ships and port facilities	• Ensure proper waste management facilities for ships and at port. • Prohibit the discharge of ship sewerage while in port • Monitoring water quality around the wharf area on a regular basis.	Medium

3. Disposal of solid waste from ships and port facilities which make the coastal waters appear dirty.	• Providing rubbish bins for port worker/ship passenger waste in all port areas and encouraging their use	Medium
4. Spillages of oil and fuel from boat operations and port fuel storage facilities	• Maintaining port areas in a clean condition to prevent oil being carried into the water by stormwater discharges • Ensure routine emergency control of oil spills exist	Medium

4.6 References

Asian Development Bank (1993). *Environmental Guidelines for Coastal Zone Development Projects.*

ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

ESCAP. 1994. *Guidelines on Monitoring Methodologies for Water, Air and Toxic Chemicals/Hazardous Wastes.* Economic and Social Commission for Asia and the Pacific. United Nations, New York.

Fiji's Draft Sustainable Development Bill. 1996. Government of Fiji.

5.0 TERRESTRIAL FLORA AND FAUNA INCLUDING MANGROVES

5.1 Introduction

The terrestrial assessment of the proposed development was undertaken to survey and compile the following information:

- Annotated checklist of the flora and fauna of the proposed site (of the coastal road and access bridge) and its surrounding (qualitative assessment on species abundance and distribution).
- Assess the presence of recognized rare and threatened species and devise conservation strategies for their protection.
- Identify species that are problematic and have the potential to become nuisance, vectors or dangerous.
- Botanical significance of the area (if any).
- Assess impacts the construction of the road would have on the biodiversity.

5.2 Methodology for Terrestrial Assessment

The survey involved the documentation of vascular plants and macrofauna found in and around the proposed quarry site based on field observations whilst trekking through the area. An assessment of the vegetation's growth status, and plant distribution in the area was also documented. Plant names are those used by Smith 1979-1991 for higher vascular plants and by Brownlie 1974 for ferns and their allies. For the birds the names are those used by Watling 2001.

Assessment of the macrofauna and in particular the avifauna involved listening to birdcalls and observing them through Pentax 12 X 50 binoculars. The concerted survey was conducted in the early morning. Further surveys were conducted later during the day during the vegetation and flora surveys

Plants and vertebrates specimens not identified in the field were collected and where necessary preserved for identification at the South Pacific Regional Herbarium and the Marine Studies Complex by relevant resident taxonomists.

The survey of the mangroves was carried out together with the survey of terrestrial flora and comprised of trekking through the mangroves and recording the species present and approximate height and diameter of trees. Any evidence of human disturbance was also recorded. Mangrove fauna observed were also noted.

5.3 Results of Terrestrial Flora and Fauna Assessment

5.3.1 Terrestrial Flora

A total of 106 vascular plants were recorded during the survey (Appendix 1). Of these, 63 were indigenous or native, with ten endemic plant species and thirty-three introduced species. Overall, the area surveyed was disturbed, and was typical of areas found along the western division of Viti Levu and Vanua Levu that was regularly exposed to fire, grazing and agricultural development. The vegetation type prevalent in the proposed area to be developed and its surrounding area is the grassland vegetation typically found on disturbed areas in the leeward side of the larger island in Fiji. Altogether there were five vegetation types observed:

Grassland

The grassland covers more than 50% of the total area proposed for the development. It was restricted to the slope and mostly towards the main road, away from the coast. Grazing of domesticated animals like cattle, horses and goats was common. Plant species commonly found in the grassland include the two ferns *Gleichenia oceanica* and *Dicranopteris caudata;* grasses and herbs like *Pennisetum polystachyon, Sporobolus diander* and the shrubs *Leucaena leucocephala, Pandanus tectorius* and *Dodonaea viscosa.* The most commonly recognized weeds for Fiji were also found here. This included *Leucaena lecocephala, Psidium guajava, Piper aduncum*, etc.

Vesi Forest

This vegetation type was restricted to the rocky and hilly parts of the coastline. The forest covers an area of about 100m x 50m. The two dominant species were *Intsia bijuga* (vesi), which was native and mango, *Mangifera indica*, which was a recent introduction. Vesi is an important traditional timber tree species used for construction, making wooden drums (lali) and kava serving bowls (tanoa) and other handicraft items and also for traditional medicines. On average vesi and mango trees had average DBH (Diameter at breast height) of 30cm but trees as large as 95cm for vesi and 92cm for mango were recorded.

Coastal Forest

The Coastal vegetation type was restricted to areas along the coastline which were not rocky. Plant species common in the area were *Barringtonia asiatica, Hibiscus tiliaceus, Wollastonia biflora, Terminalia catappa, Thespesia populnea, and Cocos nucifera* and others. This vegetation system is disturbed and degraded as indicated by common weeds and presence of old plantation.

Mangrove Forest

The mangrove forest runs along the coast and in most areas was continuous adjacent to the coastal vegetation. The two common mangrove species observed were *Bruguiera gymnorrhiza* (dogo) and *Rhizophora stylosa* (tiri). Common mangrove plant species like *Xylocarpus moluccensis, Excoecaria agallocha, Hibiscus tiliaceus, Cocos nucifera, Derris trifoliata, and Entada phaseoloides* were also found associated with the mangroves. The only area of the coast with no mangrove forest was a rocky section at Naidiriyaga Point (the area where the access bridge will commence from).

Dry Lowland Tropical Rainforest

A small patch of dry forest with an area of about 80m x 30m was also observed about 200m from the road along a seasonal dry creek marking the northern boundary of the proposed area to be developed. Native plant species like *Gymnostoma vitiense, Alstonia vitiensis, Pagiantha thurstonii* and *Cynometra pickenringii* were common. Other native plant species recorded were *Commersonia bartramia, Connarus pickeringii, Diospyros elliptica, Elattostachys falcata, Entada phaseoloides, Ficus barclayana, and Alphitonia zizyphoides.* This forest system may be what remained of a more extensive system that dominated the landscape.

Invasive Plant Species

For the area intended to be developed invasive species observed included the scandent herbs and creepers like *Mikania micrantha, Brachiaria mutica, Passiflora foetida* and *Passiflora suberosa*. The shrubs included *Clidemia hirta, Piper aduncum, Psidium guajava* and *Leucaena leucocephala*. The trees included *Albizia saman* and *Spathodea campunulata*. The occurrence of these invasive species in the areas assessed would result in native plants having problems re-establishing themselves.

5.3.2 Terrestrial Fauna

The macrofauna survey was conducted on the early morning of the 22nd of December. A total time of three hours of bird watching was spent walking around the proposed areas earmarked for new roads and surrounding areas. Mammal surveys also was conducted. A checklist of birds observed is listed in Table 3.

A total of twenty bird species were recorded from the area of which ten are native species, seven are endemic to Fiji, and three are introduced species. All these bird species are common in Fiji.

The other macro fauna observed were mongoose and horses both of which are introduced mammals.

Table 3. Checklist of birds observed at the proposed area for port development in Wairiki.

Common Name	*Scientific Name*	*Distribution*	*Abundance, other comments.*
Eastern Reef Heron	*Egretta sacra*	Native	1
Fiji Bush Warbler	*Cettia ruficapilla*	Endemic	2
Fiji Goshawk	*Accipiter rufitorques*	Endemic	1
Fiji Parrotfinch	*Erythrura cyanovirens*	Endemic	2
Fiji Silver-eye	*Zosterops lateralis*	Native	3
Fiji Woodswallow	*Artamus mentalis*	Endemic	2
Common Mynah	*Acridotheres tristis*	Introduced	Very common, pest
Golden Whistler	*Pachycephala pectoralis*	Endemic	1
Lesser Shrikebill	*Clytorhynchus vitiensis*	Native	1
Orange Breasted Myzomela	*Myzomela jugularis*	Endemic	1
Pacific Harrier	*Circus approximans*	Native	
Polynesian Triller	*Lalage maculosa*	Native	2
Red-vented Bulbul	*Pycnonotus cafer*	Introduced	Very common, pest
Slaty Monarch	*Mayrornis lessoni*	Endemic	1
Spotted Dove	*Streptopelia chinensis*	Introduced	1
Streaked Fantail	*Rhipidura spilodera*	Native	1
Vanikoro Broadbill	*Myiagra vanikorensis*	Native	2
Wattled Honey Eater	*Foulehaio carunculata*	Native	1
White-collared Kingfisher	*Todiramphus chloris*	Native	1
White–throated Pigeon	*Columba vitiensis*	Native	1

5.3.3 Mangrove Flora and Fauna

The mangroves found directly adjacent to the proposed coastal road and port site comprised of a belt of forest along the coast which ranged from 10 to 20 meters in width and 80 to 100 meters in length. It is dominated by **tiri** *(Rhizophora stylosa)* and **dogo** (*Bruguiera gymnorhiza)* and includes other mangrove associates (Table 4). The height of the mangrove stand varied from between 3 meters at the coastal fringe to around 7 meters at the landward edge. A few large trees such as vesi and tavola were also recorded. This patch of mangroves is located directly adjacent to where the road is to be constructed thus some of it may be cleared. An offshore mangrove islet is located about 30 meters offshore, the widest part being about 10 to 15 meters and the length about 80 to 100m. The island is dominated by *R. stylosa.* No human disturbance was recorded or observed for both the mangrove patches. The mangrove area described was in very good condition. A more extensive area of mangroves was located to the south of the proposed site but would not experience any direct impacts from the proposed development.

Table 4. Mangrove and Associated Plant Species.

Species	Fijian Name	Abundance	Height (m)	DBH (cm)
*Rhizophora stylosa**		Very common	3-5	-
*Rhizophora samoensis**		Rare	3-5	-
*Bruguiera gymnorrhiza**		Common	4-7	14-20
*Xylocarpus moluccensis**			6	22
*Excoecaria agallocha**			7	18
*Excoecaria agallocha**			7	18
Pongamia pinnata		Rare	8	20
Entada phaseoloides		Common	-	-
Derris trifoliata		Common	-	-
Barringtonia asiatica		Common	8	22
Terminalia catappa	tavola		14	38
Mangifera indica		Common	7	25
Intsia bijuga		Common	12	27
Cordia subcordata			-	-
Hibiscus tiliaceus		Common	-	-
Thespesia populnea			6	27
Clerodendrum inerme			-	-
Premna serratifolia			-	-
Inocarpus fagifer	vesi		-	-
Vitex trifolia		Common	-	-

*Indicates a true mangrove

Mangrove fauna observed whilst trekking and their relative abundance is recorded in Table 5.

Table 5. Mangrove associated fauna

Species	Common Name	Fijian Name	Abundance
Molluscs			
Crassostrea mordax	Mangrove Oyster	Dio	Common
Isognomon ephippium	Saddle Tree Oyster	Civa	Moderately Common
Littorina scabra	Periwinkle		Common
Nerita			Common
Crabs			
Metopograpsus messor	Mangrove Crab	kuka	Common
Scylla serrata	Mud Crab	qari	Rare
Cardisoma carnifex	Land Crab	lairo	
Fish			
Eleotridae		vo	
Periophthalmus sp.	Mudskipper	tidaloko	Common
Lethrinus sp.	Emperor	kabatia	

5.4 Discussion and Proposed Impacts of Development on Terrestrial Ecology

The proposed site for the port development is of no botanical significance, since no rare and threatened plant species listed in the Fiji Biodiversity Technical Report #7 (1998), were recorded. Also all native plants listed were common and could be found elsewhere in Fiji. The botanical significance of the area is further compounded with the presence of the following invasive species *Spathodea companulata, Piper aduncum, Samanea saman* and *Leucaena leucocephala*, plants listed in the top 100 invasive plants of the world and the serious weeds *Lantana camara, Psidium guajava, Sida acuta, Hyptis pectinata*, etc., add to the overall conclusion that it is not of any botanical significance.

Remnants of two forest types that once dominated the landscape observed were the dry forest and vesi forest that dominated the vegetation on the rocky coast towards Naidiriyaga point. Grazing had once greatly impacted the undergrowth but more recently the impacts have been reduced. Most of the area to be developed is disturbed, however, of interest was the areas of vesi forest and dry forest. These two forest systems were believed to be the original vegetation found along these areas of Vanua Levu. The two remnants are what remains after years of human disturbance. Construction of the roads should be done in a way to minimise disturbances to these two systems. The vesi and dry forest should be fenced and protected. Similar forest types (dry forest and vesi dominated forest) can be found elsewhere in Vanua Levu, in Drawa near Lutukina, Lekutu, and along the coast at Naicobocobo.

The birds tend to be concentrated on the forested areas (vesi forest, dry forest, and coastal and mangrove forest). The development of the road will have some effect on the bird diversity as the road will go through the vesi, mangrove and coastal forest and will cut through the edges of the dry forest. However there is some good patches of relatively intact forest found inland and also larger intact mangrove forest further southeast along the coast. These neighboring forested areas will serve as a refuge for displaced birds for the area.

A summary of the impacts that the proposed development (coastal road and port) may have on the terrestrial ecology including the mangroves are presented below:

During construction:

Potential Impact	*Mitigation Measures*	*Possible Degree of Impact*
Coastal Road		
1. Direct loss of habitat such as removal of large trees and other vegetation including mangroves on the coastal margin in order to clear area for road	• Unavoidable impact but can remove only that which is necessary and if possible avoid important or rare species	Medium
2. Loss of related forest and mangrove wildlife		Low
Port and Access Bridge		
1. Loss of mature trees and other vegetation including mangroves at the bottom of the headland where the access bridge will commence from.	• Unavoidable impact but can remove only that which is necessary and if possible avoid important or rare species	Medium
2. Impact on mangrove distribution if construction works disrupt coastal water circulation patters	• Ensure structures minimize any changes in coastal hydrology	Medium

During operation:

Potential Impact	*Mitigation Measures*	*Degree of Impact*
Coastal Road		
1. Encroachment by humans into the forest areas because of ease of access	•	Low
Port and Access Bridge		
1. Possible pollution of forest and vegetation close to port area from inappropriate disposal of rubbish	• Provision of rubbish bins and enforcement of litter disposal	Low

5.5 Recommendations and Conclusion

Plants found in the area are relatively common and can be found not only in the nearby pockets of forest but also elsewhere in Fiji. If the vesi forest and dry forest falls within the area leased for this development, then the onus is on the developers to minimize damages on the system, for example by re-aligning the road as not to pass through the two forests. Fencing off the area would be another option. The impact of the road construction on the fauna would be minimal as similar ecological systems found in the proposed site were noticed immediately in the adjacent forest and grassland systems. The impact of the development on the mangrove forest should be minimal because of the presence of adjacent mangrove systems, which are much larger.

5.6 References

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6.0 MARINE ECOLOGY STUDY

6.1 Introduction & Site Description

The reefs at Wairiki are of fringing reef type, the simplest kind of reef. The development site has a rocky shoreline, which provides the best conditions for fringing reefs. This site is one of a typical fringing reef including a rocky shoreline with mangroves. The reef itself is a narrow one (approximately 200 meters in width) and consists of an inner reef flat which is fairly wide and a narrow outer reef slope. The reef is shallow with the reef flat exposed at low tide. Being close to land, it is easily affected by sediments and freshwater run off. The distribution of marine fauna and flora therefore depends on location on reef. The larvae of coral and other invertebrates will settle in least disturbed and healthy areas, the outer reef slope. Algae and other flora best settle in high nutrient areas such as the inner reef flat. The substrate and invertebrate distribution normally show this general trend.

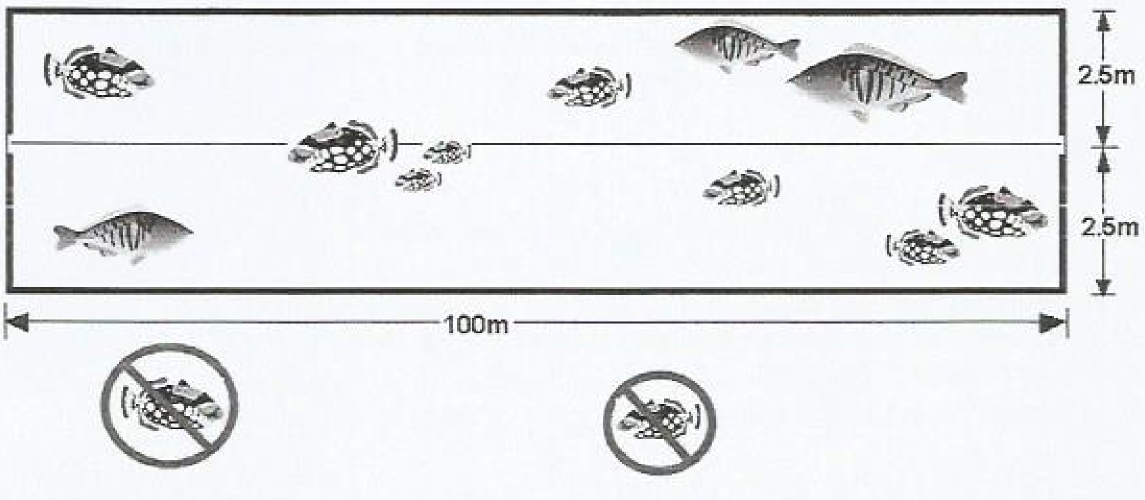
6.2 Methodology

The marine studies comprised of first a reconnaissance snorkel to determine the extent of the different reef habitats such as coral, rocky areas, and seagrass followed by transects carried out on the fringing reef adjacent to the proposed development site. A short dive and snorkel was also carried out on the offshore reef nearby.

To survey the fringing reef at the proposed port site, ten 20 meter line transects were laid along different zones of the reef (Figure 1). All transects were laid perpendicular to the reef They are described below:
Transect 1: Placed 300m to the south of the iron rod, originated from the reef crest and moved towards the inner reef.
Transect 2: Placed 10m landward of the first transect,
Transect 3: Placed a further 10m landward of transect 2
Transect 4: Placed about 150m still south of the iron rod on outer reef crest.
Transect 5: Placed about 10m landward of transect 4 along the inner reef flat.
Transect 6: In line with the iron rod and on the reef flat.
Transect 7: Placed about 150m north west of the iron rod, in front of the mangrove island and on the reef crest (outer reef slope).
Transect 8: Placed about 10m landward of transect 7 on the inner reef flat.
Transect 9: Placed 20m north of Transect 7 on the reef crest.
Transect 10: Placed 10 m landward of Transect 9 along the inner reef flat.

The surveys were conducted at rising tide. The reef survey was done using the Global Coral Reefs Monitoring Network (GCRMN) methods, where belt transects are used (Figure 3.). This method was not only used for the fish abundance but for the invertebrates as well. A meter tape (as a line) was laid perpendicular to the reef. Each transect was censored as a complete 20m x 5m belt. Three observers are involved in the surveying. The first observer swims slowly along the transects recording fish encountered within 2.5 meters on either side. Fish outside the 2.5 meters are not counted. The second person follows the fish observer counting invertebrates along the belt transect.

Figure 3. Belt Transect Method for Invertebrates and Fish



The substrate composition was surveyed using a point intercept method (PIT). The same line transect used for fish and inverts was used for this survey with the substrate surveyor following the invertebrate recorder. Readings are taken every half a meter along the 20-m line and the substrate recorded. There were a total of 40 points for each transect. From this the percentage cover of the different types of substrate for each transect can then be calculated.

6.3 Results

6.3.1 Substrate Composition

Categories of substrate identified are tabulated below.

Table 6. Different categories of substrate recorded at reef at Wairiki

Category	*Description*	*Short Form*
Rock	Solid substrate that may be covered in encrusting algae	RCK
Rubble	Loose rock and dead coral	R
Sand		S
Soft Coral	Species of soft corals	SC
Acropora Branching	Species of Acropora hard coral	ACB
Acropora Digitate	Species of Acropora but of different growth form	ACD
Coral Submassive	Hard coral including different species but submassive growth form	CS
Coral Encrusting	Hard coral which form encrusting growth form	CE
Coral Foliose	Hard coral forming earlike growth form	CF
Coral Massive	Hard Coral with massive growth form	CM
Coral Branching	Non-Acropora species of hard coral	CB
Halimeda	Species of calcareous algae which contribute to production of sand	HA
Dead Coral with Algae	Parts of coral which are now dead and covered with encrusting algae	DCA
Macroalgae	Types of algae or seaweed including brown and green algae	MA
Algal Assemblage	Substrate covered with different species of microalgae	AA

These categories were then represented as a percentage cover of the 20 meter transect. The results of the transects are described according to which part of the reef they were located on. Transects **1, 7** and **9** were from the outer reef slope; Transects **2, 4, 8** and **10** are from the outer reef flat, **3** and **5** from the inner reef flat and Transect **6** from the shallow intertidal area close to the mangroves and the shore. (ref to Figure 1).

Outer Reef Slope

The outer reef slope had a lot of live coral due to its location away from land due to the water being clearer and clean making it more suitable for corals to grow. Common species of coral encountered included *Acropora, Porites*, and *Echinopora*. Figure 4 shows composition of substrate cover for the transect from the outer reef slope to the south of the proposed port structure and Figures 5 & 6 show percentage composition of substrate cover of the outer reef slope in front of the mangrove islet just to the north of the proposed port structure.

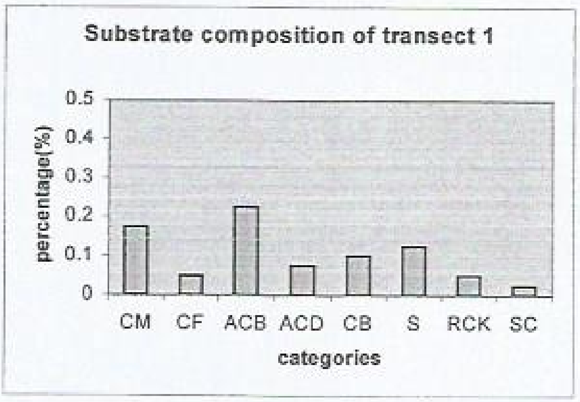


Figure 4.: *Dominated by live coral including Acropora (30%), coral massive (19%).*

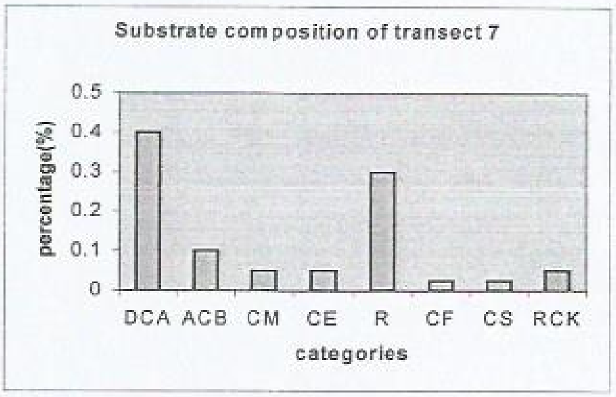


Figure 5. Dominated by dead coral with algae (40%) and rubble. (30%). Live coral also prominent (15%)

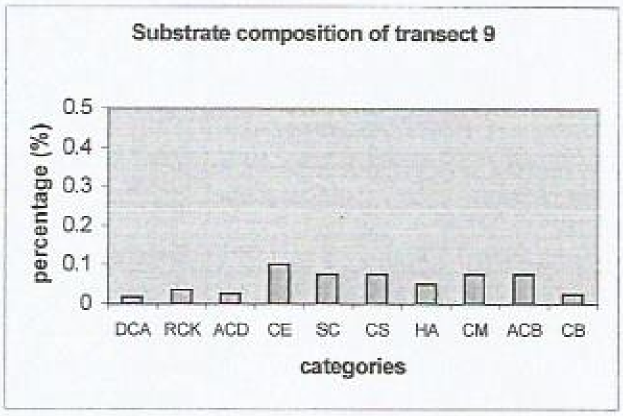


Figure 6: Dominated by live coral (42%). Encrusting coral make up 10%, coral submassive 7.5% and coral massive 7.5%.

Transect 1 comprised of a diverse range and abundance of live coral species and growth forms. Transect 7 was also on the reef crest thus live coral was present, however most of substrate consisted of dead coral with algae and rubble. High wave energy, coral bleaching and other disturbance might have led to this situation. Transect 9 was also on the outer reef slope and live coral was present.

Outer Reef Flat

The outer reef flat is just landward of the outer reef slope. Although it also includes live coral it is largely dominated by rubble which is largely a result of the strong wave action on the reef crest.

Figures 7 & 8 show composition of substrate of transects on outer reef flat to the south of proposed port structure and 9 & 10 of outer reef flat to the north close to the mangrove islet.

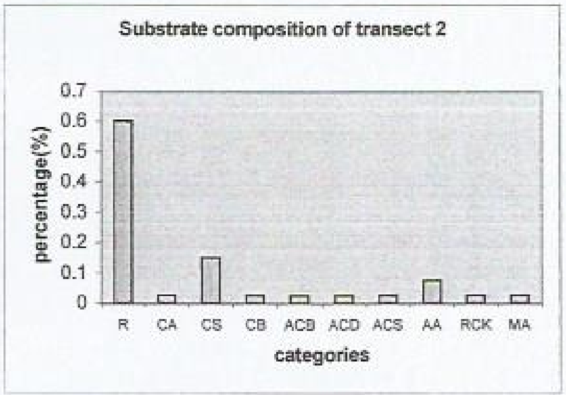


Figure 7. Dominated by rubble.

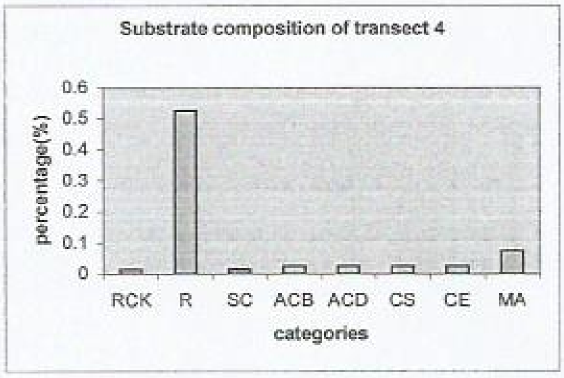


Figure 8: *Dominated by rubble (52%). Live coral(11.5%). Macroalgae is also found (7.5%)*

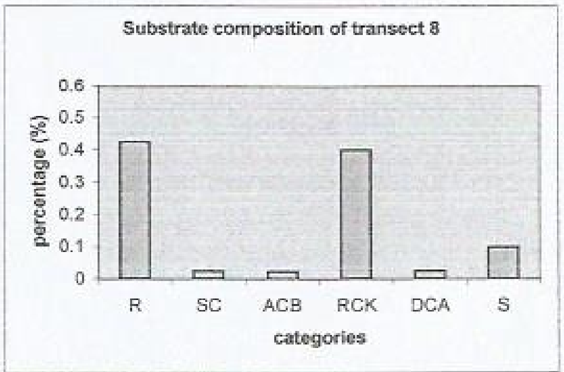


Figure 9. *Dominated by rubble (42%) and rock (40%). Live coral is (5%).*

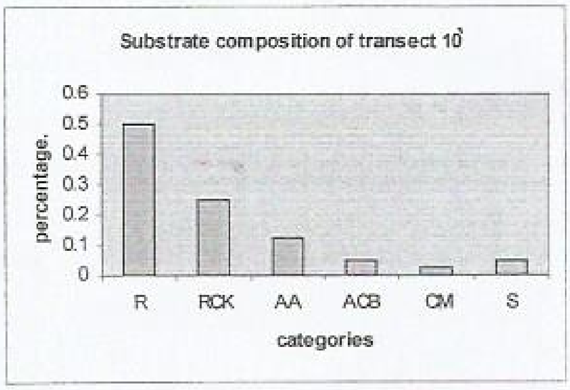


Figure 10. *Dominated by rubble (50%), and rock (25%) Algal assemblage is 12.5% and 7.5% live coral.*

All four transects are dominated by rubble. This could be a result of the strong wave action on the outer reef slope, depositing rubble on this area of the reef. Corals, however, are still found on these transects because conditions are still good for coral growth.

Inner Reef Flat

This zone of the reef is closest to the shore and is distinguished by presence of macroalgae and other species of algae and the lack of live coral.

Figures 11 & 12 show the composition of substrate of transects on the inner reef area, both to the south of the proposed port structure. Figure 13 shows the composition of substrate close to the mangroves which is dominated by macroalgae.

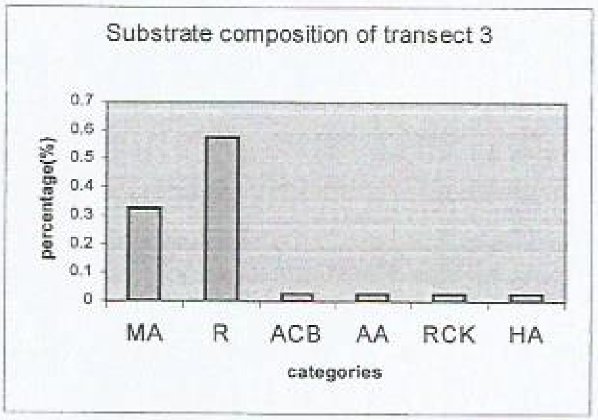


Figure 11. *Dominated by rubble(57.5%) and macroalgae (32.5%). Only 2.5% of live coral.*

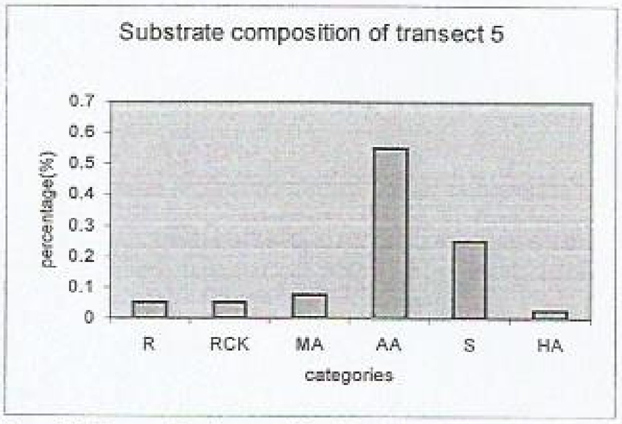


Figure 12. *Transect 5 is dominated by Algae(65%) and sand (25%). No coral was found on this transect*

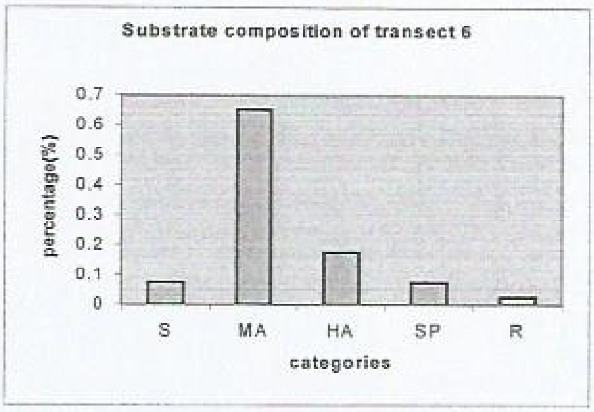


Figure 13. *Dominated by macroalgae (65%) and Halimeda.*

The above figures shows the substrate composition from the inner reef flat, the part of the reef which is vulnerable to sediment and fresh water run-off. This is an area where wave action is very low thus nutrients and silt settle best. This zone is largely dominated by algae, sand and rubble. Coral growth is very minimal due to the shallow, exposed reef and silty substrate, unsuitable condition for coral growth. Figures 12 & 13 show no live coral altogether. The area closest to shore was dominated by the brown macroalgae *Sargassum* which is often an indication of the presence of nutrients. A few small patches of seagrass were also observed but not recorded as part of the transects.

6.3.2 Invertebrate Distribution

Generally there is low abundance of invertebrates on the entire fringing reef of Wairiki. Only 5 species of invertebrates were found: Linckia starfish, Crown of thorns starfish (COT), Holothuria sea cucumber, conch shell and brittle star as listed in Table 7. The distribution of invertebrates is mainly influenced by food and larvae settlement on substrate thus distribution is influenced by substrate type as described above. Their abundance within the transects are presented in Figure 14.

Table 7. Invertebrates recorded at Fringing Reef at Wairiki

Common Name	*Scientific Name*
Blue starfish	*Linckia laevigata*
Crown of thorns starfish(COT)	*Acanthaster planci*
Brittle starfish	*Ophioderma sp*
Sea cucumber	*Holothuria atra*
Conch	*Lambis lambis*

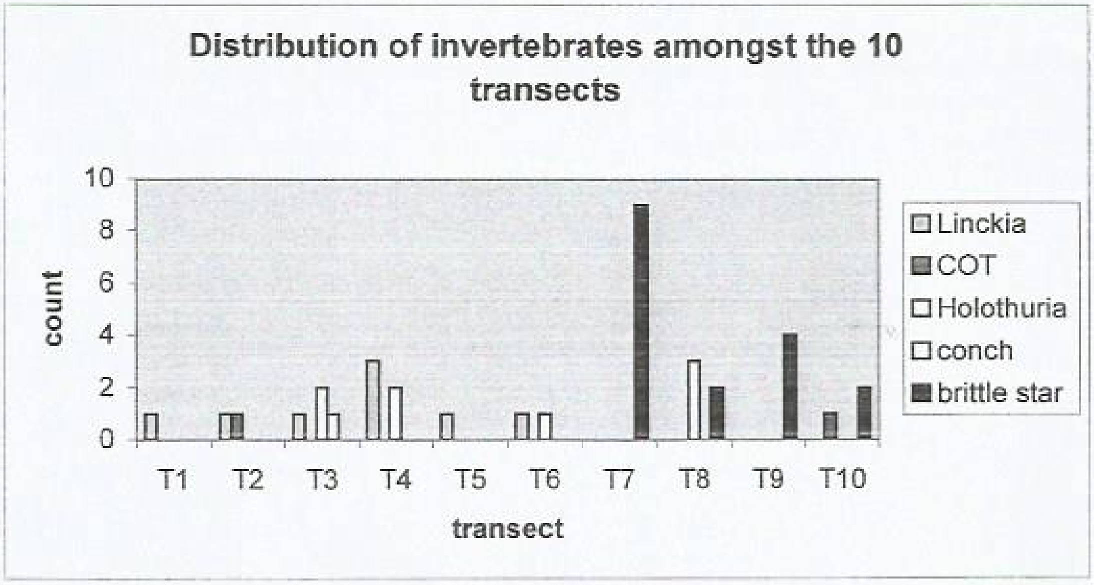


Figure 14. *The abundance of the five types of invertebrates (Linckia, COT, Holothuria, conch and brittle star) in the transects at the proposed development site at Wairiki.*

Linckia starfish was found in transects 1-6. This was from the outer slope through to the inner reef flat. Linckia can be found all throughout the reef habitats due to their adaptability to any parts of the reef as they eat almost anything.

Crown of Thorns starfish was found in transect 2 and 10, on the outer slope where live coral exists. This is because coral is food for COT. COTs are a threat to live coral and their presence should be monitored.

Holothuria was found on the outer and inner reef flat in transects 3, 4, 6 & 8. The inner reef flat is typically dominated by rubble, sand and macroalgae which is use to obtain food for holothuria. They feed on the rich organic film coating sandy surfaces by crawling over the bottom ingesting sand. The edible particles (organic matter such as plankton, foraminifera and bacteria) are extracted when sand passes through their digestive tract and the processed sand is expelled from the anus (as worm-like excrements).

Brittle stars were found close to the mangrove islet along both the outer reef slope and reef flat from transects 7-10. This is an area where current is strong and brittle stars are usually found in places where there is strong current. They are cryptic animals and hide in crevices such as under the corals, as in this case was found along the reef slope.

6.3.3 Reef Fish

The type of substrate also directly influences which types of fishes are present in a particular area because it provides habitat and food for fish. Thus fish species present and abundance is directly related to substrate type.

Abundance

Altogether, there were 15 genus of fish found in Wairiki (Appendix 2 for fish list). The most abundant and common fish species along the Wairiki reef are the Chaetodons (Butterflyfish) which are good indicators of a healthy reef ecosystem. Dascyllus (Damsels) and Helichoeres (Wrasses) were also in abundance. The presence of the fifteen genera indicates a fairly diverse reef fish community (Figure 15.). Chaetodon numbers totaled 43, Dascyllus (27), Helichoeres (25), Ctenochaetus (20), Scarus and Siganus (both 16), Acanthurus (15), Llethrinus (8), Heniochus (6), Cholorus (5), Abudeduf (4), Scolopsis (2), Lutjanus (1) and Gymnothorax (1).

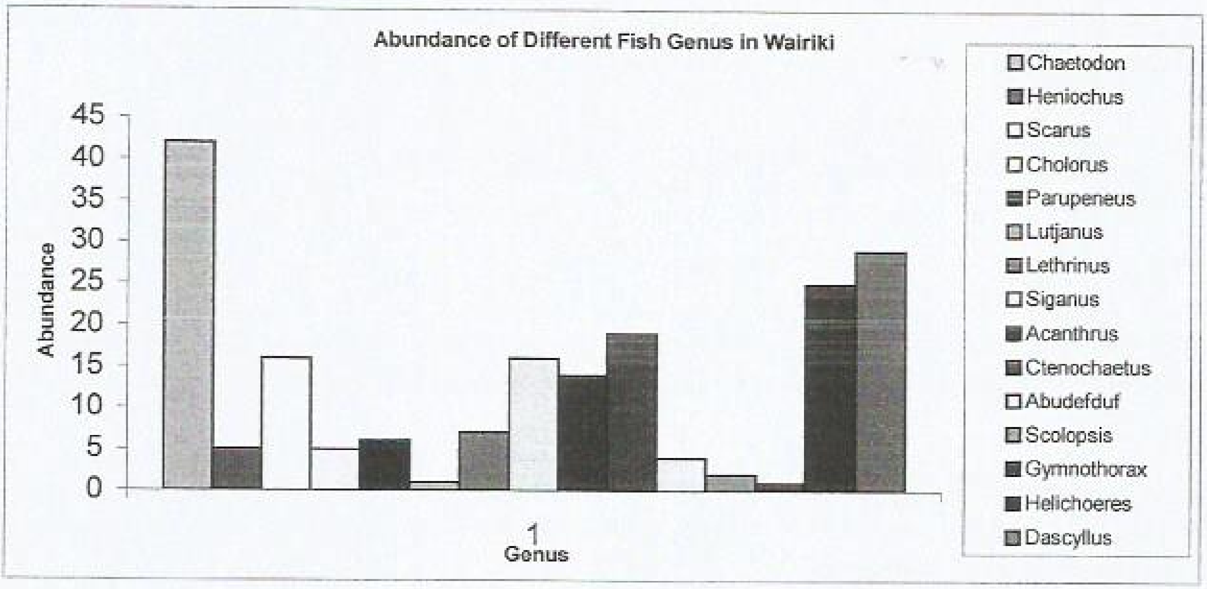


Figure 15. *Abundance of fish in 10 Transects carried out at Wairiki.*

Distribution

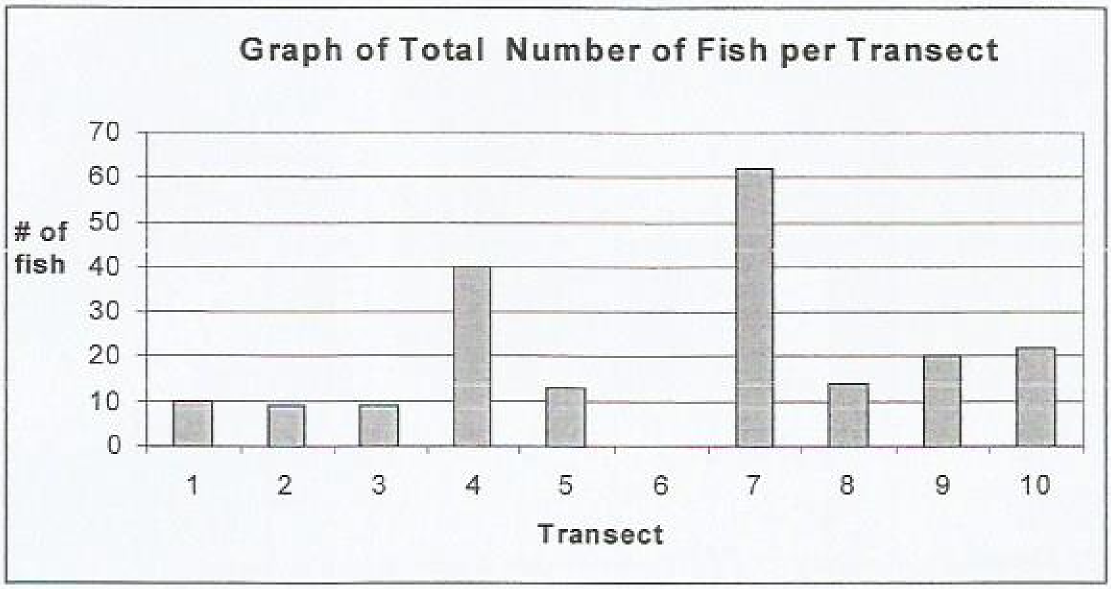


Figure 16. *Total number of fish in the different transects*

The most number of fish was found in transect 7, the reef crest (outer reef slope) which had 62 fish. Transect 4 had 40 fish species, transect 10 had 21 fish (both on outer reef flat), transect 9 recorded 20 fishes, transect 8 (14 fishes), transect 5 (11 fishes), transect 1 (10 fishes). Transects 2 and 3 had 9 fish each and they were no fishes recorded in transect 6.

The abundance of fish on outer reef transects would be due to the presence of diverse coral cover. Coral provides habitat and food for fishes, thus good coral cover would provide for a larger fish population. Transects 9, 1 and 4 are taken from the outer reef slope which explains for a more abundant fish population in the three transects with respect to the others. The rest of the transects had minimal fish with transect 6 having none at all. This was because these transects were part of the inner reef flat, which is dominated by rubble, algae and sand. Fishes are associated with corals and crevices for protection, habitat and food thus an area dominated by sand and rubble does not provide much of this thus few fishes are found.

Commercial Fish

The commercial fish species shown in Figure 17 below are those that are mostly sold in the fish markets around the country. They are important fish species in most villages in Fiji for they are the main source of protein and income for families. Altogether there were 7 commercial fish genera found. The most abundant commercial fish in Wairiki are the Scarus (parrot fish, this also includes Cholorus) and Siganus (Rabbit fish). Acanthrus (surgeon fish), Lutjanus and Lethrinus (Snappers), and Parupeneus (goat fish) were also present but not in abundance. There were 17 Siganus, 16 Scarus, 15 Acanthurus, 7 Lethrinus, 5 Parupeneus, 4 Cholorus and 1 Lutjanus. Most of these fish were found on the transects on the outer reef slope because there was more live coral present on this part of the reef. The commercial fish present on the Wairiki reef were mostly juveniles.

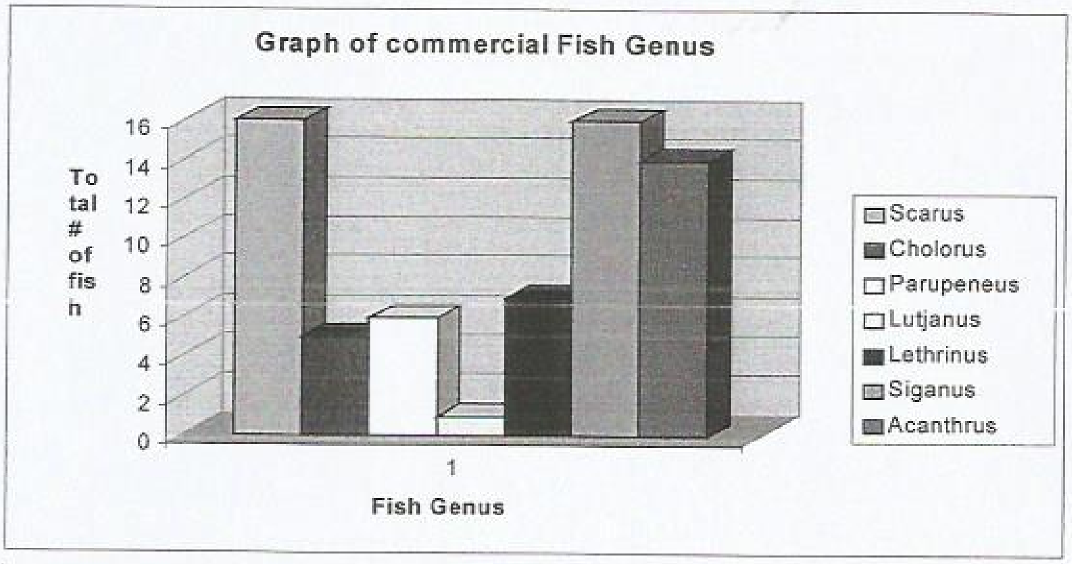


Figure 17. Abundance of commercial fish species within transects at Wairiki reef

6.4 Discussion and Impacts of Proposed Development on Marine Ecology

The marine assessment indicated that in terms of substrate, the fringing reef at Wairiki is healthy and alive on the outer reef slope. This is indicated by the high degree of live coral encountered on the transects in this zone of the reef. The most common species of hard corals observed included *Acropora, Porites,* and *Echinopora*. Various forms such as massive, branching, encrusting were present as well as soft coral and in some transects areas of dead coral covered in algae. The outer reef flat was largely dominated by rubble with some presence of live coral. The inner reef area was dominated by algae including the brown algae *Sargassum* and the calcareous algae *Halimeda*. It is obvious that the live outer reef slope of the reef will be the most vulnerable to the impacts of the development of a port in the area. This is largely due to corals requiring clear and nutrient poor water for survival.

The abundance and diversity of marine invertebrates on the fringing reef is low with only 5 species being found and very few numbers of individual species in each transect. This could partly be a result of the type of substrate i.e. some invertebrates are found largely in seagrass areas where silt is present which was lacking at Wairiki. No species of commercial importance were found, however the Crown of Thorns was observed which is a known threat to corals on which it preys. Impacts of the proposed project on invertebrates of the area are thus not likely to be significant.

The abundance and diversity of reef fish of the area is fairly good for a small fringing reef. However most of this was concentrated on the outer reef slope and outer reef flat of the reef where live coral cover was highest. Fifteen genus of fish were recorded with the most common being the butterflyfish, wrasses and damselfish. Commercial fish of importance that were common were the parrotfish, rabbitfish and surgeonfish. Others that were not abundant were snappers and goatfish. All were found on the outer reef slope and were only as juveniles. The outer reef slope which includes the live corals and the reef fish and is the most diverse and alive are most likely to be affected by the construction of the access bridge for the port which extends out to the edge of the fringing reef and any impacts on water quality as a result of the road construction.

Previously discussed impacts of the development on coastal water quality will also affect the marine ecology of the area. A summary of the potential impacts of the development activities on the marine environment at Wairiki and mitigation measures are summarised below.

During construction:

Potential Impact	*Mitigation Measures/ Recommendations*	*Possible Degree of Impact*
Coastal Road		
1. Impairment of reef areas and associated diversity due to changes in coastal water quality such as increased turbidity and silt from earthworks.	• Have systems to control silt runoff such as holding ponds or silt bunds to trap silt • Ensure mangrove belt adjacent to road is retained. • Careful construction operations	High
2. Impairment due to spills of hazardous material such as oil and grease from heavy construction vehicles which may filtrate into coastal area	• Keeping spill cleanup kits on site and educating staff in their use. • Ensure vehicles do not leak oil and grease	Medium
Port and Access Bridge		
1. Destruction of marine habitat directly beneath where pilings of dolphin structures and access bridge will be drilled.	• Unavoidable impact. Avoid locating pilings close to outer reef slope.	High
2. Impairment of marine habitats directly below access bridge as a result of shading which would inhibit photosynthesis of corals and other marine biota.		Low
3. Impairment due to increased turbidity from the drilling of piles for port and access bridge structures.	• Undertake monitoring during and post construction of port and road	High
4. Impairment and the growth of macroalgae resulting from increased nutrient levels resulting from improper disposal of solid and liquid waste from construction workers into coastal waters.	• Ensure proper facilities are provided for disposal of rubbish and sewage effluent by construction workers. • Collecting construction debris and disposing of it in a suitable, approved disposal site.	Medium

During operation:

Potential Impact	*Mitigation Measures*	*Degree of Impact*
Coastal Road		
1. Impairment of marine habitats due to increased turbidity due to continuing silt runoff if road is not properly resurfaced and areas left exposed	• Proper resurfacing of road and replanting of areas that are exposed and on steep slopes	Medium

2. Decreasing abundance of marine biota due to better accessibility to reef and mangrove areas	•	Medium
Port and Access Bridge		
1. Impairment of coral reef habitats from increased turbidity as a result of vessels visiting the port stirring up sediment on the seabed	•	Low
2. Impairment of marine habitats and increase in growth of macroalgae as a result of increase in nutrients from the inappropriate discharge of sewage and other liquid waste from ships and port facilities	• Ensure proper waste management facilities for ships and at port. • Prohibit the discharge of ship sewerage while in port • Monitoring water quality around the port area on a regular basis.	High
3. Impairment due to impacts of oil spills from boat operations and port fuel storage facilities	• Maintaining port areas in a clean condition to prevent litter and oil being carried into the water by stormwater discharges • Ensure exists routine emergency control of oil spills	Medium

7.0 OVERALL SUMMARY

The current status of water quality at the site for the proposed development of Bua Port is very good. All parameters, except dissolved oxygen levels were within the recommended guidelines for coastal waters during both the outgoing and incoming tide. Water clarity was extremely good. Dissolved oxygen levels were just below the minimum recommended level of 4.5 mg/L. However, this could be due to the sampling time being in the early morning when dissolved oxygen levels are at the lowest for the day due to respiration of marine organisms during the night which uses up oxygen, due to the elevated water temperature which diminishes the amount of oxygen that can dissolve in water and because of the nature of the fringing reef system which limits circulation of water. The levels did increase later in the morning and these levels could also be normal background levels for the area.

The assessment of the terrestrial flora indicated no rare or threatened plant species and the overall conclusion that the site was of no botanical significance. In addition, invasive species were found in the area. Of interest was the existence of two remnant pockets of forest, an area of dry forest and an area of vesi forest near the rocky coast which were probably the original vegetation of the area before grassland dominated the area. Similar forest types are found elsewhere in Vanua Levu. All the bird and terrestrial animal species recorded are common throughout Fiji. The mangroves of the area were in good condition, with large stands located to the south of the port site.

The marine assessment indicated that the fringing reef at Wairiki is healthy and alive on the outer reef slope. This is indicated by the high degree of live coral encountered on the transects in this zone of the reef. The outer reef flat was largely dominated by rubble with some presence of live coral. The inner reef area was dominated by algae including the brown algae *Sargassum* and the calcareous algae *Halimeda*. The abundance and diversity of marine invertebrates on the fringing reef was low with only five species being found and very few numbers of individual species in each transect. No species of commercial importance were found, however the Crown of Thorns was observed which is a known threat to corals on which it preys. The abundance and diversity of reef fish of the area is fairly good for a small fringing reef. However most of this was concentrated on the outer reef slope and outer reef flat of the reef where live coral cover was highest. Fifteen genera of fish were recorded with the most common being the butterflyfish, wrasses and damselfish. Commercial fish of importance that were common were the parrotfish, rabbitfish and surgeonfish

Significant impacts of the proposed development of an access road and the port on the above environmental components will result from both the construction and operation of the road and port. The most significant impacts that may result from construction activities include:

- Increased turbidity and silt in coastal waters from earthworks in road construction and drilling of piles for port which may impact on the outer reef slope (live coral and reef fish).
- Direct loss of large trees including mangroves on the coastal margin to clear area for road and access bridge.
- Destruction of marine habitat directly beneath pilings and impairment directly below access bridge as a result of shading.

The most significant impacts that may result from the operation of the road and port include:

- Increase in nutrients and faecal coliforms in coastal waters if there is inappropriate discharge of sewage and other liquid waste from ships or port facilities. This would in turn affect marine habitats adapted to nutrient poor waters and lead to an increase in macroalgae.
- Oil and diesel spillage from port and ship operations.

Since the design and location of the access road and port structure has been chosen to minimise impacts on the environment the main recommendations to mitigate against the above impacts would be:

- The use of silt retention structures and careful construction operations in the construction of the access road.
- Minimise the removal of mangroves and large trees in road and port construction.
- Undertake monitoring of coastal water quality during and post construction activities.
- Ensure proper solid and liquid waste management facilities are provided at the port once it is in operation.
- Ensure oil spill kits are available for emergency use.

APPENDICES

Appendix 1. CHECKLIST OF PLANTS FROM THE TERRESTRIAL SURVEY

A checklist of plants found in the proposed area for port development in Wairiki, Bua.

Botanical Name	Distribution & Abundance	Growth form and, other comments
Abrus precatorius	Indigenous	Creeper
Acalypha sp.	Indigenous	Shrub
Albizia saman	Exo, Nat. common	Tree, invasive, timber
Alphitonia zizyphoides	Indigenous, common	Tree
Alstonia vitiensis	Endemic	Tree
Ananas comosus	Exotic, Nat.	Herb
Artocarpus altilis	Aboriginal introduction	Tree, edible fruit
Asplenium australasicum	Indigenous	Fern
Bambusa vulgaris	Exotic, Nat	Tree/ herb
Barringtonia asiatica	Indigenous, common	Tree, Used for fish poison in past
Barringtonia racemosa	Indigenous, common	Shrub/tree
Bruguiera gymnorrhiza	Indigenous	Tree, construction, medicinal, other.
Calophyllum inophyllum	Indigenous	Tree, medicinal, other
Cananga odorata	Aboriginal introduction	Tree, scenting, medicinal
Capsicum frutescens	Exotic	Herb, spice
Carica papaya	Exotic,Nat.	Tree, food, medicinal
Cassytha filiformis	Exotic,Nat.	Creeper
Centella asiatica	Indigenous.	Herb, medicinal
Cerbera manghas	Indigenous.	Tree
Citrus limon	Indigenous.	Shrub/tree, edible fruit
Clidemia hirta	Exo, Nat.	Weed, invasive
Cocos nucifera	Indigenous	Shrub/tree, edible fruit, construction, medicinal, other.
Colubrina asiatica	Indigenous	Scandent shrub
Commersonia bartramia	Indigenous	Tree, medicinal, other
Connarus pickeringii	Endemic	Liana
Cordia subcordata	Indigenous	Tree, medicinal, other
Cordyline terminalis	Indigenous	Shrub
Culcita straminea	Indigenous	Fern
Cyathea sp.	Indigenous	Fern
Cynometra insularis	Endemic	Tree, medicinal
Cyperus pilosus	Exotic, Nat.	Grass
Dalbergia candenatensis	Indigenous	Scrambling shrub
Davallia feejensis	Endemic	Fern
Derris trifoliata	Indigenous	Climber
Dicranopteris caudata	Endemic, very common.	Fern
Dioscorea bulbifera	Exotic	Creeper
Diospyros elliptica	Indigenous	Tree, construction
Dodonaea viscosa	Indigenous	Shrub, medicinal.
Drynaria rigidula	Indigenous	Fern
Dysoxylum richii	Endemic	Tree, construction, medicinal
Elattostachys falcata	Indigenous	Tree, construction, other
Eleusine indica	Exotic, Nat.	Grass
Endospermum robbieanum	Endemic	Tree, construction
Entada phaseoloides	Indigenous, common	Liana, medicinal, water

Epipremnum pinnatum	Indigenous	Climber, medicinal
Excoecaria agallocha	Indigenous	Tree, medicinal, other
Ficus barclayana	Indigenous	Shrub
Ficus obliqua	Indigenous	Tree
Ficus prolixa	Indigenous	Tree
Ficus vitiense	Endemic	Shrub, Edible fruit
Flagellaria sp.	Indigenous	Climber
Gleichenia oceanica	Indigenous, very common	Fern
Glochidion seemannii	Indigenous	Tree, medicinal
Gymnostoma vitiense	Endemic, common	Tree, timber, other.
Hibiscus tiliaceus	Indigenous, common	Tree, medicinal, other
Hyptis pectinata	Exotic, Nat.	Herb
Inocarpus fagifer	Indigenous	Tree, food
Intsia bijuga	Indigenous, very common	Tree, construction, medicinal
Ipomoea macrantha	Indigenous	Climber
Lantana camara	Exotic, Nat.	Shrub, noxious
Leucaena leucocephala	Exotic,Nat., common	Tree/shrub, noxious & invasive
Lygodium reticulatum	Indigenous	Fern
Macaranga sp.	Indigenous	Tree
Mangifera indica	Exotic, Nat., very common	Tree, edible fruit, construction, invasive.
Manihot esculenta	Aboriginal introduction	Shrub
Mikania micrantha	Exotic,Nat., common	Vine
Mimosa pudica	Exotic, Nat.	Noxious weed
Miscanthus floribundus	Indigenous, common	Grass
Morinda citrifolia	Indigenous	Shrub/tree, medicinal
Musa nana	Exotic.	Herb, Food
Nephrolepis biserrata	Indigenous	Fern
Pagiantha thurstonii	Endemic	Tree, construction.
Pandanus tectorius	Indigenous	Shrub/tree, medicinal, other
Panicum maximum	Exotic, Nat., common	Grass
Parinari insularum	Indigenous	Tree, construction
Passiflora foetida	Indigenous, common	Creeper, naturalized & invasive
Passiflora suberosa	Exotic, Nat.	Creeper,Invasive weed
Pennisetum polystachyon	Exotic, Nat., common	Grass
Phymatosorus grossus	Indigenous	Fern
Piper aduncum	Indigenous	Tree, invasive
Pometia pinnata	Indigenous	Tree, food, medicinal, timber
Pongamia pinnata	Indigenous	Tree, medicinal
Premna taitensis	Indigenous	Tree, local construction, medicinal
Psidium guajava	Exotic	Shrub/tree,Naturalized, noxious
Psychotria sp.	Indigenous	Shrub
Psydrax odorata	Indigenous	Shrub
Pycreus sp.	Exotic	Grass, weed
Rhizophora samoensis	Indigenous	Tree, medicinal, construction, other.
Rhizophora stylosa	Indigenous	Tree, medicinal, construction, other
Sida acuta	Indigenous, common	Herb, noxious weed
Spathodea campanulata	Exotic, naturalized	Tree, invasive.
Spondias dulcis	Aboriginal introduction	Tree
Sporobolus diander	Exotic,Nat.	Grass

Stachytarpheta urticaefolia	Exotic, Nat.	Herb
Syzygium malaccense	Aboriginal introduction, Nat.	Tree, edible fruit, medicinal.
Tacca leontopetaloides	Indigenous	Herb
Tarrena sambucina	Indigenous	Shrub/tree, medicinal
Tectaria latifolia	Indigenous	Fern
Terminalia catappa	Indigenous	Tree, construction, medicinal, edible fruit, other.
Thespesia populnea	Indigenous	Tree, medicinal, construction, other
Urena lobata	Exotic, Nat	Herb, weed
Vernonia cinerea	Exotic, Nat.	Herb
Vitex trifolia	Indigenous	Shrub, medicinal
Wollastonia biflora	Indigenous	Shrub.
Xylocarpus granatum	Indigenous	Tree, medicinal, construction
Zingiber zerumbet	Aboriginal introduction	Herb, medicinal

Appendix 2. LIST OF FISH SPECIES FOUND A WAIRIKI, BUA

Butterfly Fish	**Surgeon Fishes**
Chaetodon vagabundus	*Acanthrus olivaceus*
Chaetodon baronessa	*Acanthrus auranticavus*
Chaetodon citrnellus	*Acanthrus triostegus*
Chaetodon ephippium	*Acanthrus lineatus*
Chatodon oxycephalus	*Zebrasoma rostratum*
Chatodon lunulatus	*Ctenochaetus striatus*
Chaetodon pelewensis	*Ctenochaetus marginatus*
Chaetodon reticulatus	
Chaetodon plebius	**Goat Fish**
Chaetodon ulietensis	*Parapeneus indicus*
Chaetodon unimaculatus	*Parapeneus baberinus*
Chaetodon rafflessi	*Parapeneus barberinoides*
Heniochus acuminatus	*Upeneus vittatus*
Heniochus varius	*Upeneus arge*
Parrot Fish	**Morray Eel**
Scarus globiceps	*Gymnothorax eurostus*
Scarus spinus	
Scarus oviceps	**Trigger Fishes**
Cholorurus bleekeri	*Balistapus undulatus*
Cholorurus sordidus	*Pseudobalistes flavimarginatus*
	Sufflamen chrysopterus
Jacks	*Rhinecanthus rectangulus*
Caranx melampygus	
	Groupers
Emperors	*Epinephelus hexagonatus*
Lethrinus harak	
Lethrinus obsoletus	**Rabbit Fish**
	Siganus doliatus
Coral Breams	
Scolopsis bilineatus	**Damsels (Genus only)**
Scolopsis temporalis	*Abudefduf*
Scolopsis trilineatus	*Dascyllus*
Snappers	**Wrasse (Genus only**
Lutjanus quiquelineatus	*Helichoeres*
Lutjanus fulvus	
Lutjanus semucinctus	
Lutjanus ehrenbergii	
Lutjanus gibbus	
Macolor niger	