Lagoon degradation and management in Yanuca Channel on the Coral Coast of Fiji

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ABSTRACT

Yanuca Channel is a narrow marine lagoon separating a low limestone island in Cuvu Bay from the south west Viti Levu mainland in Fiji, known as the "Coral Coast". Historical air photographs show significant changes in the drainage configuration of the lagoon and local Fijian landowners give accounts of degrading environmental conditions in the lagoon due to sediment infilling. This investigation found several processes were responsible for the aggradation. Large quantities of terrigenous sediments are discharged by streamwaters into the lagoon, as a consequence of the removal of estuarine mangroves and agricultural practices such as burning and grazing in adjacent catchments. A previous outlet into the bay became blocked in the 1980s after inappropriate sand mining and vegetation clearance caused accelerated coastal erosion. The altered lagoon drainage pattern has led to lagoon eutrophication and aggradation. Developed on the island is a large international resort complex; the resort causeway constructed across the lagoon to the island has a significant dam effect, impeding the flow of currents and preventing the periodic scouring of sand from the lagoon floor. Several modern and traditional management options have recently been implemented to improve lagoon conditions, through partnerships between NGOs, traditional landowners and the resort management. These include riparian reforestation and the establishment of marine protected areas to conserve coral reefs.

Keywords: *Lagoon degradation, sediment aggradation, Fiji Islands, traditional coastal management*

1 INTRODUCTION AND AIMS

The south west coast of Viti Levu, the main island of Fiji, is known as the 'Coral Coast' and is a major tourist destination. Lying in Cuvu Bay at the western end of the Coral Coast is Yanuca Island, pronounced "Ya-nu-tha" in the Fijian language. Yanuca is a low-lying limestone island, 50 hectares in area (Figure 1). It is separated from the mainland by a narrow marine lagoon called the Yanuca Channel, varying from 90 m to 250 m across in width. On the mainland shores of the lagoon are the Fijian villages of Cuvu and Rukurukulevu. Cuvu is the paramount chiefly village of the *Nakuruvakarua* or high chief of the Nadroga Province. The chief has the title of *Na Turaga Na Ka Levu*. The *Nakuruvakarua* and people of Cuvu and Rukurukulevu villages are the traditional owners of Yanuca Channel, Yanuca Island and the adjacent fringing reefs and lagoons, in addition to a large area of mainland coast and regional hinterland. The lagoons and reefs are important fishing grounds (*qoliqoli*) and provide other traditional marine resources.

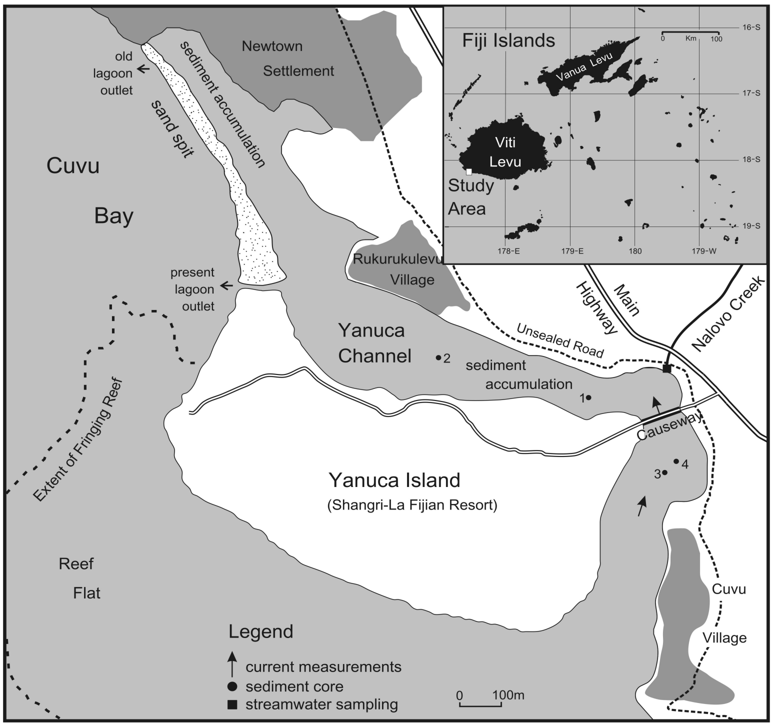

Figure 1. Map of Yanuca Island and Yanuca Channel in south west Fiji, and sites of lagoon sediment sampling and current monitoring described in the text.

Constructed on Yanuca Island is the Shangri-La Fijian Resort, an international tourist resort with extensive building complexes and a golf course. The resort is important for the local economy and a major employer of people from nearby villages and the surrounding area. Prior to the start of resort development in 1966, a causeway was constructed, linking the mainland to Yanuca Island in 1964 (Figure 2).

Figure 2. Top: Modern view of the resort causeway linking Yanuca Island with the mainland. Bottom: Yanuca Channel lagoon, downstream of the causeway at low tide, revealing dead corals and sand accumulation

This paper presents the findings of an investigation into problems and possible solutions of sediment accumulation and resulting deterioration of Yanuca Channel. This investigation forms part of a broader project which also surveyed the abundance of marine species in the lagoon and examined causes of shoreline erosion on the oceanside of Yanuca Island (Terry and Thaman 2001; Terry 2004). The impetus for the overall study was concern raised about declining health of the lagoon and surrounding reefs over recent decades.

Initial oral evidence from the people living in Cuvu and Rukurukulevu suggested that the lagoon conditions have seriously degraded within living memory. Questionnaire surveys of senior villagers indicated that healthy patch corals were once abundant in the channel, providing good fishing and areas for collecting food resources such as molluscs, octopus and sea cucumbers (Terry and Thaman 2001). They described a reduction in the extent of living corals, shallowing of the channel floor and an increase in the turbidity of the lagoon water. Several long-term employees of the Fijian Resort further explained how ten to fifteen years ago the lagoon was deep, whereas the floor of the lagoon is now exposed at low tide, suggesting that significant aggradation has occurred.

The management of the Fijian Resort is likewise concerned that sedimentation in Yanuca Channel is transforming a previously clear-water lagoon with abundant corals and reef fish into a muddy swamp environment. The former state is clearly preferable for tourism, since every tourist visitor gains their first impression of the resort environment as they cross the lagoon via the resort causeway. A muddy lagoon has little amenity value for tourists. Also, the resort runs daily pleasure cruises into the lagoon for the guests, but the increasingly shallow lagoon bed now restrict boat access at low tide.

For this study, the following objectives were undertaken. First sediments on the lagoon floor were sampled and analysed to determine their characteristics and thickness. Second, long term changes in the geomorphology of Yanuca Channel were assessed from archive maps, air photographs and earlier technical reports, in order to determine whether sediment accumulation is a recent or an historical problem. Third, the effects on lagoon sedimentation were investigated at the resort causeway and the Nalovo Creek which drains into the lagoon at its narrowest point (Figure 1).

2 PHYSICAL CHARACTERISTICS OF YANUCA CHANNEL AND ISLAND

The maximum elevation of Yanuca Island is approximately 5 m above mean sea level. The geology is Volivoloi Limestone, which has a variable composition of lithified calcareous sediments. There are more or less continuous coralline sand beaches on the west, south and east sides of the island. The ocean side of the island is fringed by living coral reefs in better health.

Yanuca Channel is a shallow marine lagoon (Figure 2), the floor of which is partially exposed at low tide. The lagoon has a microtidal environment with a spring tide range of only 2 m. The Nalovo Creek drains into the lagoon near the narrowest section of the lagoon, immediately north of the causeway. On both incoming and outgoing tides, current flow through Yanuca Channel is always in the same direction, coming from the south entrance to the ocean and exiting into Cuvu Bay. This is in response to the influence of the South East Trade Winds and breaking waves constantly dumping large volumes of water onto the fringing reef flat. These primary current-generating mechanisms cause the prevailing current to flow into the south end of Yanuca Channel at all phases of the tide. The flow is stronger during high tide when there is less protection afforded by the fringing reefs.

Variation in the character of the floor of Yanuca Channel was mapped by Prasad (1992), who identified three distinct sedimentary units. First he noted a unit of living corals and the calcareous algae *Halimeda*, with sea grass and dead corals in isolated patches. In calm conditions the lagoon had a thin deposit of unconsolidated carbonate sands, but elsewhere the floor was seen to be generally clean, with evidence of scouring. This description is in contrast to the present thick blanket of lagoon deposits (see next section). A second 'green algae unit' forms a linear sand body parallel to the north coast of Yanuca Island. A strong organic odour was present and disturbance released a dark plume of sulphides. This was explained by the decay of vegetation in a reducing environment and eutrophication due to discharge of waste water from the resort. Third there is a unit of bioturbated sand of grey, fine to coarse, carbonate materials with abundant shell and coral fragments. Bioturbation caused by burrowing crabs forms prolific conical mounds of sand approximately 15 cm high, 20 cm diameter and 0.5-1 m apart. These mounds were observed in this study over a large area of lagoon floor opposite Rukurukulevu village.

3 OBSERVATIONS AND MEASUREMENTS

3.1 LAGOON SEDIMENTATION

For the examination of lagoon sediment characteristics and thickness, vertical sediment cores were collected from the lagoon floor at two sites above (upstream of) and two sites below (downstream of) the causeway (Figure 2) during low tides on 13-14 February 2001. The coring equipment comprised 1.3 m lengths of 50 mm diameter galvanised steel pipe. The coring sites were surveyed by three-way compass and tape traverses from either side of the channel and the causeway. Cores were driven vertically into the sediments using a sledgehammer. Blocks of timber were held over the top ends of the cores to protect the pipes from the hammer blows and to seal the top ends of the pipes with a wooden plug. Once the top end of a pipe section was driven flush with the lagoon floor, it was then retrieved by digging.

Back in the laboratory, the steel cores were cut open lengthways by a milling machine. Care was taken to avoid losing material. After air drying at room temperature, the cores were divided into vertical increments of 10 cm and sieved through a 2 mm mesh to remove coarse coral fragments. A small fraction of each increment was then sieved through a 63 μm sieve to determine sediment texture by relative sand and mud content (Table 1). An attempt to measure the sediment accumulation rate using the caesium-137 method (Ashley and Moritz 1979; Ritchie and McHenry 1990) proved unsuccessful owing to low caesium counts in the sediment profiles.

From the sedimentology results, the following points emerge. A thick deposit of sediments (>130 cm) blankets the lagoon floor, since none of the cores penetrated to the underlying hard strata of dead corals. Examining the composition of lagoon deposits through time can provide information on any changes in the processes responsible for providing the sediments (Perry *et al*. 2006). However, for our samples, it is difficult to determine without detailed chemical analysis whether the sands and muds are of terrigenous or marine origin, because the local geology is a marine-deposited calcareous sand/mudstone, with a composition that broadly similar to modern lagoon sediments. The coarse fraction (>2 mm) is almost entirely made up of coral fragments, and is therefore reefal in origin.

There was no visible layering of lagoon sediments, and only small variation in the proportions of coarse gravels, sands and muds between sites. This suggests that the deposition rate has remained high over recent decades and there is regular bioturbation of sediments by macrofauna, such as the large colonies of fiddler crabs which inhabit the lagoon floor.

Table 1 Lithological logs from Yanuca Channel sediment cores

Depth (cm)	Total weight (g)	% Gravel > 2 mm	% Sand 63 µm - 2 mm	% Mud < 63 µm
Below causeway				
Core 1				
0-10	140.8	41.6	56.0	2.4
10-20	163.7	30.5	65.1	4.4
20-30	166.7	50.7	45.4	3.9
30-40	156.4	49.0	47.4	3.5
40-50	141.1	39.7	57.0	3.3
50-60	138.8	46.6	49.6	3.8
60-70	153.3	45.0	51.0	4.0
70-80	157.1	36.1	59.7	4.3
80-90	124.6	55.9	40.2	3.9
mean		**43.9**	**52.4**	**3.7**
Core 2				
0-10	116.6	14.7	81.0	4.4
10-20	137.7	16.5	80.2	3.2
20-30	213.4	36.9	60.4	2.7
30-40	251.8	45.7	52.1	2.1
40-50	216.7	57.8	40.5	1.8
50-60	270.1	54.6	43.7	1.8
60-70	198.4	47.1	50.7	2.2
70-80	275.2	54.5	43.6	1.9
80-90	213.3	32.9	64.8	2.3
90-100	194.6	42.1	56.2	1.7
100-110	200.6	54.4	43.2	2.4
mean		**41.6**	**56.0**	**2.4**
Above causeway				
Core 3				
0-10	190.2	17.6	80.4	2.0
10-20	138.0	54.9	43.0	2.2
20-30	139.2	66.9	30.9	2.2
30-40	178.4	29.5	66.1	4.4
40-50	184.4	20.5	75.3	4.2
50-60	189.6	26.6	69.9	3.5
60-70	209.4	45.4	51.7	3.0
70-80	165.0	37.4	59.3	3.3
80-90	145.6	29.3	67.1	3.6
90-100	129.7	21.9	74.6	3.5
100-110	100.1	20.8	75.8	3.4
mean		**33.7**	**63.1**	**3.2**
Core 4				
0-10	122.9	15.6	82.1	2.3
10-20	140.6	31.4	66.0	2.7
20-30	145.2	32.0	64.2	3.9
30-40	108.9	38.7	57.5	3.9
40-50	159.8	39.0	56.6	4.4
50-60	179.2	45.0	51.2	3.9
60-70	157.7	47.4	48.8	3.9
70-80	167.8	60.2	36.8	3.0
80-90	147.1	52.1	44.2	3.7
90-100	150.1	60.0	43.3	2.1
100-110	87.2	46.1	52.4	1.5
mean		**42.5**	**54.8**	**3.2**

In all cores, sand was the most important fraction making up 52-63% of the sediments, and coarse coral fragments provide 34-44% of sediments. All cores comprise less than 4% muds. The mud fractions are probably mostly terrigenous soils delivered by the Nalovo Creek into Yanuca Channel (see below). The lack of muds in the lagoon floor sediments indicates that their suspension residence time is sufficient for transportation by current flow through Yanuca Channel and out into Cuvu Bay.

3.2 CHANGES IN LAGOON GEOMORPHIC CONFIGURATION

Archive research of old maps and air photos reveals that the geomorphology of the north west end of Yanuca Island and drainage configuration of Yanuca Channel has changed through time. The earliest study of Cuvu Bay was in 1874 by officers of HMS Pearl for the British Admiralty, to produce a hydrographic chart for navigation. The 1874 chart shows the opening of Yanuca Channel into Cuvu Harbour almost at its present location, with an enclosed lagoon at the top end of the channel. However, the 1951 and 1995 pair of air photographs (Figure 3), taken from a low altitude at approximately the same location over Cuvu Bay and viewing the western side of Yanuca Island, illustrate marked changes over the last 50 years.

The 1951 photograph shows a wide spit previously formed a *circa* 400 m long peninsular adjoining the north west point of the island. The present spit is composed of coralline materials, predominantly medium to coarse grain sands, similar to the beaches along the ocean coast of Yanuca Island. In 1951 the spit was well vegetated with coconut trees and coastal shrubs. The presence of mature vegetation indicates that the spit had been stable for some time. The position of the spit directed currents flowing through Yanuca Channel to exit into the central area of Cuvu Bay opposite Newtown settlement.

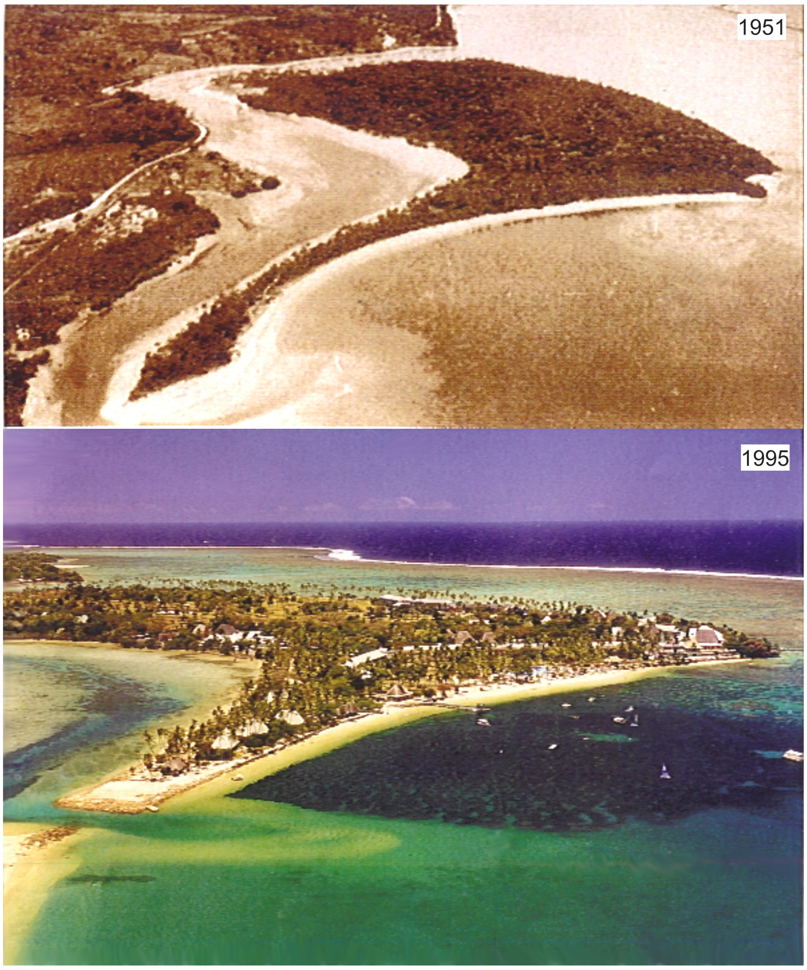

Figure 3. Oblique aerial photographs of Yanuca Channel and Yanuca Island in 1951 and 1995. Note the change in the position of lagoon outlet into Cuvu Bay. Source: Austin Bowden-Kirby (FSP) and the Fijian Resort.

Prasad (1992) examined more recent air photos (held by the Fiji Lands Survey Department) and reported that the beach front of the spit was eroding after 1979, with a maximum reduction in width of 40 m between 1979 and 1992. Anthropogenic disturbance was partly responsible for this erosion. During the mid-1980s, sand was regularly removed from the spit to replenish eroding beaches on Yanuca Island. Much of the vegetation growing on the spit was also cleared. Attempts by the management of the Fijian Resort to control the ensuing erosion of the spit with vertical wooden piles and a sand-bag groyne proved ineffective (Fijian Resort engineers, pers. comm.). The

1995 air photo shows that the south east end of the sand spit had separated from Yanuca Island. The breach was caused by wave action during Tropical Cyclone Sina in late November 1990.

The present passage through the spit close to Yanuca Island is now the only drainage exit for the lagoon into Cuvu Bay. The previous exit at the north west end of the spit has closed off through sediment accretion and northward growth of the spit by 50 m towards the mainland during the 1980s. The spit now joins the mainland as a peninsular, blocking the old drainage route of water out of the lagoon into the bay. The blocked 'cul-de-sac' section at the north end of Yanuca Channel now efficiently traps beach materials that are washed over the spit by large waves in storms. Algal blooms observed in the blocked cul-de-sac during fieldwork 2000 indicates that pollution and eutrophication are problems in this section of the lagoon because of poor flushing.

3.3 DISCHARGE FROM NALOVO CREEK

A threat to healthy conditions in the lagoon is the input of fluvial sediments by Nalovo Creek, which enters the lagoon through a road culvert 100 m north of the resort causeway. Although Nalovo Creek has only a small catchment area of 3.5 km^2 (Figure 4), a combination of both environmental characteristics and management practices in the catchment produce a large sediment input into the lagoon at times of high flow. First, the bedrock of the Nalovo Creek catchment is Naevuevu Siltstone. This calcareous rock, with a pale grey to off-white colour, is highly erodible. Second, the soils formed on the siltstone are weathered, highly friable and also easily eroded. Third, the catchment hillslopes are steep. Fourth, most of the original forest vegetation cover has been cleared by the landowners of Cuvu and Rukurukulevu villages, and replaced by farm plots of root crops, typically cassava, grassland for cattle and goat grazing, and a small area of sugarcane.

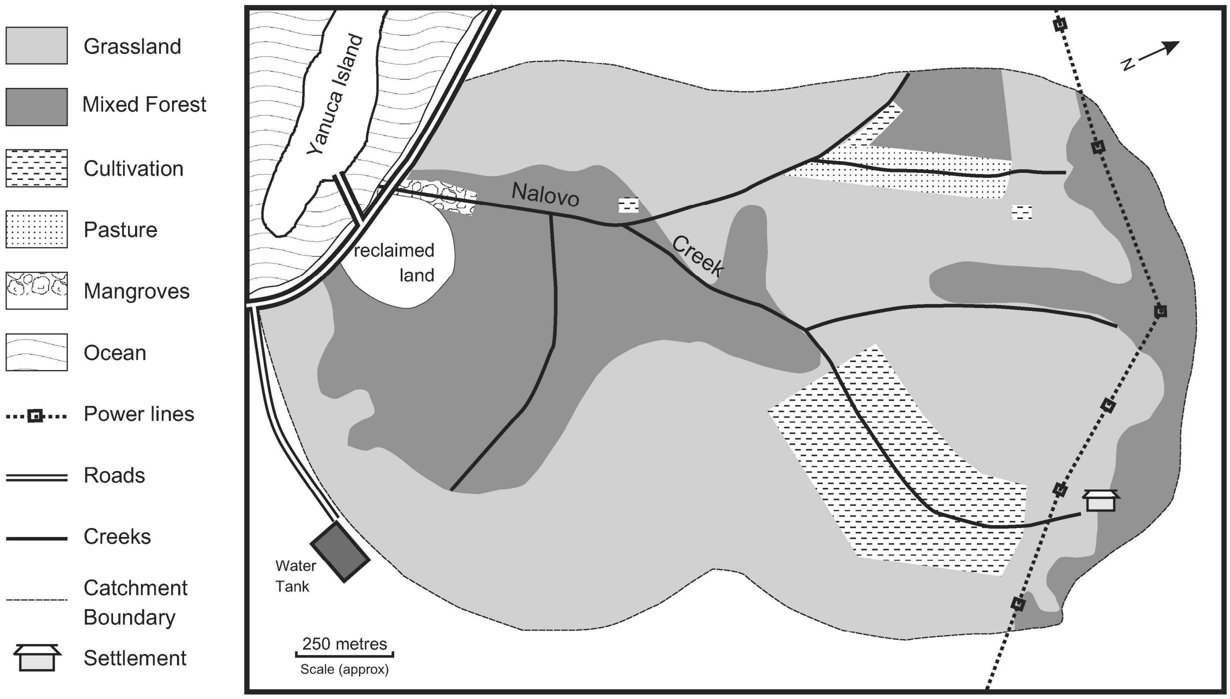

Figure 4. Land use in the catchment of Nalovo Creek, which drains into Yanuca Channel

Fifth, a common grazing management practice is to burn the grassland annually to promote new growth. Sixth, most of the original mangroves in the estuary of the creek have been removed and the land reclaimed for the site of the Fijian Resort Cultural Centre buildings. These factors promote catchment erosion, give Nalovo Creek a typically flashy behaviour, i.e. its discharge increases rapidly during storms, and present little opportunity for in-stream sediment trapping prior to discharge into the lagoon.

Consequently, Nalovo Creek delivers large loads of soil material into the lagoon in storms. This is illustrated in Figure 5, showing the Nalovo Creek in flood during a heavy rainstorm on 4 February 2001. This storm was associated with a slow moving trough of low pressure that affected much of southern Viti Levu. Heavy rain on 3-4 February led to flash flooding in the Central Division of Fiji (Fiji Meteorological Service 2001). The Nalovo Creek became a torrent within 30 minutes of intense rain and soon overflowed its road culvert into the lagoon. The torrent was highly charged with sediment, causing a turbid plume to stretch across the width of the channel to Yanuca Island. A later storm event was sampled at high stream flow on 10 April 2001 after a heavy downpour. Maximum recorded streamwater sediment concentration was 2331 mg l^{-1} (Table 2).

Figure 5. Top: Nalovo Creek in spate during an intense rainstorm on 4 February 2001; note the high turbidity of the water entering Yanuca Channel. Bottom: significant damming effect of the causeway in storm surge conditions during the passage of tropical cyclone Paula in March 2001. Source: Randy Thaman (USP) and the Fijian Resort.

Table 2 Suspended sediment concentrations in the Nalovo Creek

Sampling Date	Stream Discharge	Sediment Concentration (mg l^{-1})
12/02/01	low	43
08/04/01	low-medium	199
10/04/01	low-medium	127
10/04/01	high	2331

There is also the strong possibility that the narrow width of the lagoon outlet through the sand spit retards the natural flushing of water from the lagoon into Cuvu Bay, causing water build-up during high tides and flash flooding of the Nalovo Creek. This would aid sedimentation processes within the lagoon. No measurements were made of water discharge through the lagoon outlet as part of this study, but this would be a useful exercise as part of future investigation.

From investigation in coastal south west and south east Australia, Webster and Harris (2004) observe that many coastal lagoons are vulnerable to increased nutrient loads because of land use change. For this study area, lagoon eutrophication may be compounded by the use of manure on sugarcane farms in the stream catchment, but since the area under cane farming is small, daily discharge of N from eroded soil is not likely to be a big addition to the lagoon system. More nutrient pollution is caused by people keeping pigs in pens on the north shore of the lagoon at Newtown settlement.

3.4 DAM EFFECT OF THE RESORT CAUSEWAY

The 94 m long and 4 m wide concrete causeway across Yanuca Channel was constructed in 1964 to link Yanuca Island with the mainland. The average height from the top of the causeway to the lagoon floor is 1.67 m. The causeway has an ‘Irish crossing’ design, with a level access road built over 57 concrete culverts (Figure 2) to allow the transmission of water. The causeway was built across the narrowest part of the lagoon, but land reclamation at each end during construction increased the constriction. Visual reconnaissance during this study indicated that the causeway design restricts water flow through the channel towards Cuvu Bay. To investigate this effect, flow characteristics were measured across the lagoon in the vicinity of the causeway and partial damming by the structure was estimated from the difference in water level against the causeway between the upstream and downstream sides at high tide.

Current velocities were measured on an incoming tide on 14 February 2001, using a hand-held current meter connected to a digital logger. Readings were taken at 30 cm depths over 1-minute periods, in 20 m increments along a west to east transect above the causeway. Currents increased notably during swells, so the differences between swell and non-swell currents were recorded. The speed of water flow through the central span of the causeway was also measured for comparison. The results are summarised in Table 3 and displayed as proportional arrows in Figure 6 for clearer interpretation.

Table 3 Average current velocities across Yanuca Channel at high tide

Transect Point	Distance from Yanuca Island (m)	Average Velocity* (cm s^{-1})
1	20	68
2	40	28
3	60	26
4	80	28
5	100	29
6	120	35
7	140	37
8	160	24
	mean	34
9	velocity through central span of causeway	144

*average of four readings at each transect point

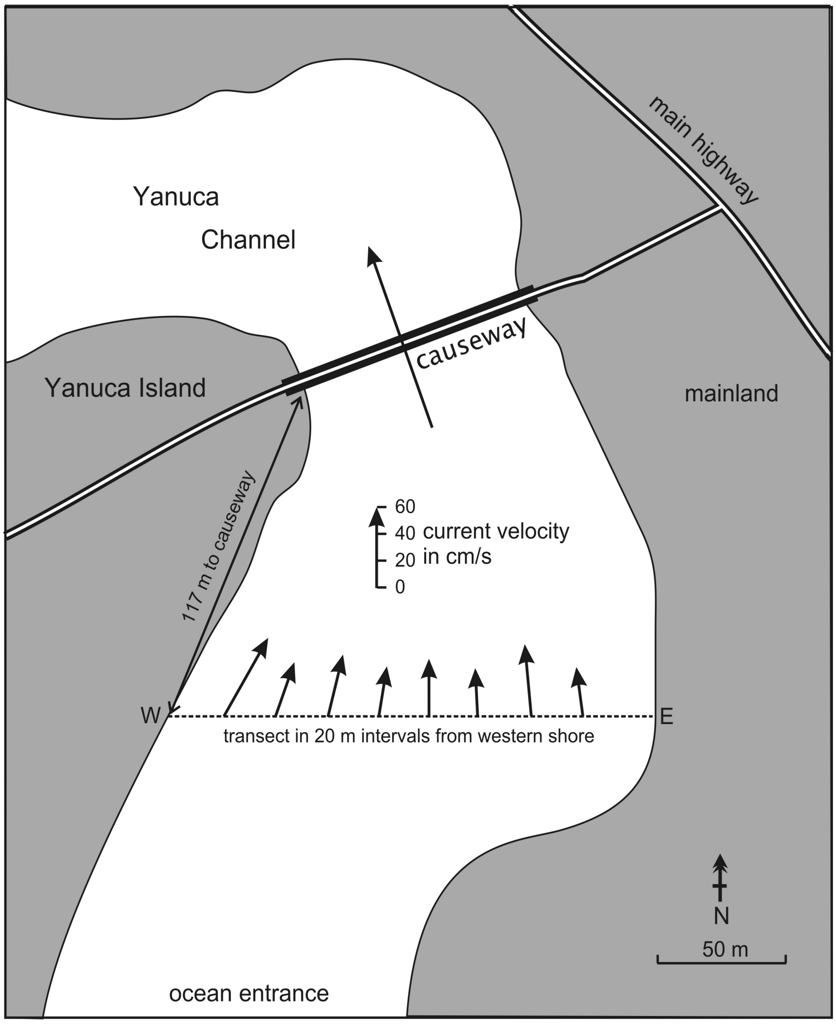

Figure 6. Proportional arrows showing measured current flow velocities on an incoming tide along a transect across Yanuca Channel and at the resort causeway.

Measurements show that there is a strong flow through Yanuca Channel on a rising tide. Velocity varies across the lagoon, with a measured average of 34 cm s^{-1}. Swells increased current velocity by 3-7 times at individual survey points. This indicates that the current is not tidal, but generated by waves and swells driven by the south east trade winds across the fringing reef flat opposite the south entrance to the lagoon. Maximum current flow will therefore be generated when the southerly swell is strongest and waves driven into the channel are largest. This will occur either when the south east trades are strong or during tropical storms blowing from a southerly direction. The fastest measured average current of 144 cm s^{-1} flows through the central rectangular span of the causeway. This is 4 times faster than the mean velocity measured in the channel upstream of the causeway, and shows that the causeway influences the normal flow in the channel, because an unconfined current increases if forced through a constriction.

The second task to estimate the dam effect of the causeway structure was carried out as follows. At high tide, the cross-sectional area of Yanuca Channel at the causeway is approximately 160 m^2. Since the causeway structure blocks part of the lagoon, there is an *apparent* dam area, which is the total cross-sectional area of the causeway structure, minus the surface area of the 'gaps' which allow water to flow through, i.e. the circular culverts and the central rectangular span. However, the apparent damming is less than the *actual* or real dam effect of the causeway, because the water velocity increases through the gaps because of water pressure. Table 3 earlier demonstrates this, as velocity through the causeway structure is significantly faster than upstream in the wider part of Yanuca Channel.

Yet, if the increase in water velocity through the culverts was sufficient to accommodate the channel flow entirely and reduce the actual dam effect of the causeway to zero, then the water level on both sides of the structure should be equal. Conversely, any observed difference in water level or 'head' on either side of the causeway indicates the magnitude of the dam effect.

At high tide on 14 February 2001, water level was measured simultaneously on opposite sides of the causeway at 45 equally spaced locations along its length. The average difference in water level on opposite sides was 12 cm. This equates to a causeway dam effect of approximately 20% of current flow at high tide (Terry and Thaman 2001). Furthermore, Figure 6 illustrates that damming is much more significant in tropical cyclones and storm-surge conditions. A storm surge is a temporary rise in sea level, caused by the very low atmospheric pressure close to the centre of tropical cyclones and other tropical depressions. Storm surges cause local submergence of any coral reefs that normally protect the coast from large wind-driven waves. These conditions occurred with the passage of Tropical Cyclone Paula across south western Fiji waters in March 2001, generating storm surge, large waves and swells. The significance of the causeway dam effect is that the strongest currents and largest waves generated in extreme conditions cannot sweep through the lower section of Yanuca Channel and scour loose sediments from the lagoon bed.

4 DISCUSSION OF MANAGEMENT OPTIONS

The sedimentation of Yanuca Channel represents deterioration of a natural lagoon, the health of which is important for maintaining the aesthetic value of the tourist resort on Yanuca Island. Any such environmental degradation threatens tourist numbers at the resort and consequently the employment of local people. Aggradation also impacts heavily on the productivity of the lagoon as a reliable subsistence fishing ground for the villages bordering the lagoon. Restoration of the lagoon is therefore an important long-term goal of the Fijian Resort and the local residents. In response, a range of remedial measures has been considered. Some of these measures involve partnerships between a number of stakeholders, including the resort management, NGOs, The University of the South Pacific (USP), several Fiji government departments, and the Fijian landowners themselves.

One possibility is to increase lagoon flushing by reopening the old drainage exit into Cuvu Bay at its previous location near the top end of the sand spit north of Yanuca Island. This soft engineering measure would improve the transport of suspended sediments by currents out of the lagoon into Cuvu Bay. In conjunction, the blocked and stagnant cul-de-sac enclosed by the spit may be dredged until the channel drainage has re-established its former course. Revegetation with native coastal forest along the sand spit would also help to stabilise the spit and reduce washover of sediments into the lagoon.

In the watershed of the Nalovo Creek, implementation of conservation measures to control hillslope runoff and soil erosion may reduce the source of terrigenous sediments entering the lagoon. A participatory workshop hosted by the Fijian Resort in 2001 and attended by NGOs, academics, scientists, local village elders and government representatives highlighted the problems associated with regular burning in the Nalovo catchment. Encouraging commitment was shown by the landowners to reduce this practice. At the same workshop, a programme was proposed to reafforest a riparian buffer zone with ethnobotanically and ecologically important species along the main Nalovo Creek watercourse and to replant mangroves in the stream estuary, in order to trap some stream sediment before it reaches the lagoon. In response, funds for purchasing tree seedlings were subsequently donated by the Fijian Resort, field and technical assistance was offered by the Foundation for the Peoples of the South Pacific (FSP), and manpower was provided by the villagers of Cuvu and Rukurukulevu.

Xue (2001) noted on Majuro Atoll in the Marshall Islands, that building causeways is one of the main influences on lagoon coast erosion. Here, replacing the resort causeway with an alternative structure, such as a bridge, is seen as an ambitious hard engineering solution to remove the present dam effect and avoid further aggradation in the lagoon, by allowing periodic scouring of the lagoon floor by storm waves. The cost of this measure may involve a large capital expenditure in the short term, but is being seriously considered as a long-term development project by the resort. A consulting engineering firm is currently examining the cost and feasibility of this proposal.

Most encouraging of all are some traditional and community-based activities that have already been implemented to attempt to reduce the delivery of coralline sediments into the lagoon from the adjacent fringing reefs. The people of Cuvu and Rukurukulevu villages have voluntarily set up marine reserves and established a traditional system of fishing taboos (for periods of a number of years) for selected areas of the surrounding reefs. A drive to catch and remove predatory crown-of-thorns starfish from the reefs has also been successful. In addition, coral garden 'planting' has been a small-scale project carried out in the vicinity of the resort. Together these measures will have the long-term advantages of restoring reef ecosystems, increasing the abundance of reef fish stocks for future harvesting by the local people, as well as improving the value of the reef for tourism-related activities.

5 SUMMARY AND CONCLUSIONS

This study has identified three sets of influences as responsible for problems of sediment accumulation and associated degradation in the shallow coastal lagoon known as Yanuca Channel on the south coast of Viti Levu island in Fiji. First, the Nalovo Creek draining into the lagoon is an important contributor of terrigenous sediment at high stream flows. Farming, grazing and regular burning in the steep catchment, the erodible nature of the weathered soils, and reclamation of estuarine mangroves are factors that promote high streamwater turbidity. Second, historical changes in coastal geomorphology have led to a shift in the position of the lagoon-drainage exit into Cuvu Bay, causing stagnation in the northern section of the lagoon.

Third, the resort causeway, built in the 1960s, restricts the flow of currents and the movement of storm waves through the lagoon, especially at high tide and during tropical cyclones and strong surge events. In the past, infrequent powerful storms scoured the lagoon bed and swept sediments out into Cuvu Bay, effectively preventing long-term aggradation. The significant damming effect of the causeway now prevents this from occurring.

The combination of the new lagoon drainage configuration, the causeway dam effect, and sediment input from Nalovo Creek, explains the aggradation and decline in environmental conditions in Yanuca Channel, compared to earlier accounts of a clean and scoured lagoon floor with healthy patch corals. Encouragingly, cooperation between local Fijian villages, the Fijian Resort on Yanuca Island and several non-governmental organisations have led to a number of modern and traditional management options being proposed, to improve lagoon conditions and the health of surrounding reefs. Some restorative activities are already in place; after a five to ten year period the benefits of these measures will be assessed.

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