The need for an integrated approach to understanding and managing coastal change in river delta areas

The case of the Rewa River

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Abstract

The watershed area of the Rewa River, the largest river in Fiji, takes up about one-third of the total land area of Viti Levu. The Rewa watershed receives high rainfall, and the Rewa catchment has the highest run-off coefficient for the major rivers in Fiji. Flooding of the Rewa River and delta causes massive losses, to the local people and to the nation in damage to infrastructure, economic costs of rehabilitation and financial assistance to affected communities. Not only is flooding of the Rewa River a major stumbling block to the expansion of Nausori Town, it also affects land formations in the delta: over time, the Rewa delta has undergone physical change, as is characteristic of deltas around the world. The causes of flooding have been attributed to a combination of factors, both natural and anthropogenic . Mitigating the effects of flooding requires an integrated approach.

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Introduction

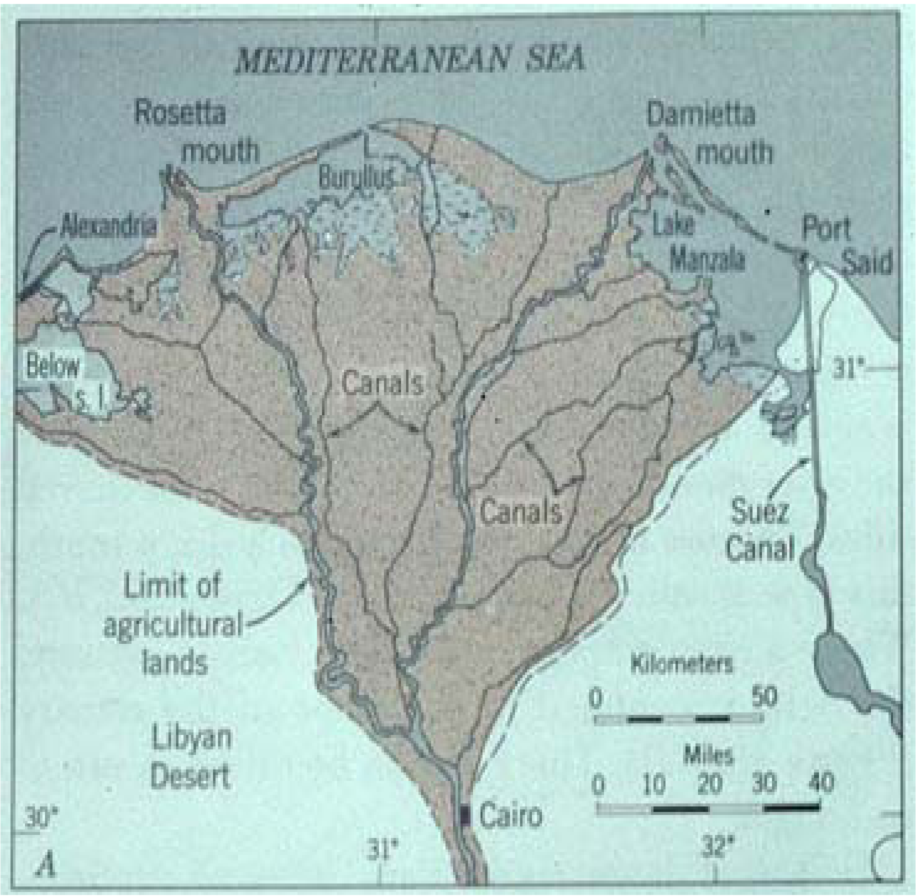
River deltas are unique regions or components of river systems, characterised by high species diversity, high production rates and, most notable, the dynamism of the area. A delta is created at the mouth of a river where that river flows into an ocean, sea, estuary, lake, reservoir or flat arid area (http://en.wikipedia.org). The term delta was first used for such landforms because of the resemblance of the shape of the landform to the fourth letter of the Greek alphabet, and it was first used for the River Nile, the Nile Delta (Figures 1a and b) in 1555 BC , around the same time as the term 'alluvial deposit' was first recorded (http://en.wikipedia.org). In fact, deltas are formed when a river deposits material faster than the sea can erode it. This signalled the 'beginning of the imbalance', most probably caused by man disturbing the natural balance of ecosystems in the river catchments . Land clearing leads to soil erosion and increased sedimentation of rivers, which results in the filling of the estuary as oceanic waters come into contact with sediment-loaded freshwater.

Figure 1a River Nile delta, of which the term delta was first used. The shape resembling the fourth letter of Greek alphabet, which explains the origin of the name delta, is clearly seen.

Source Wikipedia search, December 2010.

Deltas commonly have three main characteristics: a large catchment, or drainage basin (the area where all run-off water drains to the river); location at the mouth of a large river system that carries large quantities of clastic sediments (soils or portions of rocks that have been moved by water from where they formed); and location distant from geologically active coastlines (http://en.wikipedia.org). Delta formation and behaviour depends on: sediment deposition vs erosion by the sea; coastal/inshore currents and wave energy; land and soil characteristics and terrain around the river mouth; and land use and its changes both at the river mouth and in the catchment (Figure 1b).

Figure 1b The Nile Delta, showing canals characteristic of river deltas.



The Rewa River Delta

The Rewa Delta was formed through the process of progradation or growing out into the sea, through five principal lobes, as sediment deposition occurred at a faster rate than erosion by the sea (Figure 2). Each lobe has well-developed natural flood channels (distributaries). Flood channels become abandoned during normal river flow, but they fill up and provide outflow during floods. Problems and much damage occur when development activity disregards the presence, location and uses of these flood channels. Any flood mitigation effort must take these natural flood channel systems and their historical use into consideration.

Figure 2 The Rewa Delta, showing the 5 principal lobes with associated flood channels.

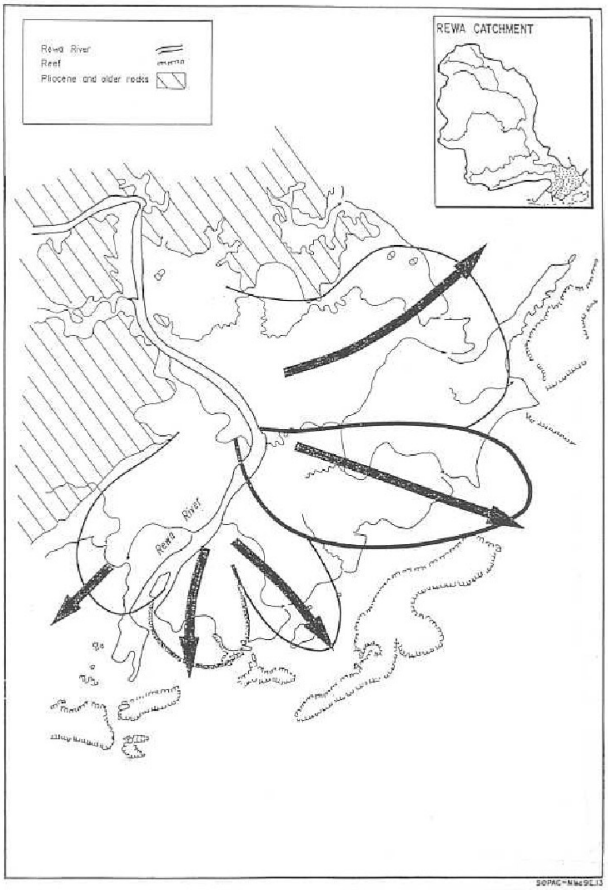


Figure 7. Map of the Rewa delta showing the principal lobes which constructed the present delta over the past 6000 years. Arrows indicate the main direction of discharge as each lobe was active. Note the position of present major channel and old channels, many of which are abandoned in normal flow conditions.

[MR149 - Howorth, Baleivanualala, Prasad]

Source Howorth et al., 1993.

The Rewa River and watershed

The Rewa River is the widest river in Fiji, and its watershed is the largest watershed in Fiji, covering an area of 3,092 km2 which is about 1/3 of the total area of Viti Levu (JICA, 1998). The Rewa River originates in the largest peak in Fiji (Tomaniivi) in Ra Province, is fed by two large tributaries, the Wainibuka and the Wainimala, in the upper reaches, while the smaller tributaries such as the Waidina and the Waimanu contribute to the flow in the lower reaches of the Rewa River. The watershed spans five provinces, namely Ra, Namosi, Naitasiri, Tailevu and Rewa (Figures 3b and 3c). These provinces are connected by tributaries of the Rewa River, but each is noted for very different land-use patterns, resource usage and contribution to the national economy.

Figure 3a Map of the Fiji Group

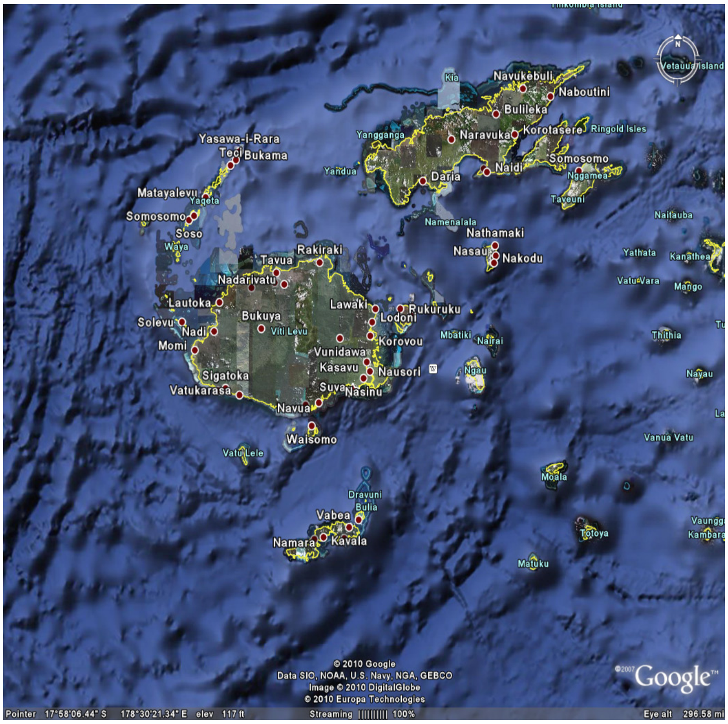


Figure 3b Map of Viti Levu

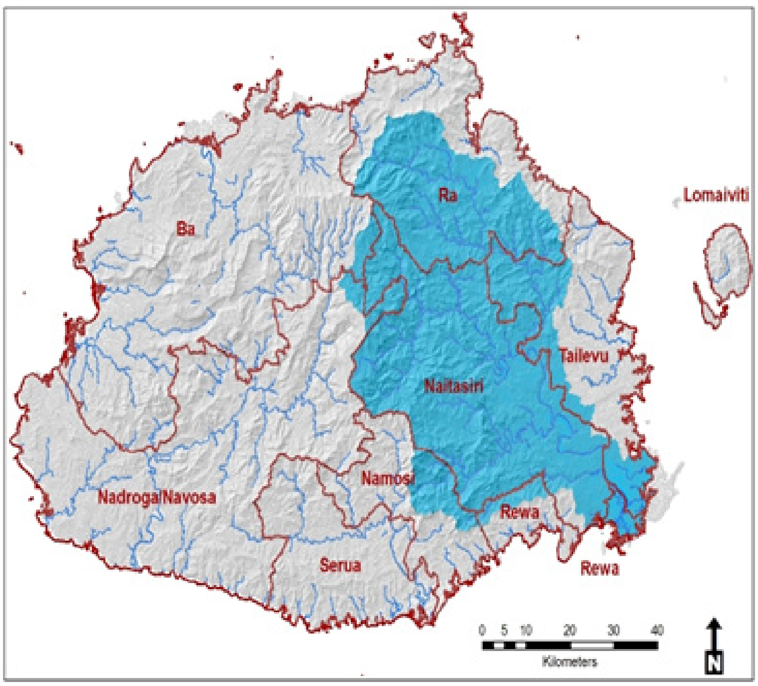
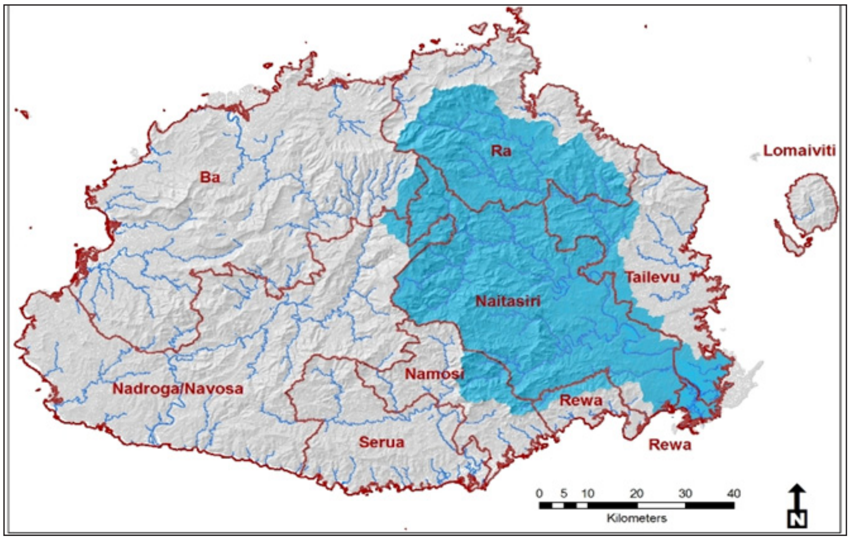


Figure 3c The Rewa watershed (shaded) spanning 5 provinces (Ra, Naitasiri, Tailevu, Namosi and Rewa).



In Namosi Province, where the Waidina River originates, the government-endorsed exploratory work for what is potentially the biggest copper mine project for Fiji is currently being assessed in an EIA study and process. In Tailevu Province, where one of the major tributaries (Wainimala River) originates, the country's main pastoral and dairy farms are located. Also, in the last several years, the construction of the Kings Highway along the northern parts of Viti Levu has been a major activity in the Tailevu Province. In Naitasiri Province, the country's largest hydropower plant is located in the upper reaches of the Wailoa River, which drains into the Waidina River. Logging of forests in the upper reaches of the Rewa River and intensive agriculture in the lower reaches of the rivers are having significant effects on the water quality in the Rewa River. The culmination of these activities in the Rewa watershed often impinges most grievously on the communities, the businesses and the villagers occupying the lower Rewa and the delta areas during periods of heavy rain and associated flooding. The high rainfall and the physical attributes of the terrain in the Rewa watershed exacerbate the devastating effects of flooding in the Rewa Delta.

This watershed receives high rainfall of 2,500–> 4000 mm annually, one of the highest for Fiji. The Rewa watershed also has the highest runoff coefficient (0.6–0.9) when compared to Nadi and Ba catchments (0.4–0.6), computed from annual rainfall and annual discharge figures (JICA, 1998). The very steep terrain is another contributing factor to erosion: as much as 70% of the Rewa drainage basin has slopes of >18^{o} (Morrison, 1992). The Rewa watershed recorded the highest soil loss in comparison with the other watersheds in Fiji, namely Ba, Sigatoka and Nadi (Table 1). Studies of soil within the Rewa watershed showed that the soil has a high erosive index of 1500–2000 (Willat & Limalevu, 1994). These are factors contributing to the severe soil loss and floods for which the Rewa River and delta have, historically, been renowned.

Table 1 Soil loss in Fiji's watersheds

Watershed	Soil loss (ton /ha/year)	Soil loss (mm/year)	Total soil loss (million ton/year)
Rewa	32.3	2.2	9.3
Ba	69.0	4.6	6.4
Sigatoka	76.9	5.1	1.1
Nadi	81.4	5.4	4.2

Flooding and the changing landforms in the Rewa Delta

Flooding severity and effects are determined by both natural factors (rainfall, physical terrain, soil characteristics, as outlined above) and anthropogenic factors including: land use practices that ignore conservation guidelines; population increase; development requiring land clearance; and development that ignores natural flood channels.

The worst floods and associated economic costs are directly linked to major tropical cyclones in Fiji (Figure 4, see appendix). In December 2009, one of the worst ever cyclones to affect Fiji, cyclone Mick, caused devastating floods in the Rewa River and delta (Figures 5a–d, in the appendix). The total economic loss from effects of floods associated with cyclone Mick was estimated at around FJ$38 m, according to the National Disaster Management Office (NDMO, January 2010). Flooding and the progressive interplay between the processes of sediment deposition and erosion around the Rewa River estuary have resulted in shifting shorelines and coastlines, as shown in the series of maps (Figures 6; 7a–c). The maps have been produced from GIS analyses using aerial photographs from 1954, 1967 and 1998, and the 2009 acquired satellite image of the lower Rewa River and delta.

Figure 6 Lower Rewa River showing water and sediment sampling sites, and dredge spoil; deposition sites for the dredging project 2010–2011.

Changes in the shape and size of Laucala Island and the Rewa River Mouth were assessed as part of the Rewa River Dredging EIA Study conducted by the Institute of Applied Sciences (IAS), University of the South Pacific (USP) in 2009 (Tamata et al., 2010). The GIS analyses on the aerial photographs and satellite image of 2009 showed that the Rewa River mouth and delta area were a highly dynamic area, with the following general findings:

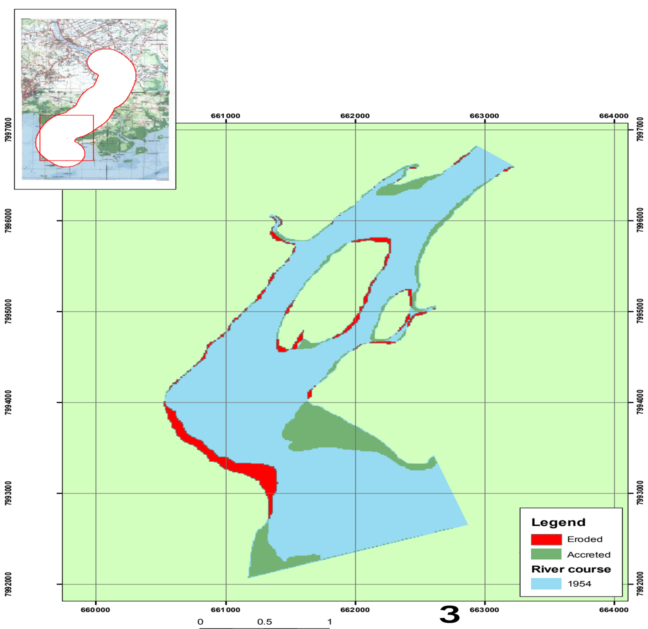
- accretion was occurring faster than erosion between 1954 and 1998, a factor that may have contributed to more severe flooding (as the estuary filled up and delayed the out-flowing of flood waters) during that period
- the north-east facing side of Laucala Island experienced erosion throughout – a total of ~500 m of part of Laucala Island disappearing into the river between 1954 and 2009.

Using the GIS software (ArcMap v. 9.x) and specific spatial analytical methods, each pair of images was analysed to estimate areas of accretion and erosion in the lower Rewa River: 1954 with 1967 aerial photographs; 1967 with 1998 photographs; and the 1998 photograph with the 2009 satellite image, resulting in three maps delineating areas of accretion and erosion. The changes are summarised below.

a) Lower Rewa River changes, 1954–1967

The main area of accretion was north-west of Mataisuva Point, i.e. the eastern side of the river bank. The accretion resulted in the westward extension of the eastern river bank (into the main river channel) by 450 m. Erosion occurred on the opposite side, i.e. on the west bank of the river. The width of the river at its narrowest point was constricted to 450 m (Figure 7a).

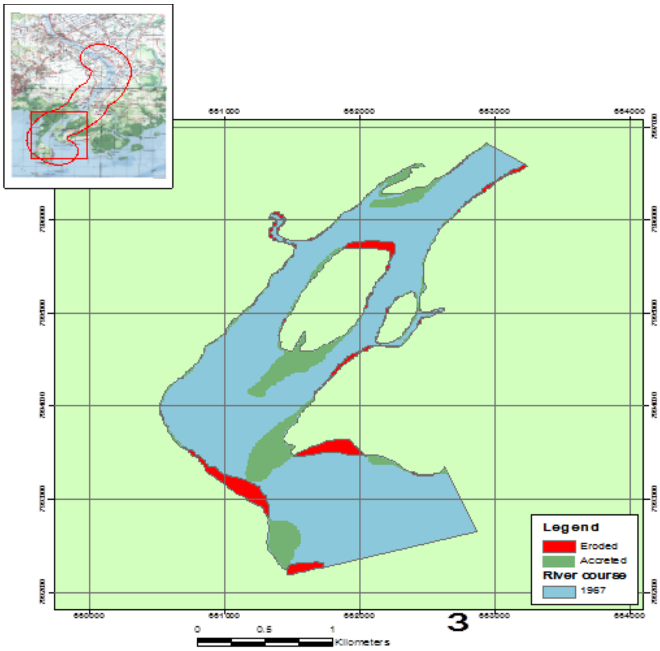
Figure 7a Changes in the Lower Rewa River between 1954 and 1967, showing areas of accretion and erosion



b) Lower Rewa River changes, 1967–1998

There were more areas of accretion, this time: north-west of Mataisuva Point; the southern side of Selo Island, where there was a linear extension of ~530 m; and at the north end of east-facing sand beach of Laucala Is., resulting in a north-east migration of river bank by ~230 m. Meanwhile there was erosion on the opposite bank (Figure 7b).

Figure 7b Changes in the Lower Rewa River between 1967 and 1998, showing areas of accretion and erosion

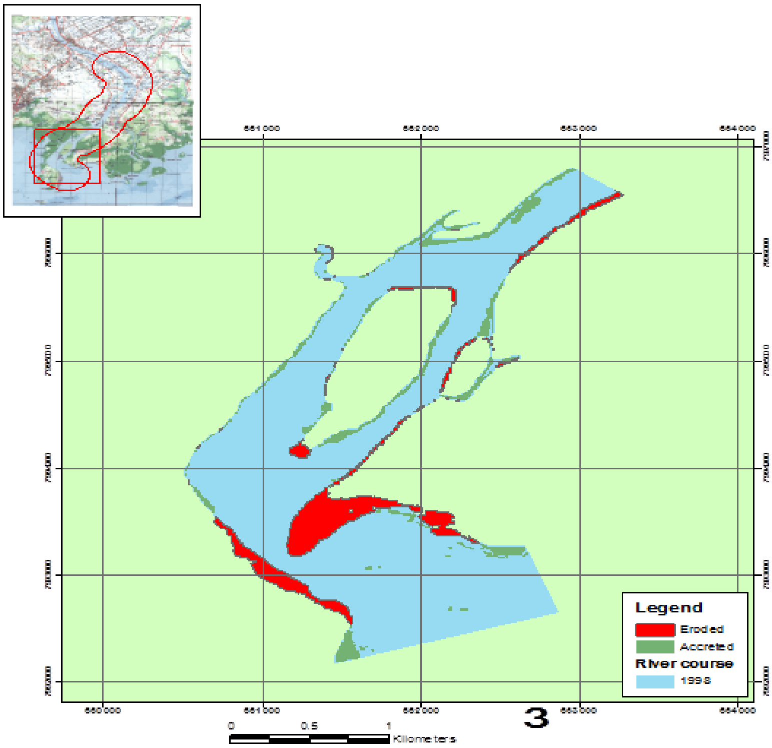


Source JICA, 1998.

c) Lower Rewa River changes, 1998–2009

There was substantial erosion at the headland, north-west of Mataisuva Point (which was previously accreted) by ~600 m, to within 20 m of its 1954 position. This phenomenon shows how dynamic such an area is, and why flood mitigation strategies need to take into account historical events and changes. During this period, erosion continued on the opposite bank, at the narrowest point of the river mouth, by a further 150 m. This brought the total eroded coastline on Laucala Is. to ~500 m, a substantial loss indeed for an island that supports much of the plantations for the villagers in the Rewa delta (Figure 7c).

Figure 7c Changes in the Lower Rewa River between 1998 and 2009, showing areas of accretion and erosion



Flood mitigation options

The Fiji government, through the Ministry of Primary Industries, has implemented a number of measures to try to mitigate the effects of floods in the Rewa and other major rivers in Fiji (LAWRM, 2009). A team of experts from Japan conducted a major study of the main watersheds in Fiji, including the Rewa watershed, to assess the whole spectrum of conditions (physical, sociocultural, economic) for each watershed and recommend the most appropriate flood mitigation options. One of the non-structural options proposed is dredging of the river mouth, and this has been carried out for some time now in the Rewa, Ba, Navua and also the Nadi Rivers.

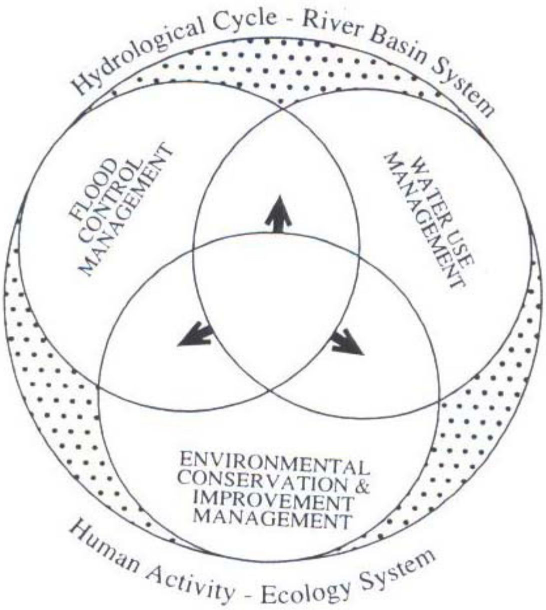
Dredging

The question often asked is whether dredging is a sustainable solution to flooding problems. Dredging is only a temporary flood mitigation option. The dynamic nature of the Rewa River mouth (accretion and erosion continually interchanging) requires an integrated approach that extends upstream to the catchment. Dredging is expensive and the government, not (currently) having the machinery needed to dredge the rivers, out-sources this task; for example, the Chinese Railway Company was dredging the Rewa and Nadi Rivers in 2010–2011. There are many uncertainties – when to dredge; exactly where to dredge and to deposit the spoil; how much to dredge; and so on. At times, dredging of the river mouths has created other problems, particularly at the disposal sites (Fiji Times, September 14 2010). The JICA study (1998) recommended the integrated management of watersheds, for sustainable flood mitigation.

Integrated watershed management

The JICA study of major watersheds in Fiji proposed a Framework for Watershed Management, as a sustainable framework for flood mitigation (Figure 8).

Figure 8 The proposed Framework for Watershed Management (JICA, 1998).



Source JICA, 1998.

The Framework recognises the connection between two main systems: the hydrological cycle – river basin system; and the human activity – ecology system.

The balance between these two systems can be achieved by the sustainable management of three inter-connected sub-systems: flood control management; water use management; and environmental conservation and improvement management.

Conclusions

The sustainable management of the Rewa Delta and its problematic flooding events requires a holistic and integrated approach. Dredging is only a temporary flood mitigation option, which has many disadvantages counterbalancing its benefits. The technical knowledge that is contained within agencies like SOPAC (Applied Geoscience and Technology Division), USP, and the Hydrology section of the Public Works Department needs to be shared and fed into the Integrated Management Information database. The important stakeholders that ought to play their role include government (through Forestry, Mineral Resources, Agriculture, and Public Works ministries and LAWRM); Provincial (Ra, Tailevu, Naitasiri, Namosi and Rewa); non-government (including church and the traditional leadership) and external donor agencies.

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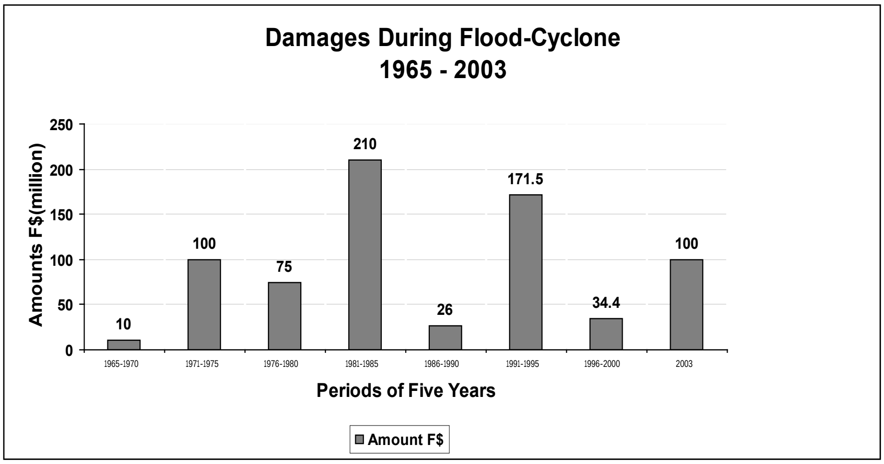
Appendix

Figure 4 Costs of damage from floods and cyclones in Fiji



Note Highest peak of 210 m (1981–1985) from 7 cyclones in Fiji.

Source Director, LAWRM, 2009.

Figures 5a–d Cyclone Mick of December 2009 caused devastating floods in the Rewa, as seen in the photographs a, b, c, and d.

a. Water level beneath the old bridge as seen from the new bridge.

b. Looking across the Rewa River from the Suva bank.

c and d Before the floods (above, photo taken from boat looking towards Davuilevu) and during the floods (below, photo taken from highway looking towards Nausori), showing destruction to Metromix cement plant (yellow).