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The Exceptional Flooding on Vanua Levu Island, Fiji, during Tropical Cyclone Ami in January 2003

James Peter TERRY[1], Simon MCGREE[2] and Rishi RAJ[3]

[1]Head of Geography Department, The University of the South Pacific, Private Mail Bag, Suva, Fiji Islands
[2]Climate Services Division, Fiji Meteorological Service, Nadi Airport, Fiji Islands
[3]Hydrology Division, Fiji Public Works Department, Tamavua, Suva, Fiji Islands

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ABSTRACT

In mid-January 2003 Tropical Cyclone Ami passed directly across the Fiji Islands in the southwest Pacific Ocean. The main northern island of Vanua Levu experienced torrential rainfall and consequent record-breaking flooding of its major rivers. The aims of this study were to document these record floods and compare them with previous floods on Vanua Levu Island. The Nasekawa River in southern Vanua Levu produced a phenomenal discharge of more than 6100 m^3/s. Moreover, near the main town of Labasa on the north coast, simultaneous flooding of the Labasa, Qawa, and Wailevu rivers combined with storm surge to cause inundation of up to 4 m depths over a wide area of the floodplain. Tragically, seventeen people died, and there was extensive damage to farms, the infrastructure, homes, and commercial property.

Historically, the north coast of Vanua Levu island has suffered frequent severe floods, owing to several factors: 1. the approach of most tropical cyclones towards Fiji from the northwest; 2. Vanua Levu's steep volcanic topography, which rises in excess of 1000 m, and has strong orographic influence on rainfall generation during tropical storms, then rapidly transfers moisture into river channels, 3. the configuration of several drainage basins which deliver floodwaters to the same area of the coastal hinterland. Future regional ocean warming and more sustained El Niño conditions are projected to increase the intensity of tropical cyclones and thereby the potential for worse flood disasters. Disaster mitigation and adaptation options recently proposed by the World Bank and JICA need to be implemented to reduce flood impact in this vulnerable area of Fiji.

1. INTRODUCTION

Tropical Cyclone Ami (TC Ami) struck the Fiji Islands on 14 January 2003. The system originated as a tropical depression far to the east of Tuvalu on 10 January 2003 and strengthened into a tropical cyclone near Niulakita Island on 12 January 2003 (Fiji Meteorological Service 2003). TC Ami rapidly developed into an intense system with very destructive hurricane force winds. Its track passed across the large, well-populated island of Vanua Levu in northern Fiji. Resulting destruction was extensive and severe due to high winds, heavy seas, and torrential rainfall. Some of the worst-ever flooding occurred in many rivers on Vanua Levu Island, and tragically 17 lives were lost. The aims of this study were to document these record inundations and to compare them with previous large floods on Vanua Levu. This is important because flooding may become more severe in the future owing to an increase in tropical cyclone intensity in the South Pacific region if the climate changes due to more sustained El Niño-like conditions, as many climate scientists now project (see Holland, 1997; Trenberth and Hoar, 1997; Timmermann *et al*., 1999; Whetton *et al*., 2000). Such information will assist us in education for better disaster preparedness and in planning for improved flood adaptation measures.

2. CYCLONE HISTORY

TC Ami was the third tropical cyclone to form in the Fiji area (RSMC Nadi[1]) during the South Pacific cyclone season in 2002-2003 (November to April). A tropical depression, coded TD 05 F, was first identified as an embedded system in an active monsoon trough about 386 km east of Funafuti Atoll in Tuvalu at about 9 a.m., FST[2] local time on 10 January 2003. Its development was affected by diurnal variations and relatively strong vertical shear, but the system moved steadily southwest. On 12 January, TD 05 F underwent rapid maturation. Subsequently, the storm was named *Tropical Cyclone Ami* about 12:00 FST on 12 January, while it was located near Niulakita Island (Fig. 1) and blowing gale force winds[2] across southern Tuvalu (average 75 km/h and momentary gusts to 100 km/h).

Initially, the cyclone followed a southwest track at about 15 km/h but gradually veered southwards as it approached the island

KEY WORDS: Fiji Islands, tropical cyclones, river floods

[1] Fiji Meteorological Service, Regional Specialised Meteorological Centre (RSMC Nadi Airport) area of responsibility.
[2] FST (Fiji Standard Time) is equivalent to UTC (GMT) + 12 hours.
[3] Tropical cyclone strength based on wind speed:

TC strength	average wind speed km/h	wind gusts km/h
Gale force	63 – 87	up to 120
Storm force	88 – 117	up to 157
Hurricane force	=118	=157

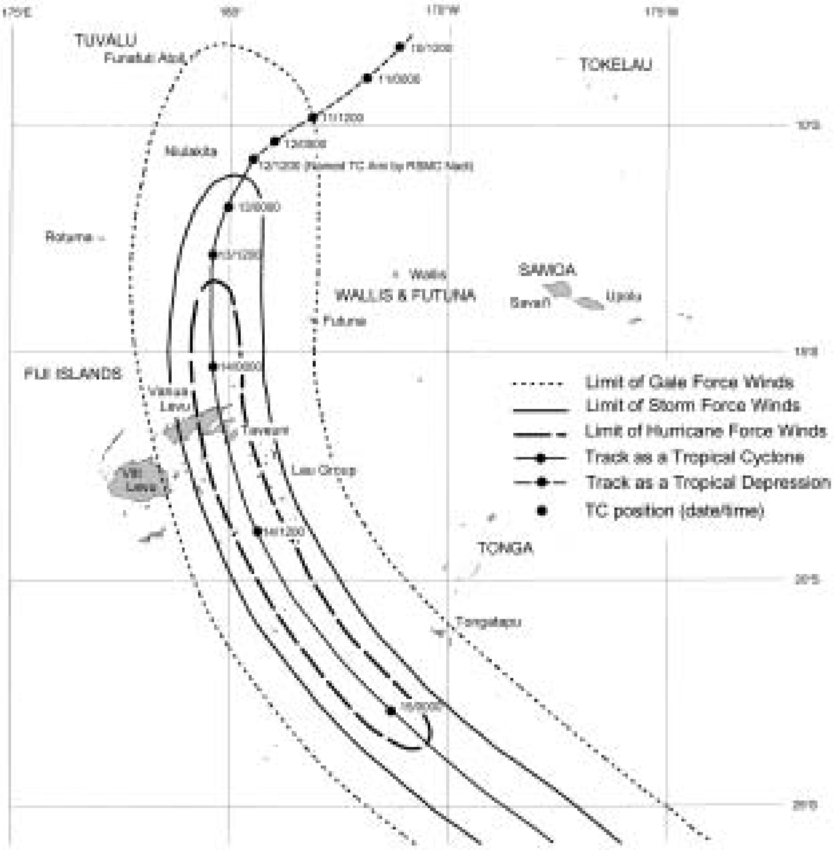


Fig 1. Track of Tropical Cyclone Ami 10-15 January 2003, showing the approximate limits of gale, storm and hurricane force winds.

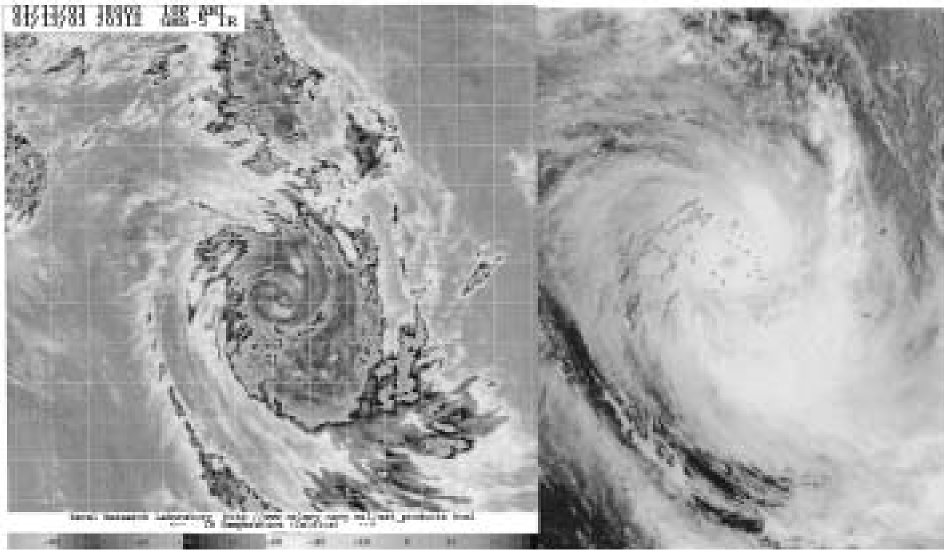


Fig 2. Two satellite images of TC Ami taken at approximately the same time on 14 January 2003 (but at slightly different scales). The centre of the storm is passing through the eastern Fiji Islands (the Lau Group) on a south southeasterly track. The left picture is a thermal image of the upper level temperatures. Right is a visible image showing the organisation of the cloud bands. Source: US Navy and NOAA.

of Rotuma. Once named, TC Ami intensified quickly to storm strength about midnight on 13 January, with destructive winds of 110 km/h and momentary gusts 140 km/h. Operationally, the system then behaved as expected, except for rapid intensification to hurricane force on 14 January and acceleration along its path. At 1.51 a.m. 14 January the first *hurricane warning* was issued by the Fiji Meteorological Service. The eye of the storm then was located by radar about 225 km north-northeast of Labasa Town on Vanua Levu. As Ami travelled quickly south, the radius of its damaging gale and storm force winds increased. The cyclone centre made landfall near Dogotuki on the north-east peninsula of the Vanua Levu coast shortly after 3 a.m. 14 January, bringing extremely destructive hurricane force winds (averaging 140 km/h and maximum gusts of up to 185 km/h) to much of Fiji's Northern Division. Thereafter, Ami accelerated and turned south- southeast.

The eye passed the western tip of Taveuni Island after 5 a.m. 14 January. The system then moved rapidly through the Lau Island group (Fig. 2), curving more to the southeast as it did so. At 12 noon 14 January, Ami reached peak intensity while its centre was located about 97 km south- southwest of Lakeba Island. Ten-minute average winds of about 200 km/h with momentary gusts of 230 km/h were reported (NIWA 2003). Ami travelled south southeast at 22 km/h as it left Fiji waters, maintaining hurricane intensity.

Next, it brushed past Tongatapu Island in the Kingdom of Tonga, driving enormous seas and causing widespread damage due to gale force winds and heavy rain. The storm held a south-easterly track and further accelerated as it moved out of RSMC Nadi's tracking area. The system retained tropical cyclone status for another 18 hours inside the New Zealand (RSMC Wellington) area of forecast responsibility. The tropical cyclone structure then decayed, and Ami made the transition to an extra-tropical low pressure system at midnight, 16 January. This was attributed to strong vertical shearing and cooler sea surface temperatures.

3. CYCLONE EFFECTS

The destruction caused by TC Ami was extensive and severe (e.g., Fig. 3), across Fiji's Northern and Eastern Divisions, especially to roads, the infrastructure, buildings, houses, farm animals, crops, and natural vegetation. The confirmed number of fatalities was 14 and 3 people were counted as missing. Communications to and within the two divisions were cut for several days, and Fiji's Disaster Management Centre declared Vanua Levu Island a natural disaster zone. Massive waves and strong storm surges led to both coastal and inland inundation in many areas along Ami's path. Deep flooding in Labasa on Vanua Levu had severe effects on the town's population (Fig. 4) and posed serious health and environmental risks. Domestic water supplies were badly disrupted, leaving residents without clean drinking water and forcing the Fiji Government to transport potable water from mainland Viti Levu Island to affected areas. Torrential rain led to many valley slopes failing in landslides, and on the low-lying floodplains huge quantities of sediment deposited by the swollen rivers ruined many sugar cane farms. The extent of damage requiring immediate government attention was valued at $F60 million. The socio-economic loss, however, is likely to have exceeded $F100 million (FMS 2003).

3.1 Rainfall

From 1970 through 2000, 40 tropical cyclones tracked through Fiji waters. These often produced extreme rainfall events due to orographic lifting of storm-spiralling rain bands caused by the rugged terrain of Fiji's high volcanic islands. Different cyclones, however, deliver contrasting total rainfall patterns and maximum intensities because these precipitation characteristics depend on such factors as the strength and longevity of the cyclone, the proximity of the storm track to land, and the organisation of cloud bands.

A visual impression of the total cumulative precipitation along the storm path of TC Ami, across the Fiji Islands can be seen in Fig. 5. Dark shading shows the highest precipitation received. In addition, one-day (9 a.m. to 9 a.m.) rainfall figures for climate stations on Vanua Levu Island are given in Table 1. The data shows that large-scale rainfall was widespread. Of the 18 stations listed, 16 recorded more than 100 mm of rainfall in 24 hours. Of these, 5 received more than 200 mm. The majority of stations experienced their heaviest downpours on 13 January. Maximum recorded rainfall was 311 mm at the coastal site of Vatuwiri on Taveuni Island. Ami approached Fiji from the north, and Vatuwiri was on the windward coast beneath the highest mountain in the region (1241 m), and so the intense rainfall there reflects orographic effects.

Fig 3. Destruction by TC Ami of a village in the Lau Islands (see Fig. 1) of eastern Fiji. Source: Fiji Navy, supplied by the Fiji Ministry of Information.

Fig 4. Severe flooding in Labasa Town on the northern coast of Vanua Levu island, generated by the combination of inundation by the sea (storm surge) and flooding of the Labasa River.

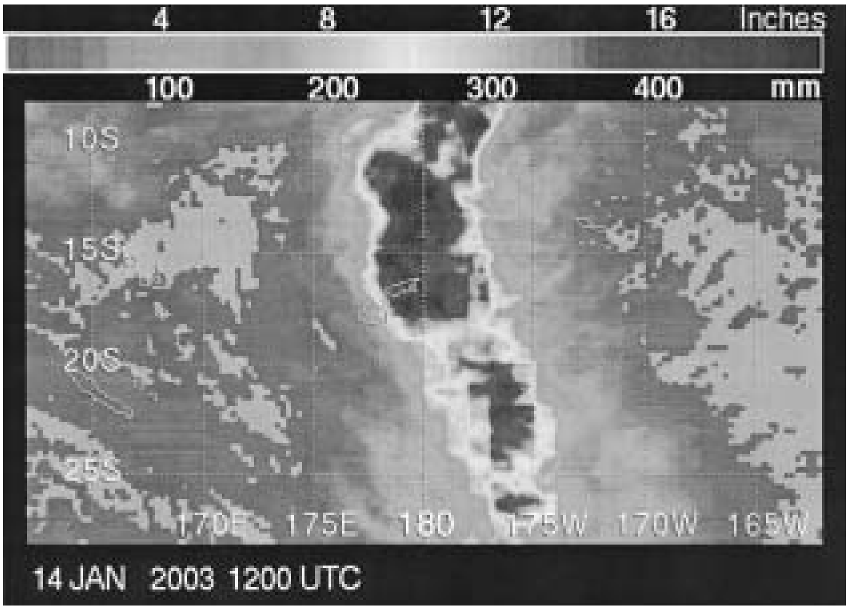


Fig 5. Cumulative precipitation totals delivered along the track of TC Ami as it traversed the Fiji Islands. Much of eastern Vanua Levu Island received >400 mm of rainfall (dark shading) during the passage of the cyclone.

Table 1. Maximum 1-day rainfall (9 a.m. to 9 a.m.) delivered by TC Ami at Fiji Meteorological Service climate stations on Vanua Levu Island.

Location	Island	ID no. in Fig. 6	Rainfall (mm)	Date (January 2003)
Vatuwiri	Taveuni	1	311	13
Seaqaqa Forestry Station	Vanua Levu	2	270	13
Labasa Airfield	Vanua Levu	3	245	15
Wailevu	Vanua Levu	4	214	14
Vunimoli	Vanua Levu	5	200	15
Labasa Sugar Mill	Vanua Levu	6	194	14
Naravuka	Vanua Levu	7	192	13
Waiqele	Vanua Levu	8	192	13
Nagigi	Vanua Levu	9	175	13
Tutu	Taveuni	10	167	13
Batiri Citrus Farm	Vanua Levu	11	162	13
Natua Sector-Seaqaqa Office	Vanua Levu	12	145	14
Wainikoro	Vanua Levu	13	132	14
Kurukuru	Vanua Levu	14	124	15
Seaqaqa Agriculture	Vanua Levu	15	109	13
Seaqaqa Sub Station	Vanua Levu	16	109	14
Nabouwalu Port	Vanua Levu	17	79	13
Rokosalese	Vanua Levu	18	63	13

Rainfall of high magnitude produces big flows in Fiji rivers because the upper reaches of the river basins have rugged volcanic topography. The size of the peak discharge produced in individual rivers depends on local physiographic factors that influence the hydrological behaviour of hillslopes; the types of geology, soils, and vegetation. In general, there is a high degree of hydrological short-circuiting, and large overbank floods consequently are a frequent problem during the passage of tropical cyclones through Fiji (Kostaschuk et al. 2001). Table 2 shows the history of flooding on Vanua Levu Island since the early 20th century (FMS 2002).

3.2 River Floods

Vanua Levu's geology is made up of volcanic rock types; mainly lava flows, breccias, and conglomerates. Its geomorphology is dominated by a chain of volcanic mountains aligned in SW to NE orientation, forming a central highland spine along the island and giving it a mountainous profile. The three tallest peaks are located towards the centre of the volcanic chain, south of Labasa. They are Delaikoro (941 m), Koroalau (1032 m), and Dikeva (957 m). Most river networks therefore generally drain northwest or southeast, controlled by the linear arrangement of the volcanic mountains. At their headwaters the individual river basins are separated by narrow, serrated interfluves, and slope angles are steep, frequently approaching 30° or more. Upper river channels are steep with many boulders. Lower watershed areas have hilly terrains with flat alluvial terraces and floodplains in valley bottoms. The highlands have natural rainforest vegetation, whereas the coastal hinterlands have commercial sugar cane fields.

Peak discharges of the 8 main rivers on Vanua Levu are presented in Table 3, to show the river floods produced by TC Ami on

Table 2. Record of floods on Vanua Levu Island. Source: Fiji Meteorological Service (2002)

Year	Date	TC Intensity[3] (or other reason for high rainfall)	TC Name	Area of Fiji affected	Flood details on Vanua Levu island
1912	Jan. 28-29	Hurricane		Entire country	Labasa River in high flood on Jan. 28.
1929	Dec. 8-13	Hurricane		Widespread and slow moving; moved SW to Rotuma, recurved to SSE passing over eastern Viti Levu.	In the Labasa area floodwater extended 22.5km inland (Derrick 1951). Three fatalities in Labasa.
1931	Feb. 21-Mar. 2	Hurricane		Labasa, western Viti Levu, and southern Lomaiviti islands. The hurricane track looped near the Yasawa islands producing two flood peaks; the first on Feb. 21, the second on the Mar. 1-2.	Worst floods in many rivers in living memory; flood peaks occurred on the night of Feb. 21 (FNA 1931).
1942	Dec. 27				Labasa flooded in places (Blong 1994).
1943	Jan. 1-3	Hurricane		Vanua Levu and Lau islands.	Labasa flooded in places on Jan. 3 (Blong 1994). Flood damage recorded across the country (FMS 1997a).
1950	Feb. 25 – Mar. 1	Storm		NW Viti Levu and Vanua Levu.	Floods in the Labasa District on Feb. 25 (Blong 1994).
1952	Jan. 24-28	Hurricane		On the 28, passed over northern Yasawas and crossed the coast of Viti Levu. A second minor cyclone occurred on Jan. 24 affecting SE Vanua Levu and the Lau Group.	Labasa River flooded Jan. 24 (Blong 1994).
1978	Dec. 29-30	Storm	Fay	Rotuma, Eastern Vanua Levu, Taveuni, Lau Group.	Major flooding in Vanua Levu and Taveuni (FMS 1997a).
1982	Jan. 23-31	Storm	Hettie	Mamanuca Islands and western Viti Levu.	Flooding in many areas of Labasa (Blong 1994). Extensive flooding in Vanua Levu (FMS 1983).
1984	Mar. 16-18	Gale	Cyril	Western Fiji	Significant flooding in northern and western Vanua Levu.
1986	Dec. 22 – Jan. 1	Hurricane	Raja	Rotuma, NE Vanua Levu, Lau and Koro.	Main street of Labasa was under a metre of water for the first time in 57 years (Blong 1994).
1988	Jan. 9				Knee-deep water in parts of Labasa's main street (Blong 1994).
1988	Feb. 25	Hurricane	Bola	Mamanuca Islands, Kadavu and southwest Viti Levu.	Flooding in the Labasa area (Blong 1994).
1988	Dec. 16-28	Storm	Eseta	Yasawas, Mamanucas and SW Viti Levu.	Widespread flooding in the Northern Division on Dec. 16 (Blong 1994).
1989	Feb. 9-15	Tropical Depression		Developed near SW Fiji on Feb. 6, later moved slowly eastward.	Flooding in northern Vanua Levu.
1989	Nov. 15				Floodwater in the main streets of Labasa, approximate depth 0.6m (Blong 1994).
1990	Mar. 16-30	Storm and Hurricane	Rae and Sina	Most of the Fiji Group affected. Torrential rain fell over most parts of the country.	Closure of roads and bridges all over the country (FMS 1997a).
1991	Jan. 10	Shallow low pressure		Passed southwards to the west of Viti Levu on the 9th.	Roads closed in Labasa (FMS 1991).
1993	Jan. 3	Hurricane	Kina	Yasawas, Northern and Eastern Viti Levu, Southern Vanua Levu, Lomaiviti and Southern Lau.	Prolonged heavy rain with a combination of factors, including high tide and heavy seas, blocked mouths of major rivers resulting in extensive flooding (FMS 1996a). Overall flood damage for the country (1998) amounted to approximately F$188 Million (World Bank 2000a).
1995	Mar. 16-19	Presence of troughs		Moderate to heavy rainfall.	Flooding in Labasa.
1996	Feb. 22	Shallow depression		NW of northern Yasawa islands.	Two bridges on the SW tip of Vanua Levu were under water (FMS 1997b).
1997	Jan.19 – Feb.2	Tropical cyclones and several other low pressure systems	Evan and Freda	Dominated Fiji's weather.	Crushing at the Labasa sugar mill temporarily suspended (FMS 1998).
1997	Feb. 18-19	Tropical Depression			Severe flooding in low-lying areas and Labasa (FMS 1998).
1997	Mar. 8	Hurricane	Gavin	Yasawas, Mamanucas, Western Viti Levu.	Severe flooding in Labasa (FMS 1997a). Overall flood damage for the country (1998) amounted to approximately F$35 Million (World Bank 2000a).
1997	May 3-5	Storm	June	Significant rainfall over most parts of the Fiji Group. Record breaking rainfalls on Vanua Levu and Taveuni.	Localised flooding on the northern coast and consequent damage to the infrastructure and property. (Terry & Raj 1999).
1999	Jan. 19	Frequent succession of westward moving troughs, traversing the country	Manumanu or 'The Beast'	Deep convective activity that converged over Fiji.	Severe flooding in Labasa (FMS Reports).
1999	Dec. 6-10	Trough of low pressure			Flooding caused damage to the infrastructure in Vanua Levu.
2000	Apr. 15-16	Tropical Depression	Neil	Northern Lau Group	Flooding in the Northern Division caused damage to the infrastructure and agriculture (FMS 2000).

[3] In the South Pacific, a rotating tropical storm with a central vortex is called a Tropical Cyclone. Its intensity (hurricane, storm, or gale force) is determined by the average 10 minute wind speeds. In other oceans, tropical cyclones are known as Hurricanes or Typhoons.

Table 3. Peak river discharges on Vanua Levu Island produced by TC Ami on 14 January 2003

River	Gauging station location	Catchment area km^2	Discharge m^3/s
Nasekawa	Bagata	104	6139
Labasa	Korotari	86	2377
Wailevu	Nakama	77	2118
Qawa	Bulileka	38	1802
Dreketi	Natua	128	996
Wainikoro	Nasasa	45	676
Nakula	Nakelikoso	16	559
Bucaisau	Qelemumu	80	447

the island. Flooding was carefully surveyed by the Hydrology Division of the Fiji Public Works Department at their long-term gauging stations, shortly after the flood waters receded. Locations of the rivers and their gauging stations are given in Fig. 6. To provide an idea of how these peak discharges corresponded to flood height, river cross-sections are drawn in Fig. 7 a-h. TC Ami maximum flood levels are shown in comparison to those of other severe floods of recent decades. In 5 of the 8 rivers, Ami produced the largest floods on record. At the other 3 stations, the magnitude of Ami's deluge was surpassed only by other cyclone-generated

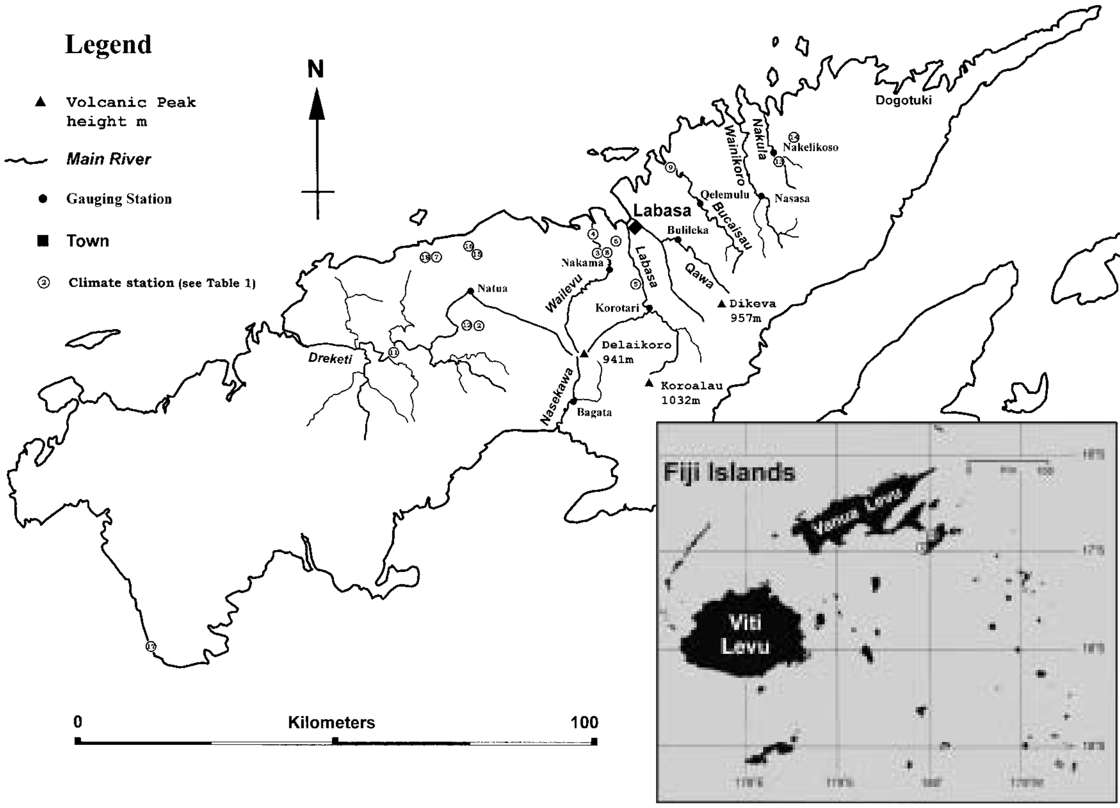


Fig 6. Major rivers and gauging stations on Vanua Levu Island operated by the Hydrology Division of the Fiji Public Works Department. Record flood discharges generated by TC Ami are discussed in the text.

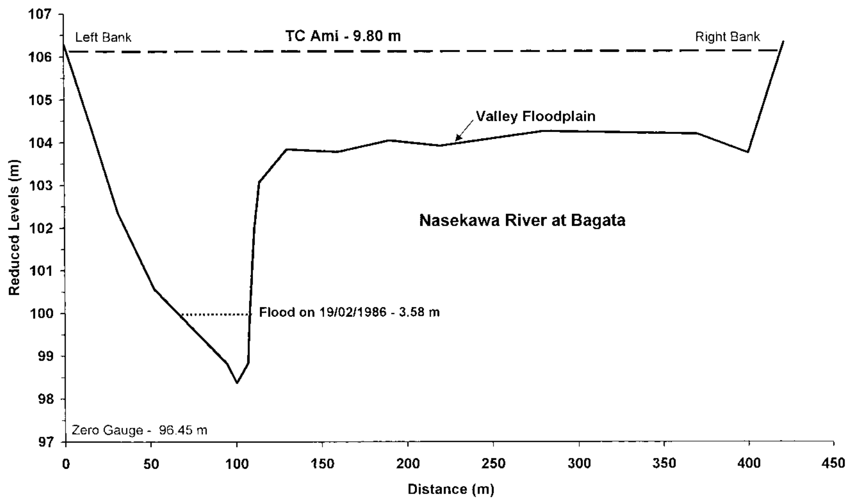


Fig 7.a

flood events. The Nasekawa, Labasa, Qawa, and Wailevu rivers all drain Vanua Levu's most mountainous terrain (described earlier), in the centre of the island. The Nasekawa River had a phenomenal peak discharge of more than 6100 m^3/s which destroyed the main highway bridge on the south coast at Bagata Village. On the north coast, the Labasa and Qawa rivers both drain into the same sheltered bay near Labasa Town, and the Wailevu River has its estuary only 4 km along the coast to the west. The peak flows in these rivers were all record-breaking ones, respectively 2377, 1802 and 2118 m^3/s. The discharge at the same time of these large volumes of water from all three rivers to the same coastal plain was combined with a strong storm surge felt along the north coast of Vanua Levu. This resulted in terrible inundation to depths of 3 to 4 m above the floodplain, over a wide area around Labasa. This caused loss of life and unprecedented destruction of farms and houses across rural communities. Extensive infrastructure and property damage likewise was suffered in Labasa Town, the main urban and commercial centre for Vanua Levu and the Northern Division of Fiji (Fig. 4).

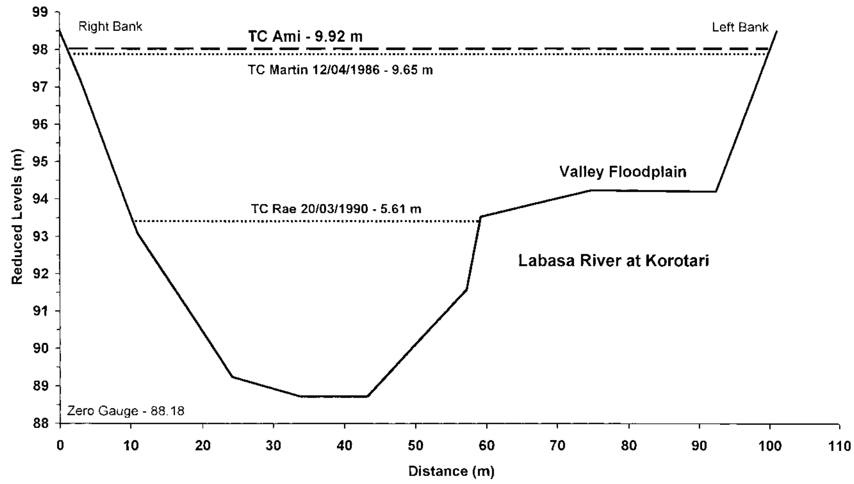


Fig 7.b

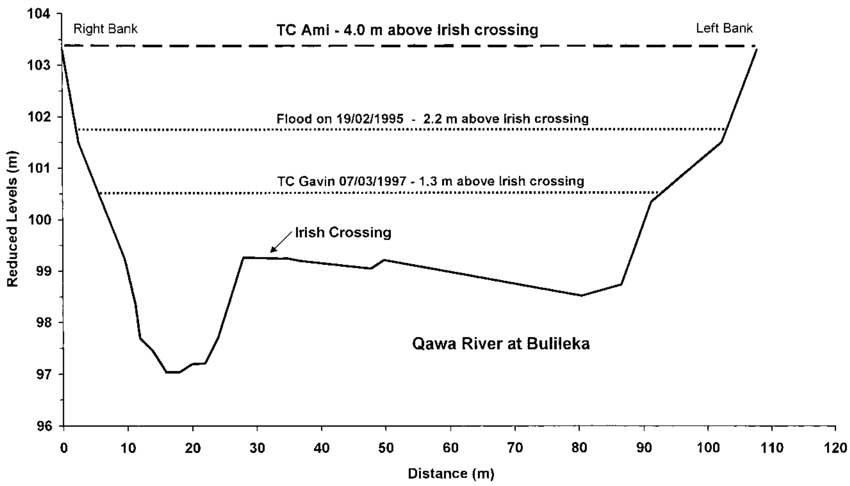


Fig 7.c

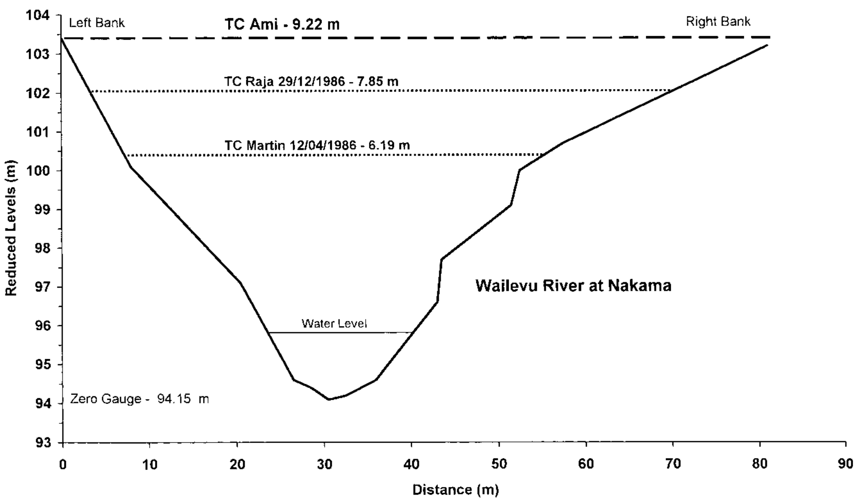
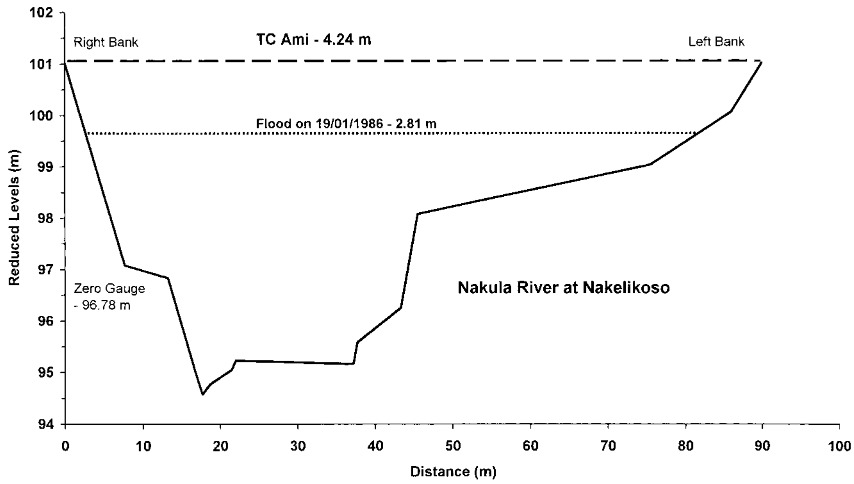


Fig 7.d



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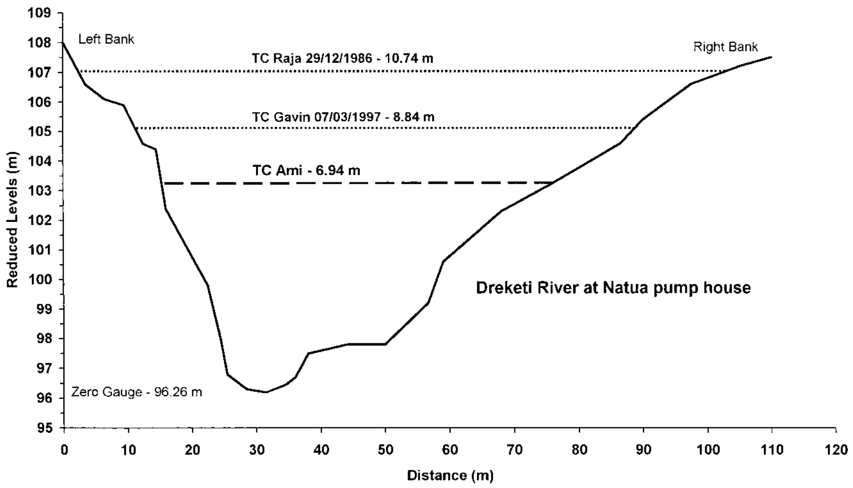

Fig 7.f

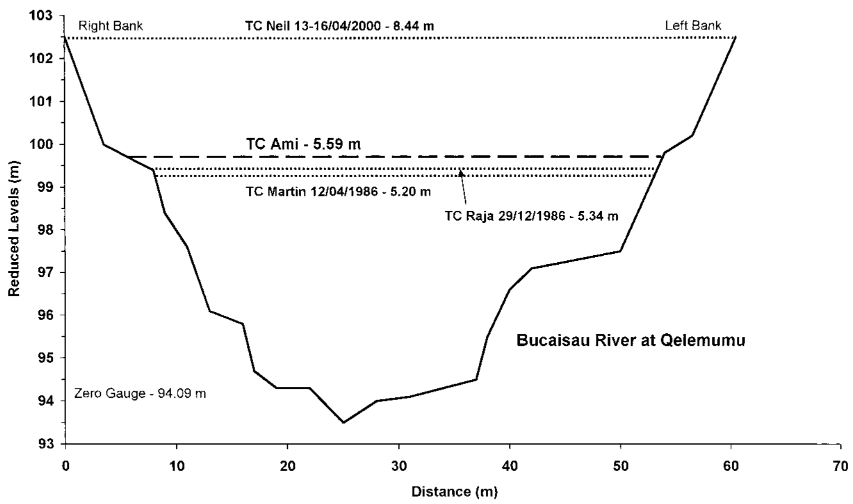

Fig 7.g

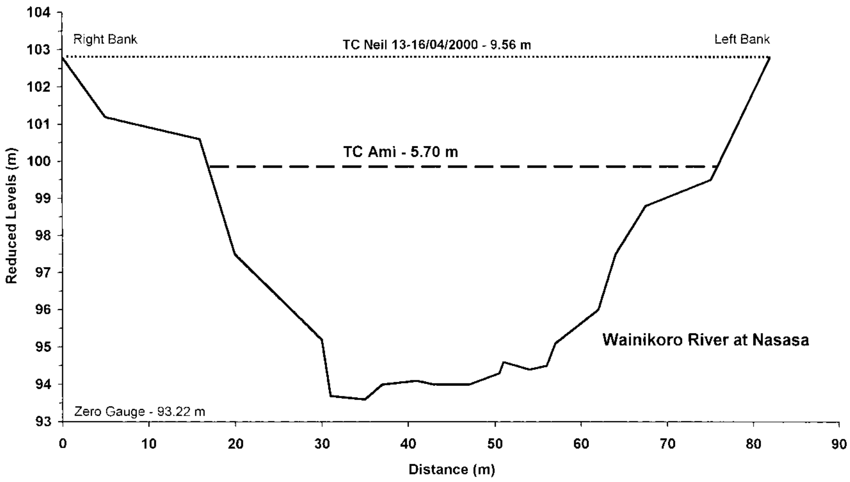

Fig 7.h

Fig 7.a-h Maximum flood heights produced by TC Ami in 8 rivers on Vanua Levu. Source: Fiji PWD Hydrology Division unpublished data.

4. DISCUSSION-FLOOD HAZARD MITIGATION

The historical record of tropical cyclones which have affected Fiji indicate that storms rarely develop close to the islands. They tend to form nearer the equator then approach on a southerly track over 2 or 3 days. This critical delay should prove useful for alerting vulnerable segments of the Fiji population, who live on the low-lying floodplains and coastal areas, in advance of expected flooding. Unfortunately, the example of TC Ami shows that in particular dispersed rural communities are not sufficiently prepared to cope with severe flooding. Many people either ignore warnings given by the Fiji Meteorological Service because they are unwilling to leave their homes, farms and property, and others, who are aware of the dangers, do not have adequate mobility to escape to higher land. As inundation waters rise, many people become trapped in their houses, panic and try to wade to dry ground with fatal consequences.

Flooding is especially perilous for the coastal hinterlands around Labasa. First, the north coast of Vanua Levu is convoluted with many embayments; a configuration which increases the possibility that storm surge inundation will combine with river flooding (Terry and Raj 1999). Second, three rivers have their estuaries in the same area. Third, these rivers rise in the highest mountains on the island, and fourth their basins face the direction from which most cyclones arrive. Therefore, owing to orographic effects, exceptional rainfalls are to be expected, and these are then rapidly converted to a very large flood response. Fifth, replacement of natural vegetation on lower catchment slopes by sugar cane plantations exacerbates runoff and erosion (Morrison 1981).

Regarding the future, tropical cyclone intensity in the Pacific region may increase due to climate change, ocean warming, and more sustained El Niño-like conditions (see Holland 1997, Trenberth and Hoar 1997, Timmermann *et al.* 1999, Whetton *et al.*, 2000). In consequence, the magnitude of the flood hazard on Vanua Levu probably will increase. Based on this scenario, better flood disaster reduction programs are needed in Fiji to avoid further loss of life. A recent survey by the World Bank (2000 b) found that moderating the impact of tropical cyclones can be categorised as follows:

Catchment management.

This includes reforestation, soil conservation, regulating land development, and protecting natural wetlands. These activities improve the water retention function of drainage basins and maintain river flow capacity by avoiding excessive silting of channels.

Flood control.

A report complied by JICA (1997) examined various feasible flood control measures for the major rivers on Fiji's main island of Viti Levu. Engineering measures assessed included diversion channels, retarding basins, cut-off channels, control dams, raising embankments, river channel widening, and bed excavation. These measures also are applicable to Vanua Levu Island which has a physical geography similar to that of Viti Levu. In the context of climate change, flood control dams may be the most beneficial option for Fiji because they can be used for water resource development as well as for mitigating floods.

Mitigation.

Flood damage potential may be reduced by restricting the urbanisation and development of low-lying areas and by promoting flood-proof house design where necessary. The social infrastructure as well as resilience can be improved through education programmes to raise community awareness of tropical cyclone characteristics and behaviour, and better communication about impending flood hazards during storm events (World Bank 2000 b).

5. CONCLUSIONS

Vanua Levu Island of northern Fiji in the tropical South Pacific historically has experienced severe flooding associated with extreme rainfall during tropical cyclones. Floods present serious hydrological hazards because of their impact on both the natural and human environments causing loss of life, damage to the infrastructure, the ruin of subsistence and commercial agriculture, and deleteriously affecting public health. Vanua Levu Island's north coast is particularly vulnerable as most cyclones approach from the northern Fiji waters. During Tropical Cyclone Ami in mid-January 2003 very large rainfalls occurred. The mountainous terrain of the island rapidly transferred this moisture to river channels, producing record-breaking floods in 5 of 8 rivers for which long-term hydrological information exists. The Nasekawa River had an extreme peak flow exceeding 6100 m^3/s. In the Labasa area, 3 rivers simultaneously delivered large amounts of water to the same coastal hinterland, at the time there was a cyclone-generated storm surge. This produced flood heights of more than 4 metres on some floodplains.

Although it is difficult to predict the occurrence of tropical cyclones in the South Pacific, it is clear from the experience of TC Ami that improved mitigation and management of flood hazards should become a priority on Vanua Levu to avoid loss of life and to lessen the heavy socio-economic burden caused by flooding. More of the recommendations in the recent reports of the World Bank (2000 b) and JICA (1997) need to be adopted. Solutions include improved catchment management and flood control structures. A small, resource-limited island nation like Fiji, however, will probably require international aid and project assistance for effective implementation

ACKNOWLEDGEMENTS

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