FLOOD AND LANDSLIDE HAZARD
NORTHERN GUADALCANAL
SOLOMON ISLANDS

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DLS Contract Report 89/07

A report for

United Nations Technical
Cooperation for Development
New York
Contract 6/89-SOI/87/001

August 1989

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Department of Scientific and Industrial Research
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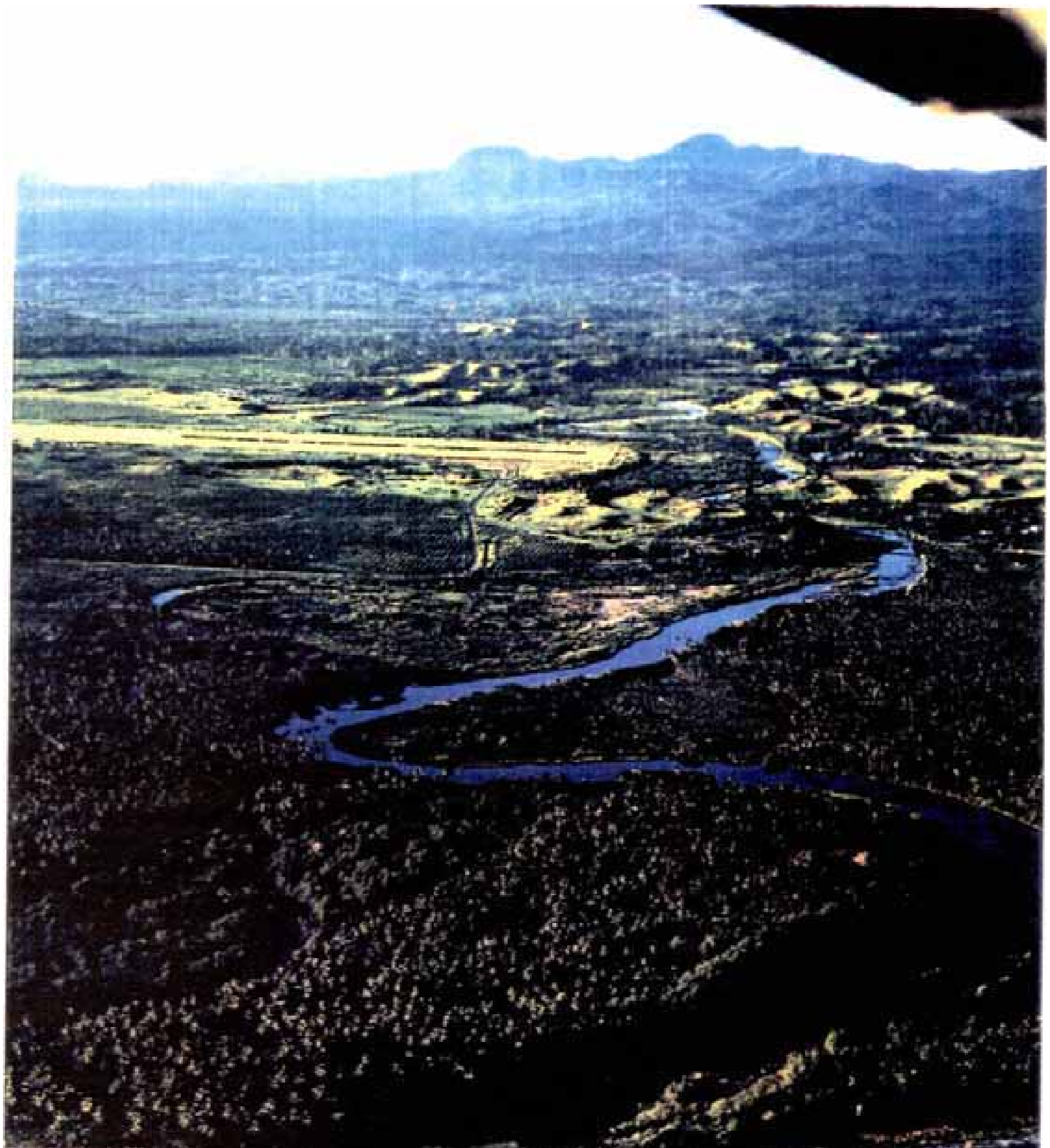

Frontispiece. Lungga River and Henderson Airfield. During Cyclone Namu in 1986 floodwater covered much of the Airfield and areas coastward of it to a depth of about one metre.

FLOOD AND LANDSLIDE HAZARD, NORTHERN GUADALCANAL, SOLOMON ISLANDS

EXECUTIVE SUMMARY

Flood and landslide hazard maps are provided for eight major watersheds in northern Guadalcanal. Five categories of flood hazard are recognized on the basis of how often the area is likely to flood. These categories range from areas that flood annually to those not flooded in cyclone Namu and considered safe. Five landslide hazard categories are recognized on the basis of frequency and type of landsliding, and indicate likely sediment production.

Over three-quarters of the $400km^2$ Guadalcanal Plain flooded in cyclone Namu and can be expected to flood in similar low probability events in the future. Areas of frequent flooding are confined to the river channels and adjacent low terraces. Most of the plain has a moderate flood hazard, with the likelihood of flooding occurring in anyone year assessed as 1- 5%. Impeded drainage makes surface water flooding a problem over much of the Plain.

Landsliding is frequent on steep slopes in the mountains and is most widespread in Mbalisuna, Ngalimbiu and Mberande watersheds.

Siting of developments, such as airfields, schools, villages, factories, water supply and sewerage systems, should consider the consequences of flooding and landsliding. Ideally, new development should occur in areas considered safe or with a low probability of flooding or landsliding. Where applicable, protection from flooding may be required. We recommend that stopbanking be considered to ensure that Henderson Airfield is not flooded as it was during Cyclone N amu. Evacuation strategies, and relief planning to better cope with future flooding should reflect the location of safe areas. An integrated flood hazard management plan should be prepared for Guadalcanal Plains.

To ensure that development, land use and evacuation strategies are compatible with assessed frequency and severity of flooding and landsliding we recommend that this report and accompanying maps are sent to relevant Government agencies in Guadalcanal. Follow-up is required to prepare simple handouts that explain what the hazards are, how to reduce them, the consequences of living in flood-prone areas, and evacuation strategies.

RECOMMENDATIONS

1 Planning for developments such as airfields, schools, villages, water supply and sewerage systems, and processing plants, should consider the consequences of flooding and landsliding. Ideally new development should occur in areas considered safe or with a low probability of flooding.

2 A detailed study is required to design adequate flood protection for Henderson Airfield. Stopbanking should be considered to ensure that it is not flooded as it was during Cyclone Namu.

3 A detailed study is required to ensure that the proposed industrial development on Lungga delta is compatible with the frequency and severity of flooding in this area.

4 There is an urgent requirement to remove the piers of the old Ngalimbiu Bridge to avoid damming of the river with logs as occurred in Cyclone N amu.

5 Evacuation strategies and relief planning to best cope with future cyclones and flooding should reflect the location of safe areas as identified in this project.

6 A working group comprising staff from relevant Ministries, Guadalcanal Province, and local community representatives should be set up to coordinate preparation of a flood management plan for Guadalcanal Plains. Technical assistance for this task could be provided by UNTCD.

7 A simple handout or presentation should be prepared to educate villagers on the consequences of living in hazardous areas and the ways of reducing the hazard. This should be done by Department of Natural Resources, Solomon Islands College of Higher Education, in conjunction with Ministry of Natural Resources, Planning Division, and DSIR, New Zealand. UNTCD should consider funding this small project as a means of ensuring that the messages from the present contract reach those who most need them.

8 Copies of the report and maps should be sent to Solomon Island Government and Guadalcanal Province planners, National Disaster Council, Ministries of Natural Resources, Agriculture and Lands, and Transport, Works and Utilities, and Solomon Islands Development Bank. This will help ensure that the information reaches those agencies who are responsible for disaster planning, and those who plan, finance and approve development on the plains.

CONTENTS

Accompanying maps of flood and landslide hazard

Sheets 1 to 4 (1 :50 000 scale)

Sheet 5 (1:150 000 scale)

1.0 INTRODUCTION

The enormity of the risk to life and property on Guadalcanal from natural hazards was highlighted in 1986 by the damage incurred in Cyclone Namu. Landslides were widespread in steep inland areas, and most of the plains were inundated with floodwater and covered with silt. If the consequences of future cyclones are to be minimized, it is important that the lessons of Namu are not forgotten. Villages and other developments should be sited in safe areas, and land use and disaster strategies planned to reflect the risk of flooding and landsliding. It is opportune, while the memory of Namu is still fresh, to plan for safe, sustainable land use and development so that the consequences of the next major cyclone are less.

Hazard mapping ranks the likelihood of damage and delineates safe areas. Hazard maps provide a basis for planning where to site developments such as villages, airfields, oil palm refineries, water supply facilities, schools, *etc.* In general it is best to avoid high risk areas. Where major development has already occurred, or is planned, the hazard maps provide an indication of the hazards that must be taken account of and managed to minimize their consequences.

'Flood hazard' and 'landslide hazard', as used in this document, incorporate the adverse outcomes of flooding and landsliding. Such outcomes include inconvenience, injury and loss of life, damage to property, loss of amenities, and economic and social disruption.

1.1 Outline of project

This project maps flood and landslide hazard in eight watersheds in northern Guadalcanal (Fig. 1). It concentrates on flood hazard on Guadalcanal Plain, but includes reconnaissance landslide hazard zoning of the watersheds draining to the plains. The mapped watersheds have a total area of 2087km^2, about 39% of Guadalcanal.

1.2 Previous DSIR involvement

Following Cyclone Namu in 1986, a request by the Solomon Islands Government to New Zealand Ministry of Foreign Affairs resulted in an aerial photography and mapping survey of Guadalcanal and Malaita. The Soil Conservation Centre, DSIR, was commissioned by the Ministry to arrange aerial photography and to interpret the photographs. A reconnaissance assessment of the physical impact of Cyclone Namu on Guadalcanal and Malaita, and a preliminary map of flood and landslide hazard in Ngalimbiu watershed were prepared (Stephens *et al., 1986).*

1.3 Guadalcanal

Guadalcanal is the largest of the six major islands of the Solomons group. It has an area of 5 31Okm^2, being 150km long from northwest to southeast and, at its broadest, 45km wide. Approximately 90000 people live on Guadalcanal, with more than one third of these in Honiara. The Guadalcanal Plains are the next most densely populated area. Population there continues to increase as people move from the highlands or immigrate from other islands. Population density is greatest on the western end of the plains, close to Honiara. The population of the Solomons is increasing at 3.5% annually with Honiara's population increasing at three times this rate. The increasing demand for food in Honiara is intensifying land use on the plains.

The Guadalcanal Plains, on the north coast between Honiara and Aola (Fig. 1), is the largest area of flat land in the Solomons. They offer the greatest potential for agricultural in tensification. Hansell and Wall (1976) consider the Guadalcanal Plains a major national asset too valuable for piecemeal development. The need for land-use planning is recognized. The hazard maps prepared as part of this project should be an important component of this planning.

2.0 PROJECT GOAL

To prepare flood and landslide hazard maps at a scale of 1 :50 000 for eight watersheds on Guadalcanal Island (Fig. 1), as an input to developing a strategy for rational land use and water and sewage development of the Guadalcanal Plains.

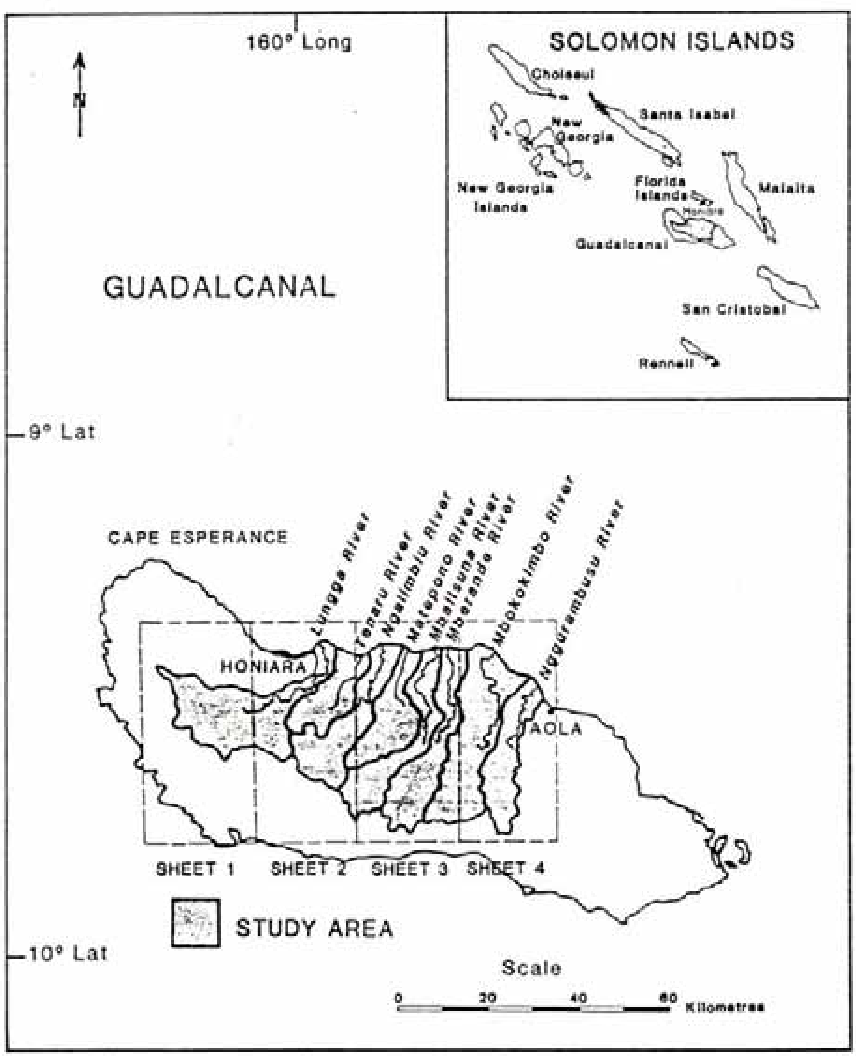

Figure 1. Location of eight watersheds studied on northern Guadalcanal. The area covered by the four accompanying 1: 50 000 hazard maps is outlined. A 1: 150 000 hazard map also is attached and combines all the information in the other four maps.

3.0 PROJECT JUSTIFICATION

Flood and landslide hazard maps can be used to:

- identify areas of high flood risk to aid the economic and physical planning of infrastructural developments and sustainable land use.

  It is important that industrial development, hospitals, schools, villages, air terminals, hotels, water supply, irrigation and sewage systems, etc. are located in safe areas, or that the hazard to such developments are mitigated, using, for example, flood protection structures, so that risk is reduced to an acceptable level.

  In addition, diversification and distribution of agriculture development should take account of the likelihood of flooding. For example, long term crops, like coconuts, cocoa and oil palms, should be planted in areas that are not subject to frequent floods as young plants are intolerant of siltation and flood flows.

- assist planning of disaster prevention measures.

  Cyclone Namu highlighted the vulnerability of the transport system. Henderson Airfield was flooded and closed for at least 24 hours. Flood protection should be planned so that disruption to the external transport system is minimized in future cyclones. In addition, strategies for future cyclone relief should see that safe shelter and distribution sites and evacuation routes are identified and their location publicized.

- determine the condition of the upper watersheds as an indication of potential long term sediment supply to the Plains.

  This may indicate how rivers may change in the next decade as sediment supply reduces following revegetation of landslides.

4.0 PHYSICAL BACKGROUND

4.1 Topography

Most of Guadalcanal is rugged and steep. A northwest-to-southeast trending mountainous spine, close to and parallel to the south (Weather) coast, is flanked successively northwards by dissected high hills, terraces and a narrow coastal plain. Hansell and Wall (1974) provide a detailed description of landforms and physiography. Three broad physiographic regions can be recognized (Hackman, 1980):

The *mountain zone,* occupying the southern half of the island, rises to over 2 300m. Slopes are generally long and very steep with deep and intense dissection.

The *intermediate zone* comprises dissected plateaux, cuestas, rounded and dissected hills, and flat-to-rolling ridges forming the northern foothills of the mountains. Elevations range from 50-1000m. The southern part of the zone is higher and more intensely dissected than the lower hills nearer the plains. These northern foothills comprise a series of dissected terraces and low hills generally less than 60m high. Slopes are often steep in the intermediate zone but are shorter than in the mountain zone. Dissection is intense in places. The zone is transected by the middle courses of numerous rivers draining from the mountains.

The northern *alluvial zone,* referred to in this report as the Guadalcanal Plains or simply the plains, has been formed from coalescing of the floodplains of the major rivers draining the north side of Guadalcanal. The plains extend 50km, from Lungga River in the west to east of Nggurambusu River (Fig. 1). They are llkm at their widest, near Matepono River. Major rivers have incised into the plain by up to 6m, but water covers most of the plains in large floods. The rivers bifurcate and meander extensively. Relief on the gently sloping floodplains between the rivers is minimal, although drainage lines dissecting these interfluves may be incised I-3m. Generally, the rivers carry silt, sand and fine gravel, with grain size decreasing seaward. Poorly drained areas are common. Swamps are common adjacent to the foothills especially east of Mberande River.

4.2 Climate

Guadalcanal (latitude of 9° 30" S) has a tropical climate. The north-facing slopes of Guadalcanal experience a wet season during the northeasterly airstream period between December and April. For the rest of the year, when the southeasterly wind predominates, the rain shadow of the high peaks forming the axis of the island creates a drier season. Typically about 65% of the 2 100mm mean annual rainfall at Honiara occurs in the 5-month wet season. Over 50mm of rain can fall in Honiara in one hour, with peak daily rainfall occasionally reaching over 200mm. Rainfall is highest near the south coast and in the mountains (Fig. 2). At Chikora, on the south coast, 13 452mm of rain fell in 1976 (Hansell and Wall, 1974).

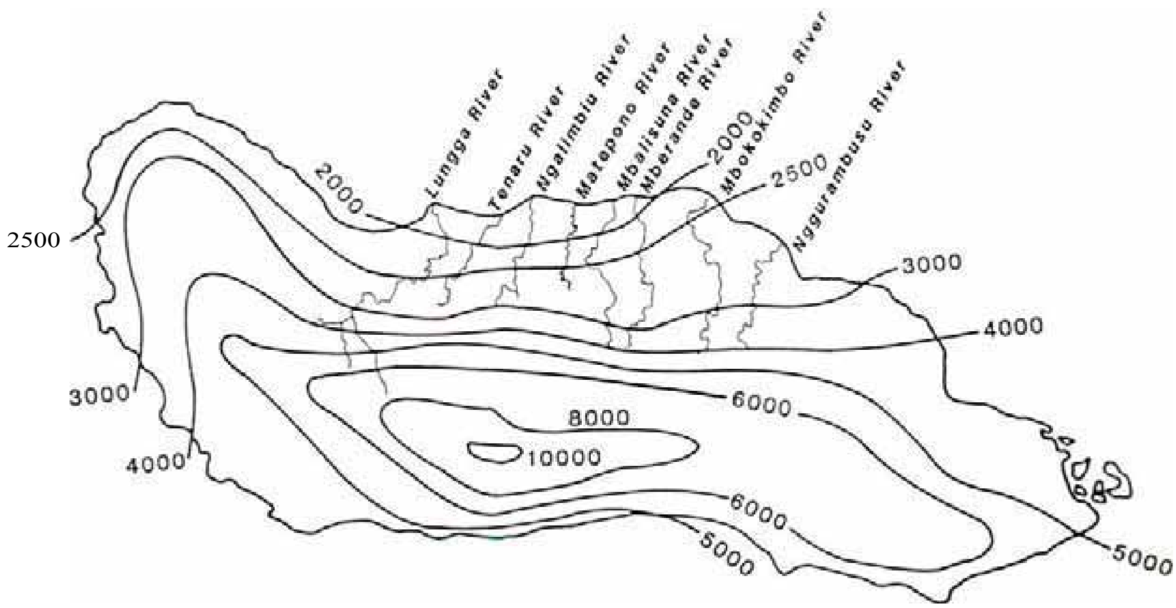

Figure 2. Distribution of average annual rainfall (mm) on Guadalcanal. From Curry (written comm., 1989).

4.3 Cyclones

On average, a cyclone passes the Solomon Islands every year or two, but it generally is small (Fisher, 1989), but the devastating effects of large cyclones can be seen in the forests of most islands (Whitmore, 1969, 1974; Stephens *et. al.,* 1986). Cyclones usually originate to the east and north of the main island chain forming the Solomon Islands, move southwest, then swing to the east in higher latitudes (Fig. 3). Cyclone paths are usually deflected by the major mountain ranges. Since 1951, six cyclones have passed over eastern Guadalcanal. The worst damage generally is confined to a relatively narrow belt.

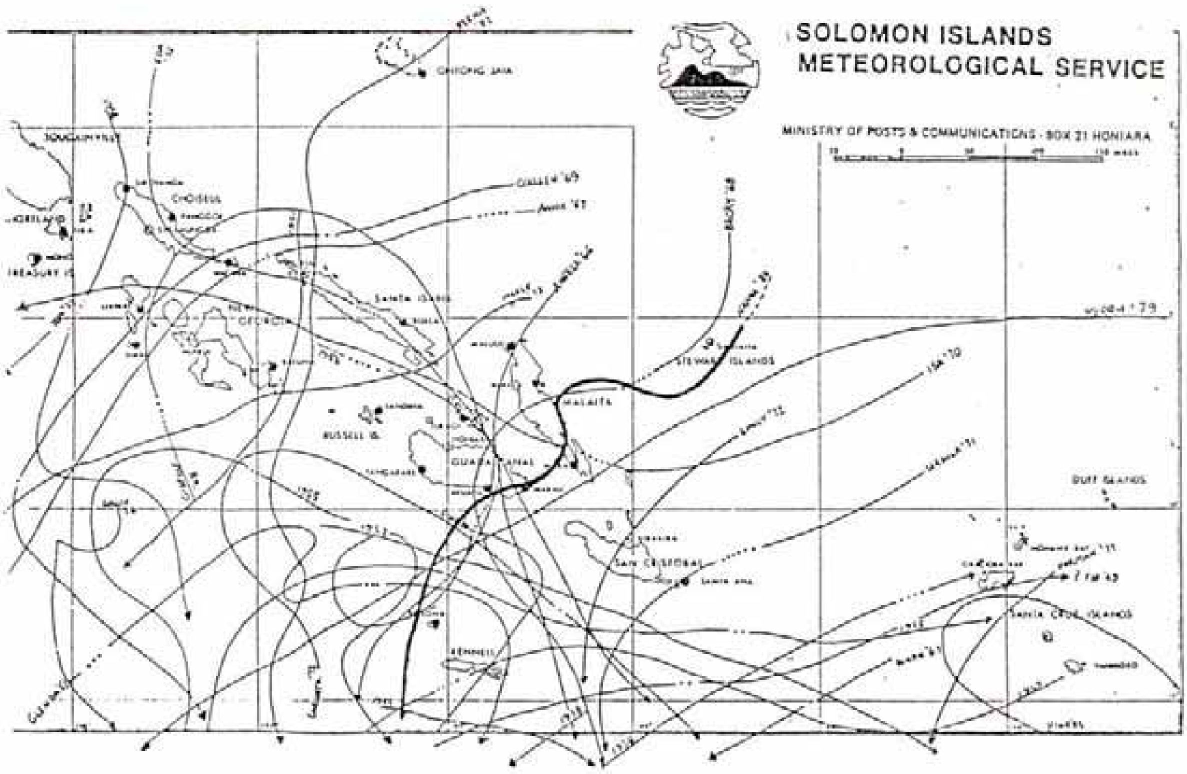

Figure 3. Cyclone paths, 1951 to 1986. Figure courtesy of Meteorological Service, Honiara.

4.4 Cyclone Namu

The largest storm in many years occurred in May 1986. Between 17-20 May about 350mm of rain fell on the northern coast. Rainfall inland was much greater (Curry, written comm., 1989). At Gold Ridge, at an altitude of 290m, cyclone rainfall was 874mm. In the higher areas to the south rainfall would have been much greater. Curry estimates that over two metres of rain fell in the vicinity of Mt Popomaneseu (2 OOOm altitude).

Extensive flooding occurred on the plains. About a metre of water covered much of the area. Many large trees were transported by the floodwaters and, in combination with the extreme flows, destroyed bridges on Ngalimbiu and Mbalisuna Rivers. As floodwaters retreated, about 0.3 to 0.5m of silt was left over large areas. Most rivers and streams aggraded. For example, aggradation was about 4m at Hgompo Village (Map sheet 4), approximately 5km from the mouth of Nggurambusu River.

Oil palm, rice, cocoa and coconut plantations were severely damaged. Houses and gardens were washed away or damaged. About 90% of the gardens on the plains were lost and over half the livestock drowned (National Disaster Council, 1986a). Many villages were evacuated. About 5% of the population of the plains were forced to move to other villages as a result of the cyclone. Coastal areas, particularly on the south coast, also were damaged.

Landsliding was widespread in the highlands. Many gardens were destroyed and villages damaged (Figs. 4 and 5). Many trees were damaged by wind. The village of Valembaimbai, in the headwaters of Mbalisuna River, was covered with gravel killing 38 people (Figs. 5 and 6). In total, about a hundred people were killed in the cyclone, mostly on Guadalcanal (National Disaster Council, 1986b). Nationally, about 90 000 people were made homeless.

4.5 Geology

The core of the island consists of intensely faulted pre-Miocene basic lavas that are, in part, regionally metamorphosed to greenschist or amphibolite facies (Hackman, 1980). These are overlain by a Miocene to Holocene sedimentary succession, up to 5000m thick, predominantly of limestones and sandstones. The Guadalcanal Plains consist of young alluvial sands and silts.

The Solomon Islands lie along a convergent boundary between the Pacific and Indo-Australian plates. Earthquakes are common. Extensive uplifted plateaux formed on Pleistocene deposits occur in the northern foothills. Uplift rates are rapid but not known. The pattern of uplift is complex with different faultbounded blocks moving at different rates (Walshaw, pers. comm., 1989).

4.6 Erosion and deposition

A variety of erosion and deposition occur on Guadalcanal including:

- *debris sliding* is the most common erosion process in the mountains and hills. Debris slides are triggered by rain storms and earthquakes, and often carry debris from ridges down into channels. In large storms, debris slides may erode large areas (up to several hectare), to a depth of more than a metre, in the mountains. Such deep debris slides generally erode to bedrock and transport boulders up to 25m diameter into rivers. Shallower debris slides, less than one metre deep, also are common in the mountains. These generally transport debris smaller than boulder size to the river system. Shallow debris slides occur on the short slopes in the intermediate zone but usually do not transport debris far downslope.

- *debris flows* are common on the steep slopes in the mountain and intermediate zones. They occur in heavy rainfall and often are initiated when debris slides fall in steep narrow ravines.

- *rock falls* occur on steep rock faces. They are usually triggered by earthquakes.

- *debris floods* occur in channels in the upper watersheds. They are transitional between debris flows and bed-load transport by rivers. Often deposition from flood flows raises river-bed levels by many metres. They are a major flood hazard in river channels in the mountains.

Debris slide, debris flow and rockfall are collectively referred to in this report as *landslides.* We have classified landslides as either shallow (less than a metre deep) or deep (greater than one metre, generally removing all material down to bedrock).

4.7 Vegetation

The following major types of vegetation occur (Whitmore, 1969), of which the first two cover the largest area:

Lowland primary tropical rain forest, characterized by large trees up to 45m in height. Climbers and epiphytes are common. With increasing elevation, tropical rain forest grades into montane forest.

Secondary growth, where the forest has been disturbed, either naturally or by clearing for gardens. These are characterized by thickets of low scrub, ferns and vines.

Montane forest, above about 1000m altitude in the mountains, with a low canopy of trees (6-12m), characteristically draped with ferns and mosses.

Open heath, with ferns and shrubs and a few tree species, This vegetation type is often associated with ultrabasic rocks.

Grass-covered areas, mainly on the plains and northern foothills, where the forest has been removed. The grassland is frequently burnt.

4.8 Land use

Traditionally the land is used for subsistence farming, mainly by shifting cultivation. Hansell and Wall (1976) indicate that all land not cliffed, rocky, flooded, exposed by recent landslip or above 1000m is potential garden land. Land use on the northern plains has intensified in the last 50 years, and in particular in the decade to 1986. Cash crops, including oil palm, coconuts, and cocoa, cover large areas, particularly west of Mbalisuna River. A wetlandrice venture was destroyed by flooding in Cyclone Namu. Some cattle graze on the plains and adjacent foothills, but the cattle population was reduced by about half in the Cyclone Namu flood. Forests have been logged in some areas for several decades but logging is not widespread except in the northern foothills of Nggurambusu watershed.

5.0 HAZARD MAPPING METHODS

5.1 Flood-hazard mapping techniques

There are three basic techniques for assessing flood hazard (see, for example, Yoshino and Yoshikawa, 1985; Wolman, 1971):

- *Geomorphological method.* Interpretation is made of landforms (terraces, relic channels, floodplains, etc) and their age, as inferred from relative height, to assess areas likely to flood in different magnitude events.

- *Historical records.* The extent of flooding in historical floods is used to assess the likely flooding in future floods.

- *Hydraulic method.* Depth and duration of flooding is estimated using hydrological and hydraulic models. Runoff from rainfall of known probability is estimated using hydrological models and water level along the river length predicted for this runoff using flood-routing models.

5.2 Flood hazard mapping on GuadaIcanal

This project uses a combination of the first two methods Precise leveling data and flood-frequency relationships necessary for the third approach are not available.

Aerial photographs were studied stereoscopically to determine relative height above river level of landforms and the locations of overflow channels. The extent of flooding and siltation in Cyclone Namu was estimated from the excellent 1 :25 000 scale colour aerial photographs taken 10 weeks after the cyclone. The estimate was refined by asking people at most villages on the Plains to indicate the height and nature of flooding in Cyclone N amu. Information from Mr Donn Tolia, Senior Water Resources Officer, Ministry of Natural Resources, was invaluable for assessing amu flooding. At the time of the cyclone, Mr Tolia was living in the village of California (Map Sheet 3) on the west bank of Mbalisuna River, and commuting daily to Honiara. Following the cyclone, he visited much of the eastern plains and thus is able to indicate the extent of flooding west of Mbalisuna River. From the August 1986 aerial photographs, discussions with people living on the plains during Namu, and our field observations we were able to reliably assess the extent of flooding in Namu.

Villagers also were asked to indicate if flooding had occurred previously and, where the village was close to a river, the extent of flooding in a minor flood in February 1989. For Lungga River this flood is estimated to have an annual exceedance probability of less than 0.2 (De Pledge, pers. comm., 1989).

Photographs taken before Cyclone Namu in 1947, 1962 and 1984, were studied to assess channel changes and the extent of river incision prior to Namu.

5.3 Flood-hazard categories on Guadalcanal Plains

Five categories of flood hazard are recognized:

1 Very high: flooding occurs frequently. The probability of flooding in any year is likely to be greater than 0.2 (20%). These areas are predominantly river channels and most will flood every year. Generally

low terraces confine these frequent floods that are likely to occur on average every five years or less.

2 High: flooding occurs less frequently. These areas are generally adjacent to "very high" hazard areas. Most are abandoned meander channels, overflow channels, or relatively low areas adjacent to main rivers. There is insufficient information to accurately predict flood frequency but it is likely that the probability of a flood occurring in anyone year is 0.05-0.2 (5 to 20%). That is, flooding can be expected to occur on average once every 5-20 years, but it must be remembered that flooding can occur more than once over this period as there is a 5-20% likelihood of a flood in any year. Thus, it is possible that two of these size floods could occur in one year or in consecutive years. Adjacent to major rivers, channel changes occur frequently (see section 12.2) and over a twenty-year period, any site in an area mapped as "high" hazard has a high probability of becoming the location of the main river channel.

3 Moderate: flooding occurs infrequently. These areas are relatively high above the river channels but were flooded in Namu. However, they are lower than areas classified as "low" (see below). There is insufficient information to accurately predict the probability of a flood that will cover these areas. Interpolating from an estimate of the probability of Namu flows we suggest that these areas would be covered by floods that have annual probabilities somewhere in the range 0.01 to 0.05. That is, flooding can be expected to occur about every 50 years but there is a 1 % to 5% chance that flooding will occur in anyone year.

4 Low: flooding occurs rarely. These areas were inundated in Namu but are higher than areas classified as "moderate". The areas will be flooded in events of similar size or larger than the flood that occurred in Cyclone Namu. This suggests that the probability of flooding in anyone year is about 0.01 (see section 9.2). That is, flooding can be expected to occur on average about every 100 years but there is a 1 % probability that flooding will occur in anyone year.

S Safe: these areas were not flooded in Cyclone Namu and are considered safe from flooding.

5.4 Landslide hazard mapping methods

Landslide hazard was mapped from an assessment of the factors determining landsliding frequency and magnitude, and correlation of this with landforms and physiographic units. Landslide hazard is primarily mapped from recognition of physiographic characteristics with each hazard category corresponding to one or more terrain types (Table 1).

The correlation between landslide hazard and terrain type was based on:

- an assessment of the frequency and distribution of landsliding in the past through appraisal of aerial photographs taken in 1962 and 1986 and from interpretation of topographical and vegetation patterns.

- an assessment of landsliding in Cyclone Namu as visible on aerial photographs taken in July 1986 and supplemented by an aerial reconnaissance of all watersheds and by field observations. Landslide distribution and variability, vegetation recovery on landslide scars, and sediment transport and river downcutting since Cyclone Namu, were studied at Gold Ridge and Mt Chaunapaho, and during a five-day visit to upper Sutakama River.

Landsliding is primarily related to rainfall, relief, slope steepness and previous erosion history. In recent major cyclones, regardless of the exact path of the cyclone, most landsliding occurs in the central mountains, where rainfall is highest, relief greatest and slopes steepest. In this zone, the location of landslides is largely independent of rock type, but in other areas geology may affect landslide type, size and frequency, through its influence on topography.

No attempt was made to assign probability of landsliding to hazard categories. There is little quantitative information on landslide frequency on different landforms and in different physiographic zones.

5.5 Landslide hazard categories

The following landslide hazard categories are identified:

lL Very high. Subject to frequent shallow and deep landslides (Figs. 4 and 6). This category corresponds to the long, steep to very steep slopes in the mountainous upper parts of the watersheds.

2L High. Subject to frequent shallow landslides. Deep landslides are uncommon. This category corresponds to the steep dissected lower slopes of the mountains in the upper to middle reaches of the watersheds (Figs. 4 and 6). Slopes are generally shorter than in areas classified as "very high" hazard.

3L Moderate. Infrequent shallow landslides, with the potential for deep landslides in extreme storms. This category corresponds to the rolling to short steep slopes on ridge crests above 1 OOOm altitude in the mountainous upper watersheds (Fig. 4). Generally they occur above areas classified as "very high" hazard (Table 1).

4L Low. Subject to infrequent shallow landslides (Figs. 6 and 7). This category corresponds to steep, but relatively low relief terrain throughout the intermediate zone (Table 1).

5 Safe. No significant landslide hazard. This category corresponds to rolling terrain and high terraces of the lower watersheds flanking the plains, the plains themselves and stable plateau surfaces in upper watersheds (Figs. 6 and 7).

Figure 4. Landslide hazard in upper Mbalisuna watershed in vicinity of Nanala. lL Very high landslide hazard; 2L High landslide hazard; 3L Moderate landslide hazard. Field observations of landslide distribution and variability were made in this area. Shallow landslides from Cyclone Narnu have been revegetated with ferns, vines and low scrub. Deep landslides from Cyclone Narnu remain predominantly unvegetated. Coarse sediment is still being provided from these landslides. Forest disturbance from shifting cultivation can be seen on the slopes below Nanala.

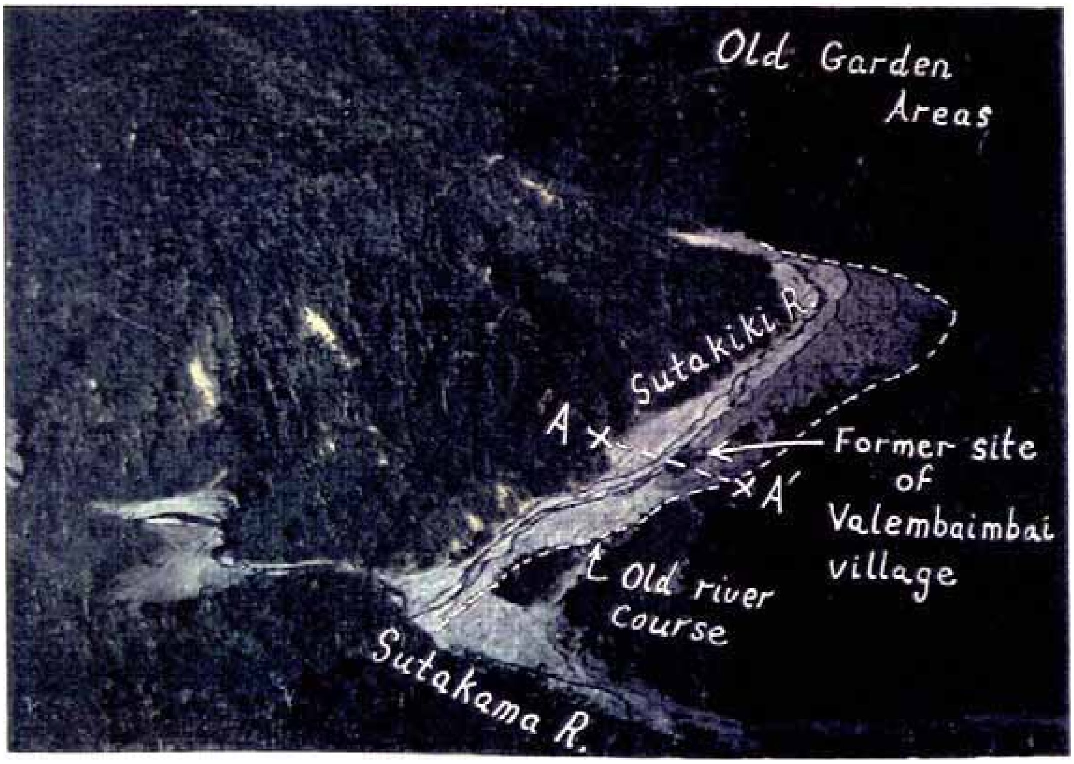

Figure 5. The site in upper Mbalisuna watershed of Valembaimbai village destroyed by a debris flood in Cyclone Namu. The river bed rose at least 6m and the river changed course. A cross section (A-A') is shown in figure 8. Garden areas destroyed by landsliding in Cyclone Namu can be seen in the upper right.

Figure 6. Landslide hazard in upper Nggurambusu watershed in vicinity of Salamarao. lL Very high landslide hazard; 2L High landslide hazard; 4L Low landslide hazard; 5 Safe. Shifting cultivation occurs on most areas mapped as 4L. These areas are subject to infrequent shallow landslides. "Safe" areas illustrated here are limestone-capped dip slopes. These areas are generally the safest sites in the mountains and most villages are located in them.

Figure 7. Landslide hazard in Lungga watershed close to Lungga Gorge. Savo Island in centre background. 4L Low landslide hazard; 5 Safe.

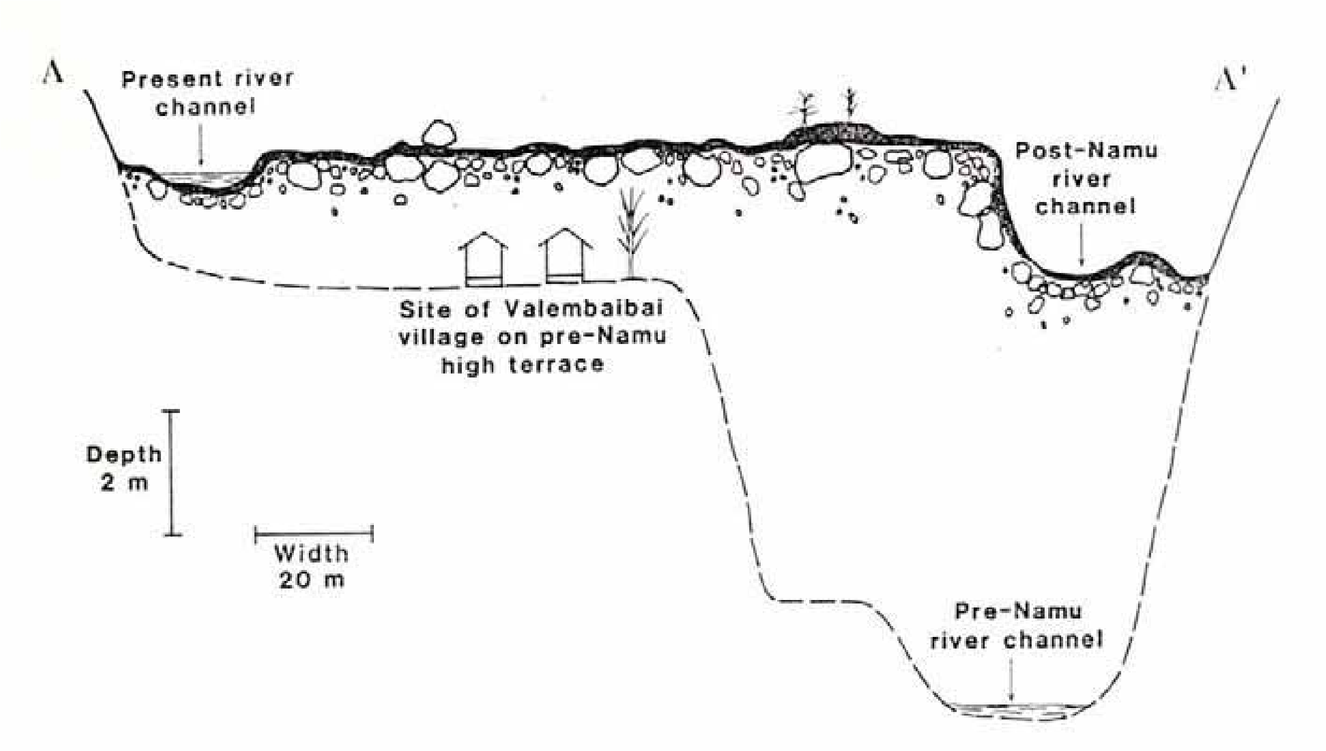

Figure 8. Cross section of lower Sutakiki River, in vicinity of Valembaimbai village, destroyed by debris flood in Cyclone Namu. Location of section marked on figure 7. Solid line indicates cross section in June 1989. Pre-Narnu topography (dotted) is reconstructed from villagersdescriptions.

Table 1. Landslide hazard categories.

Landslide hazard	Description of hazard	Sediment production	Physiographic region	Dominant Terrain(s)
1 Very high	Frequent shallow and deep landslides	Very high	Mountain zone above 800m	Long, steep to very steep (>35°) slopes
2 High	Frequent shallow landslides, infrequent deep landslides	Very high	Lower elevations (< lOOOm) in mountain zone & some river valleys in intermediate wne	Mod. steep to short steep extensively dissected lower mountain slopes on sedimentary rocks
3 Moderate	Infrequent shallow Landslides. Potential for rare large deep landslides on edge of units.	Moderate	Mountain zone above lOOOm	Rolling to short steep (15-35°) slopes on ridge crests and mountain tops.
4 Low	Infrequent shallow landslides	Low	Intermediate zone generally 200-800m	Short steep hillslopes, scarps and dissected terraces
5 Safe	No significant landsliding	Negligible from landsliding. Some sediment from surface wash and stream bank erosion.	Intermediate zone generally 40-200m	Rolling slopes and terraces. Includes stable low-angle dip slopes in mountain zone up to lOOOm altitude

6.0 OVERVIEW OF LANDSLIDE AND FLOOD HAZARD

Four 1: 50 000 and one 1: 150 000 maps of flood and landslide hazard accompany this report. They indicate areas where flooding and landsliding is likely to occur. Both flooding and landsliding are most likely to occur in Ngalimbiu, Mbalisuna and Mberande watersheds (Table 2). They are much less frequent and widespread in Tenaru, Matepono and Lungga watersheds.

Table 2. Areal extent of flood and landslide hazard categories on northern Guadalcanal.

	Watershed								
	Lungga	Tenaru	Ngalimbiu	Matepono	Mbalisuna	Mberande	Mbokokimbo	Nggurambusu	
	Area								Total
Flood hazard									
1 Very high	12.6	6.7	12.7	8.4	16.4	9.2	15.4	6.5	87.9
2 High	10.4	6.8	9.6	7.5	15.6	11.0	32.2	5.7	98.8
3 Moderate	7.0	25.2	28.4	19.0	25.2	21.6	43.1	7.4	176.9
4 Low	3.1	2.8	6.3	7.2	10.7	2.8	0	1.9	34.8
Landslide hazard									
lL Very high	43.9	0	90.7	10.2	89.0	95.0	58.1	39.3	426.2
2L High	37.2	0	17.8	25.5	18.9	31.0	43.9	10.2	184.5
3L Moderate	6.0	0	8.1	6.4	7.6	6.1	6.0	5.2	45.4
4L Low	191.6	43.5	50.8	86.7	29.0	21.7	93.4	73.3	590.0
5 Safe areas	96.5	76.9	30.7	34.1	33.6	22.5	99.3	54.8	448.3
Total (km^2)	408.2	161.9	255.0	205.0	246.1	220.9	391.4	204.4	2092.8

7 .0 **APPRAISAL OF FLOOD HAZARD**

The hazard maps accompanying this report provide an assessment of the likelihood of flooding by river water. They do not indicate the flooding that will occur from surface water ponding as a result of impeded drainage. Such flooding is likely to occur in most parts of the plains at least every two years. Many areas of the plains and the slightly higher flat areas immediately to the south are swampy. These areas are indicated on the maps but are not given a flooding hazard ranking as they are more influenced by surface water than by flooding from rivers. Drainage is possible in most of these areas, except those close to the coast, where there is insufficient gradient for water to drain away.

The hazard assessment also does not include assessment of flooding in coastal areas from storm surges or tsunami. The risk of such flooding is high for much of the low-lying north coast of Guadalcanal, but is beyond the scope of this investigation.

7 .1 **Overview of flood hazard on Guadalcanal Plains**

In the flooding that occurred during Cyclone Namu water covered all areas on the Plains assessed as having "very high", "high", "moderate" and "low" flood hazard. About 77% of the Plains was under water (Table 3). The maps indicate that there are few areas safe from flooding for events of the size of the floods that occurred in Cyclone Namu. The largest areas likely to be safe are: east of Ngalimbiu River in the vicinity of the World War II Carney Airfield (southeast of Mbokolovo) and the old ammunition dump east of Teavadha (Fig. 9), part of the oil palm plantation in the vicinity of Eto Stream northwest of Mbinu, and southeast of Henderson airfield (Fig. 10). Even in these areas, however, impeded drainage is likely to frequently cause surface flooding. Hansell and Wall (1974) indicate that the slow surface runoff of rainwater causes flooding in these areas but normally less than once every 2 years. Seepage channels dissecting the high terraces will flood more frequently.

In addition to the high floodplain areas that are safe from flooding, there are large areas of dissected, low terraces at the head of the plains that also are safe from river flooding. These are most extensive south of Henderson airfield (Fig. 10), near Kongga trail, between the Mbalisuna and Mberande Rivers, in the vicinity of Sumbaniu and Loimbora, and in the eastern plains.

While floodwater covered 95% of the floodplain in Cyclone Namu, most of the plains are not at risk in small, frequent floods. Only those areas adjacent to the present river channel are flooded regularly. Such flooding usually is confined within low terraces.

In large flood events with annual probability of occurrence of greater than 5%, however, the rivers not only overtop their banks but also flow in overflow "channels", often joining with the dense network of I-2m deep channels that dissect the higher parts of the plains (Fig. 11). Overflow generally occurs near the top of the plains or on the lower reaches near the coast. In both areas, confining terraces are low or absent.

The surfaces of high terraces bordering all the rivers on the Plains slope away from the channels and when waters overtop the terraces the rivers can spread out to cover large areas (Fig. 12). In large floods the rivers may coalesce. This occurred in Cyclone Namu.

The surfaces of high terraces bordering all the rivers on the Plains slope away from the channels and when waters overtop the terraces the rivers can spread out to cover large areas (Fig. 12). In large floods the rivers may coalesce. This occurred in Cyclone Namu.

Table 3. Areal extent of flood hazard categories on Guadalcanal Plains. Flood hazard areas in the mountains are not included (c.f. Table 2).

	Watershed								
	Lungga	Tenaru	Ngalimbiu	Matepono	Mbalisuna	Mberande	Mbokokimbo	Nggurambusu	
	Area								Total
Flood hazard									
1 Very high	2.6	1.7	9.7	5.2	10.4	3.5	6.2	0.2	39.5
2 High	5.7	1.7	8.8	5.5	10.6	7.0	24.2	1.7	65.2
3 Moderate	7.0	25.2	28.4	19.0	25.2	21.6	43.1	7.4	176.9
4 Low	3.1	2.8	6.3	7.2	10.7	2.8	0	1.9	34.8
5 Safe	8.7	14.0	8.4	5.8	18.6	1.7	24.9	9.8	91.9
Total (km^2)	27.2	45.5	61.6	42.6	75.4	36.5	98.5	21.0	408.3

Figure 9. Flood hazard adjacent to Ngalimbiu River. 1 **Very high**; 2 **High**; 3 **Moderate**; 4 **Low**; 5 **Safe**. The safe areas include the World War II ammunition dump and Carney airfield on the east (right) side of the river. All areas mapped as 1, 2, 3, and 4 were covered by at least one metre of water in Cyclone Namu.

Figure 10. Flood hazard adjacent to Lungga River at Henderson Airfield. 1 **Very High**; 2 **High**; 3 **Moderate**; 4 **Low**; 5 **Safe**. In Cyclone Namu floodwater from Lungga River covered much of Henderson Airfield. Stopbanking is required if this is not to occur in large floods in the future.

Figure 11. Schematic diagram of major river courses on Guadalcanal Plain. In large floods, overflows generally occur at the head of the Plains and on the deltas near the coast. At these locations the confining terraces are relatively low. Terraces tend to be higher in the middle sections of the rivers.

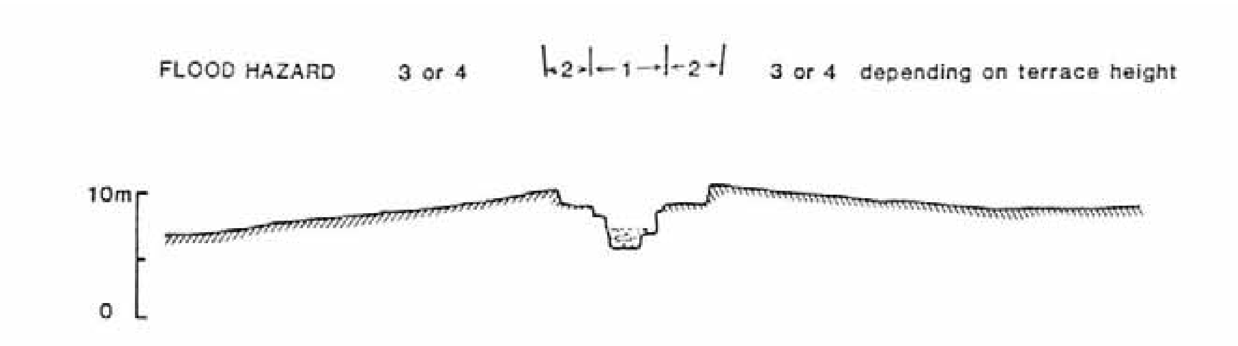

Figure 12. Schematic cross section for the major rivers on the plains. Slopes and heights are exaggerated. The rivers are perched. Consequently large areas of the Plain arc flooded when water level rises higher than the confining terraces. This occurred during Cyclone Namu. Deposition in Cyclone Narnu has raised the level of the river bed, reducing the freeboard for Ilood flows. Rood hazard categories are indicated.

7.2 Variation west to east

Of the eight watersheds, Ngalimbiu, Mbalisuna, Mberande and Mbokokimbo Rivers have the greatest proportion of their floodplains affected by moderate-sized or larger floods (Table 3). The Mbokokimbo River also has large, lowlying, swampy areas. Ngalimbiu, Mbalisuna, Mberande and Mbokokimbo Rivers rise in the highest mountains. Consequently flood flows are greater in these rivers than in rivers that do not rise in the mountains.

The Tenaru and Matepono Rivers do not rise in the high mountains and flood flows in Namu appear to be much less than in other rivers. The areas of "high" and "moderate" flood hazard adjacent to these rivers is relatively small. However the floodplains of these rivers are very swampy and surface flooding is likely to occur, particularly in areas close to the coast, in most heavy rains.

The Lungga River floodplain is relatively small as the dissected uplifted surface, that much of Honiara is built on, extends to within a few kilometres of the mouth of Lungga River. As a consequence, there is only a small area assessed as "moderate" or "high" flood hazard in Lungga watershed. It is important, however, that flooding is minimized adjacent to Lungga River as Henderson Airfield was flooded in Namu and an area on the Lungga delta proposed for industrial development may flood within the life of such a development (Fig. 8 and frontispiece).

The Nggurambusu River also is confined by low hills until near the coast. The "high" and "moderate" flood hazard area is small (Table 3).

7.3 Silt deposition

Siltation occurs in most floods. In Cyclone Namu approximately 30cm of silt was deposited over most of the Plains, although thicknesses varied locally (Danitofea and Baines, 1987). In some areas it was thicker, while in other areas no silt was deposited. Silt deposition can be expected in most floods. It will be restricted to the main channels in most floods, except when the rivers overtop their banks. No attempt has been made to assess the likely depth of silt deposition.

7.4 Flood hazard in mountain and intermediate zones

Although the same flood-hazard categories are used in the upper watersheds as on the Plains, the nature of the hazard in the two areas is different. Debris flows and debris floods are common in the mountains and river-bed levels rise rapidly. In addition, water levels rise more rapidly in the upper watersheds. Thus, flash floods, debris floods, deposition and bank erosion are the major flood-related hazards in the mountain and intermediate zones.

Rivers may rise tens of metres in the mountains where the narrow valleys confine water. In large floods, metres of gravel may be deposited in channels. Terraces even 6m above river level have a high probability of flooding (Fig. 6). Deposition of gravel in Cyclone Namu raised river beds, and has increased the likelihood of high terraces being flooded. Generally, two to four metres of incision has occurred in most tributaries since Namu, but it may be decades before rivers return to their pre-Namu level.

Most of the terraces in the upper watershed are assessed as having "high" or "moderate" flood hazard. At the scale of mapping we have had to map small "high"-flood-hazard terraces with "very high"-hazard channel areas, and some "low"-hazard terraces with "safe" areas. Safe areas are confined to very high terraces and to low-angle, lower hill slopes considered to be above flood level and not at risk from landsliding.

7.5 Correlation of flood-hazard categories and land systems

Guadalcanal has been divided into land systems by Hansell and Wall (1976). These systems delineate areas that are homogeneous with respect to climate, geology, vegetation and landform pattern. Within each land system more detailed units, land facets, are described. These usually correspond to individual landforms. Land systems generally include more than one flood hazard category but land facets often correspond to a distinct flood-hazard category (Table 3). Thus, descriptions of land facets in Hansell and Wall provide a summary of the landforms present in each hazard category, and their spatial and topographic arrangement.

Table 4. Correlation of flood hazard categories with land systems and land facets of Hansell and Wall (1974).

Flood hazard	Terrain	Land system	Land facet
1 Very high	River channels	Lungga	3
	Drainage lines	Matepono	2
	Fore-swamp margins & estuaries	Kumotu	1,2,3,4
2 High	Abandoned channels & meanders, drainage depressions, backplains	Lungga	1,2,4,5
	Floodplains in intermediate zone	Poha	3
	Alluvial plains & overflow channels	Matepono	5
	Backswamps near river delta	Matepono	4
	Wet alluvial valleys	Pusuraghi	4
	Frontal beach ridges	Tenaru	1, 3
3 Moderate	Stable alluvial plains	Matepono	1
	Terraces in intermediate zone	Poha	1,2
	Stable & inland beach ridges	Tenaru	
4 Low	Prior point bars, levees and alluvial plains flanking the hills	Matepono	3, 1
5 Safe	Low dissected terraces with gentle slopes	Kongga	1, 2
	Low dissected hills	Tinahula	1,2,3
	Deep to shallow water swamps	Pusuraghi	1,2,3

7.6 Factors determining flood hazard

The degree of hazard associated with flooding is determined by a variety of factors. These are discussed below with reference to Guadalcanal.

- size of flood

  The size of a flood, and the damage that it causes, varies from one storm to another. Small floods occur frequently, but generally cause minor damage. They are usually confined within terraces and do not flood large areas. In contrast, large floods, although somewhat rare, can cause massive damage and community disruption. Unfortunately it is impossible to predict in advance when floods will occur. Also, there is no guarantee that if a major flood has occurred recently, another will not occur in a relatively short period of time. A flood of similar size to that which occurred in Cyclone Namu could occur, for example, next year.

- effective warning time

  Flood hazard and flood damage can be reduced by evacuation if adequate time is available. However, even if people and possessions are fully evacuated, a flood will generally cause significant damage and community disruption. People are temporarily displaced from their homes and workplaces, flood-affected buildings need to be cleaned and restored, evacuated possessions have to be returned.

  Available warning time is determined largely by watershed characteristics. For the short, steep watersheds on Guadalcanal warning time is short. Even if sophisticated telemetered flood-warning systems were in place in the upper watersheds, warning time would probably be as little as 6 hours. Cyclone warnings provide longer warning time for flooding on Guadalcanal. However, cyclone warnings may give little indication of flood magnitude and there are likely to be many "false alarms", where areas are evacuated, but massive flooding does not occur. This is preferable to loss of life resulting from inadequate warning but it causes people to take less notice of subsequent warnings.

- flood awareness

  This is a measure of the the time taken by flood-affected people to respond to flood warnings. In communities with a high degree of flood awareness, the response is prompt and efficient. Residents have developed evacuation plans and implement them rapidly. In communities with a low degree of flood awareness, flood warnings are liable to be ignored and residents are often confused about when to evacuate, what to take, and where it should be taken.

  The major factor determining the degree of flood awareness is the frequency of moderate to large floods in the recent history of the area. Many people on Guadalcanal Plains will have a high degree of flood awareness at present, but this will fade rapidly as memories of Cyclone Namu fade.

- rate of rise of floodwater

  Situations in which floodwaters rise rapidly are potentially far more dangerous, and cause more damage, than situations in which flood levels increase in a slow and gradual manner. In the steep rivers in the mountains of Guadalcanal rivers rise very rapidly, probably a metre or so per hour at some locations. On the Plains flood levels also rise rapidly, probably about 0.5m per hour at some locations. In large floods overflows from the river channels will occur and quickly bring water to much of the Plains.

- evacuation problems

  The damage and disruption caused by a flood also depends upon the difficulty of evacuating flood-affected people and property. Evacuation may be difficult because:

  (i) of the difficulty of wading through floodwater. This can be exacerbated by distance, uneven ground, fences, debris and localized high velocities. In Cyclone Namu the rivers carried large trees making wading dangerous in some areas. However, in other areas, particularly down-flow of oil palm plantations, the flood waters were relatively free of floating trees and people waded many kilometers through metre-deep water.

  In Cyclone Namu, evacuation of flooded villages was made easier by the timing of the flood peak. Highest water levels occurred during daylight hours, enabling people to see where they were fleeing to. If the floods had peaked during night many more lives would have been lost.

  (ii) the distance to flood-free ground. On Guadalcanal this distance is relatively small. While in Narnu-size floods there are few safe areas on the Plains, generally people will not be more than 15 kilometers from flood-free areas in the foothills at the top of the Plains.

  (iii) the large number of people that have to be moved over roads, which cannot cope with the increased traffic. The availability of sufficient vehicles to transport evacuees also may limit effective evacuation.

- depth and velocity of floodwater

  The threat to life and limb and the structural damage caused by floods depends largely upon the speed and depth of floodwaters. The ability to safely wade or drive through floodwaters is very dependent on depth and velocity.

  Depth and velocity vary with flood size. At a particular location, water depth and velocity will increase as the size of the flood increases. Thus, in an area assessed as "high" hazard, water depth and velocity will be greater in rare large floods than in the more frequent smaller floods.

  Depth and velocity also vary across flood-prone areas. They are greatest in the vicinity of main river channels. Towards the edge of flooded areas depths are generally shallower and floodwaters move at slow speeds. In Cyclone Namu velocities were low and water depth generally a metre or less over most of the Plain, except in or adjacent to the main river channels. Velocities were sufficiently high adjacent to Ngalimbiu River at SIPL headquarters to carry away cars and construction machinery.

- potential flood damage

  The amount of flood damage to the contents of a building depends largely upon the depth to which the building is flooded. If the floodwaters do not rise above the habitable floor level of residential dwellings, damage is generally slight. Thus, the height of floor level is an important factor in minimizing damage. Higher floor levels, as when houses are on stilts, reduce damage.

  Flood damage to agricultural land depends on the nature of the crops grown. Flooding in Cyclone Namu had little lasting effect on mature oil palms, but damaged young trees. Rice growing areas were adversely affected by siltation of the irrigation system. Livestock farming also was severely affected through stock losses.

- obstructions

  Depth of flooding, and hence the overall degree of flood damage, is increased by the presence of obstructions to the movement of floodwater. Such obstructions include buildings, inadequate drainage structures through embankments, bridges, areas built up by land-fill, and the blocking effect of trees and debris. In Cyclone Namu the build up of trees behind Ngalimbiu Bridge exacerbated flood damage upstream of the bridge.

7.7 Reducing flood hazard

Damage and social disruption from flooding may be reduced through a variety of measures, including:

- zoning. Land use in flood-prone areas should be compatible with the nature of the flooding hazard. Zoning is an effective and long term means of limiting flood damage. Care must be taken, however, not to unnecessarily restrict the use of flood-prone land. In addition, zoning may be inappropriate where development has already occurred.

- building and development controls. To minimize flood losses conditions can be imposed on new developments to ensure that they do not significantly add to the overall level of flood damage. Typically buildings are flood-proofed by ensuring that habitable floor level is above flood level.

  The present design of some houses on the Plains, with their floors about one metre above ground level, mitigates flood hazard. Some recent housing development, particularly in settlements for plantation workers, do not use houses on stilts but more conventional "western-style" houses. These houses and their contents are much more likely to be damaged in flooding.

- construction of river protection structures. Stopbanks (revetments, levees or dikes) or floodways may be constructed to prevent flooding of protected areas. However, it must be remembered that protection can generally only be for floods less than a certain magnitude. In a flood that is larger than that for which the protection is designed, the area being protected will be flooded and damage to developments may be high. This arises because the stopbank gives a false sense of security, encouraging development and because once water has overtopped the stopbank it often has nowhere to flow away to as the flood recedes. For these reasons there has been a move away from structural solutions to flood hazard in some countries.

It may be possible, in some parts of the Plains, to build stop banks that will provide protection from the maximum possible flood. For example, in many of the areas assessed as having "moderate" flood hazard two metre high stopbanks probably would provide protection from all flooding.

Certainly the flood hazard could be reduced over large areas of the plains by stopbanks along the major rivers. Such stop banking would reduce the probability of the rivers overflowing, as occurred in Namu. However, the cost of such protection must be weighed against the benefit of reducing flood hazard. At present, extensive flood protection does not appear economically justified for most of the Plains, given the high cost of stop banking and the relatively low value of the assets to be protected.

However, if stopbanking is considered, even only locally, it is important that stop banks be well designed and maintained. We observed an attempt to control the Mberande River below the bridge by bulldozing banks of river-bed material. This was unsuccessful as the river removed the stopbank To be effective, stopbanks must be erosion-resistant. This is generally achieved through the use of large boulders or concrete structures to armour or core the stopbanks. However, even well-designed and constructed stop banks erode in high floods as scour occurs on river bends. Thus, it is essential that stopbanks be regularly inspected for damage, and well-maintained. It also is important that stop bank design includes drainage of areas behind the stop banks.

As discussed in section 11.6 we consider that stop banking should be used to reduce flood hazard at Henderson Airfield and Selwyn College. Stopbanks and river training also should be considered if industrial development occurs on the lower parts of Lungga delta. Protection also may be warranted in other areas if the consequences of flooding to existing or proposed development are considered to be unacceptable.

- evacuation planning. Evacuation planning and adequate flood warning can reduce flood damage by enabling people to move out of the way of an approaching flood. Planning makes people aware of when and how they should evacuate themselves and their possessions and where they should go when a flood eventuates.

8.0 APPRAISAL OF LANDSLIDE HAZARD

8.1 Overview of landslide hazard

Mountainous areas in upper watersheds generally have "very high" and "high" landslide hazard (Map sheets 1 to 5). The few "safe" areas in upper watersheds are usually on gently sloping ridge crests formed by the dip-surfaces of well-consolidated sandstone beds. "Safe" and "low" hazard areas are widespread and extensive in the intermediate zone. Most villages are located in "safe" areas in the intermediate zone.

8.2 Variation between watersheds

Of the watersheds mapped, Ngalimbiu and Mbalisuna watersheds have the greatest area assessed as "very high" and "high" landslide hazard (Table 5). They suffered most damage in Cyclone Namu, having the greatest density of landsliding, and the greatest number of deep landslides (Stephens *et al., 1986).* Most villages and gardens damaged in Cyclone Namu were in these two watersheds. Landslide density was greatest on north- and east-facing slopes in the upper Ngalimbiu watershed.

Mberande watershed has large areas assessed as "very high" and "high" hazard. Landslides were widespread in Cyclone Namu, although not as extensive as in Ngalimbiu and Mbalisuna watersheds.

Of the watersheds mapped, Mbokokimbo and Ngggurambusu watersheds were closest to the path of Cyclone Namu, but suffered less landslide damage than Ngalimbiu, Mbalisuna and Mberande watersheds (Stephens *et al., 1986).* Large areas in upper Mbokokimbo watershed are assessed as "very high" landslide hazard, however, as the vegetation pattern shows evidence of frequent landsliding Landslide hazard in upper Ngggurambusu appears less, probably reflecting lower rainfall (Fig. 2). Extensive high, gently-sloping ridge crests developed on well-consolidated sedimentary rocks occur in upper Ngggurambusu and Mbokokimbo watersheds and assessed as "safe".

Matepono watershed only has a small area of mountainous terrain assessed as "very high" hazard. Shallow landslides were widespread in upper Matepono watershed in Cyclone Namu. This area has a "high" landslide hazard. The intermediate zone, of dissected hills with short steep slopes with "low" hazard and "safe" ridge crests, is extensive in Matepono and Mbokokimbo watersheds. Population density is greatest in these two watersheds, with most villages located on ridges in the intermediate zone.

Lungga and Tenaru watersheds have the lowest landslide hazard (Table 5). Only the southeast corner of Lungga watershed is mountainous. Most of the Lungga and all of Tenaru watersheds comprise dissected plateaux that are not landslide-prone or have "low" landslide hazard.

8.3 Correlation of landslide-hazard categories and land systems

Landslide-hazard categories generally include several land systems as mapped by Hansell and Wall (1974). However, land facets and landslide-hazard categories are better correlated (Table 6). Hansell and Wall's description of land facets provide a good summary of landforms present in each of our landslidehazard categories, and their spatial and topographic arrangement.

Table 5. Landsliding hazard on Guadalcanal. Proportion of hazard categories in the mountainous part of the watersheds (i.e. this does not include flood hazard units or "safe" areas on the Plains).

	Watershed								
	Lungga	Tenaru	Ngalimbiu	Matepono	Mbalisuna	Mberande	Mbokokimbo	Nggurambusu	
Landslide hazard	Area (km^2)								Total
1L Very high	43.9	0	90.7	10.2	89.0	94.9	58.1	39.3	426.1
2L High	37.2	0	17.8	25.5	18.9	31.1	43.9	10.2	184.6
3L Moderate	6.0	0	8.1	6.4	7.6	6.1	6.0	5.2	45.4
4L Low	191.5	43.5	50.8	86.7	29.0	21.7	93.4	73.3	589.9
5 Safe	87.8	62.9	22.3	28.4	15.0	20.8	74.3	45.0	356.5
Total (km^2)	366.4	106.4	189.7	157.2	159.5	174.6	275.7	173.0	1602.4

Table 6. Correlation of landslide-hazard categories with land systems and land facets of Hansell and Wall (1974).

Flood hazard	Terrain	Predominant land system and facets	Minor land facets
1L Very high	Long mountain slopes Precipitous lower mountain slopes Steep narrow ridge crests Very steep cuesta slopes	Chiri 2, 3 Sinoli 3 Sinoli 4 Sinoli 2 Namalova 1 Chiri 1 Namalova 2	Chiri 4 Namalova 4 Sinoli 5
2L High	Dissected hillslopes on volcanic rocks Dissected hillslopes on sedimentary rocks Uneroded mountain slopes Scarp slopes on high cuestas Rounded hills on ultramafic rocks	Chiri 2, 3 Ghove 3 Sinoh 3 Leomate 4 Marapa 1, 2	Mbina 1 Vanusa 3, 4 Ghove 4 Sura 2, 5
3L Moderate	Broad ridge crests Gentle mountain tops	Chiri 1 Sinoli 1 Namalova 3 Sura 4	Okea 3 Mbina 2 Leomate 3
4L Low	Hill slopes on dissected plateaux Sloping ridges Shallow gullies Terrace scarps and short steep hill slopes	Ghove 3 Vanusa 3, 4 Leomate 2 Sura 3 Vanusa 2 Sura 2 Kongga 3 Tinahula 3 Leomate 4 Paripao 2, 3	Ghove 1 Sura 5 Lengakiki 2, 4 Soto 1, 2
5 Safe	Broad ridges on gently sloping sedimentary rocks Dipslopes on high cuestas Broad ridges on Tertiary rocks Karst areas of low relief Broad terrace treads Gentle slopes on low terraces	Ghove 2 Vanusa 1 Leomate 1 Okea 1, 2 Sura 1 Huranja 1, 2, 3 Kongga 1 Paripao 1 Tinahulu 2 Kongga 2 Paripao 3 Tinahulu 1, 3	Sura 2 Lengakiki 3

8.4 Sediment production from watersheds

Sediment production is likely to be correlated with landslide frequency, magnitude and density. Ngalimbiu, Mbalisuna and Mberande watersheds, with large areas of "very high" and "high" landslide hazard, are likely to contribute more sediment than those with lower landslide hazard.

In the three years since Cyclone Namu, most shallow landslides have revegetated, and little sediment is supplied from them. Large, deep landslides remain unvegetated and continue to supply sediment. These landslides are most common in Ngalimbiu, Mbalisuna, Mberande and Mbokokimbo watersheds. Gravel terraces deposited in Namu also are revegetating rapidly. Rivers have down cut into most of these terraces. Sediment stored in these terraces will supply material to the rivers for decades.

8.5 Human influence on landsliding and flooding

Rainfall, slope steepness and slope length are the dominant factors controlling landslide occurrence. Flooding is primarily a result of extremely high rainfall in the mountains. Locally, however, human activity may exacerbate flooding and landsliding. Shifting cultivation and logging disrupt vegetation. Overseas studies indicate that landsliding rates may increase thirty-fold when trees are removed from steep slopes (Sidle *et al.,* 1985). Such an increase will be localized, however and may be relatively short-lasting if slopes quickly revegetate. Most landsliding and increased sediment production from forestry operations is associated with logging roads and tracks. Sediment from such roads may be increasing the sediment load of Nggurambusu and Mbokokimbo Rivers, but no measure of this is available. Forestry operations may add to flood hazard if organic debris, left near river courses, is transported downstream in floods. Such debris may form dams behind bridges, locally increasing flood levels. In large floods, however, landslides carry many trees into rivers and those derived from logging operations are likely to be only a small proportion of the total.

While there are no data to indicate the affect of human activities on landsliding and flooding in Guadalcanal, we believe that their affect is small in comparison to the naturally high rates of erosion and runoff resulting from the frequent heavy rainfalls. However, if large-scale forestry did occur, erosion rates, sediment yields and flood peaks would all increase.

9.0 RELIABILITY OF FLOOD HAZARD ASSESSMENTS

The hazard mapping accompanying this report was compiled on 1 :25 000 scale aerial photographs. It is presented here in map form at twice this scale. The maps are suitable for broad planning. They are not a substitute for detailed site investigation. Where major development is planned, detailed leveling will be required to more accurately delineate flood hazard.

The low relief of the plains, and the limited data available on flood frequency, reduce the precision of the hazard assessment, particularly the estimates of flood frequency. This is discussed below.

9.1 Position of boundaries

In general, boundaries between "very high" and "high", and "high" and "moderate" flood hazard areas are marked by terraces visible in the field and on aerial photographs. Boundaries between other categories are often less clear, and gradational in many cases. As a consequence, boundaries on the map must not be regarded as sharp unless they correspond to a topographic feature such as a terrace scarp. Gradational boundaries are represented as dotted lines on the accompanying maps.

Gradational boundaries are very difficult to map in the field, because vegetation masks any subtle topographic expression. We found stereo-photographic interpretation of aerial photographs to be the best method of locating gradational boundaries. In oil palm and forested areas, however, the boundaries are extremely difficult to locate, even on aerial photographs.

The mapped flood hazard units take into account the effect of existing man-made structures that alter flood hazard. This is particularly important in assessing the flood hazard in areas irrigated for rice prior to Cyclone Namu. Flood water followed irrigation channels during Namu, flooding some areas that were topographically higher than surrounding terrain. This pattern of flooding is likely to be repeated if the irrigation channels remain intact and floodwater enters them again.

Downcutting of river channels will alter the extent of the high and moderate flood hazard classes in the future. Cyclone Namu deposited large amounts of sand and silt in most river channels. Landslide debris has aggraded many reaches in upper watersheds and is likely to provide ample sediment to the river over the next decade or so. Over time, this debris will either be removed, or revegetated and become less available for transport. Flood flows then are likely to cut into the Namu and post-Namu sediments, returning the channels on the plains to their pre-N amu condition. Aerial photographs taken in 1984 show narrow, highly sinuous, channels entrenched at least a metre into a broad channel area. Annual flood flows would have been contained within the narrow channels rather than spreading across a wide floodplain as at present. It is not known how long it will take for channels to degrade following Namu. Ten or more years may be required Flood hazards have been assessed for the present channel condition. When degradation occurs the "very high" hazard areas will contract to the entrenched channels (Fig. 11). In general, the boundaries between "moderate" and "high" categories will not change. No change will occur in the position of the "moderate"-"low" and "low"-"safe" boundaries as these relate to large floods which raise the level of the riverbed. Construction of river protection structures, such as stop banks, also would contract the hazard zones.

Siltation of many areas of the Plains has altered infiltration rates. In many areas, surface water flooding has been common after Namu where silting has reduced drainage. It is not known how long this effect will persist. However, eventually the silt will be incorporated into the soil. Drainage probably will improve in five years, and after 20 years should be similar to before Cyclone Namu. This will not affect the flood hazard mapping, however, as the maps show only flooding from rivers rather than from ponding surface water. Most areas on the plains are likely to flood, at least locally, from surface water ponding in heavy rainstorms.

9.2 Frequency of flooding

Flood hazard has been assessed in five categories corresponding to probability of flooding. These probabilities are based on scant data. They are crude estimates based on interpolation between what is clearly flooded annually and what occurred in an extreme event, Cyclone Namu. They are informed guesses, based on our experience mapping flood hazard in areas with better records. We are confident of the relative ranking of the hazard categories but the probabilities of flooding for each category is imprecise.

The benchmark provided by flooding in Cyclone Namu is an important ingredient in our assessment of flood hazard. However, the probability of an event of this size is only crudely defined. The recurrence interval of flood flow in Lungga River at the gauging station, where there is approximately 20 years ofrecord, is estimated to be somewhere in the range 60 to 120 years (Cameron McNamara, 1986). Cameron McNamara estimate that flow at the Ngalimbiu Bridge had a recurrence in excess of 200 years, but as a solid wall of trees formed against the bridge and dammed the river, their estimate of recurrence must be considered speculative.

The estimate for Lungga River is based on a record of only moderate quality. Lungga watershed had less landslide damage, and did not have as large flows as the Ngalimbiu, Mbalisuna or Mberande Rivers to the east. Cameron McNamara argue that the recurrence interval for the peak flow in Ngalimbiu River was greater than that for Lungga River because the Ngalimbiu was closer to the cyclone path. However, it seems more likely that the Lungga River flow was less because the river mainly drains hills rather than mountains. Certainly the rainfall pattern (Fig. 2) suggests that specific flood flows should be less in the Lungga than in rivers draining from the mountains. It is not known if rainfall in Namu was distributed in the same way as annual rainfall totals. However, given that the cyclone, like most storms, was deflected by the mountains it would seem likely that the pattern of rainfall in the Cyclone was similar to the pattern in the frequent storms that in total give the pattern of annual rainfall. This suggests that the probability of floods of Namu-size in the other rivers may be similar to that estimated from the flow in the Lungga River in Cyclone Namu.

One other piece of evidence can be used to estimate the frequency of Namu-size events. Sections exposed in the banks of Matepono River near the highway bridge show at least six layers of silt. Each of these layers overlie a soil layer and relate to overbank deposition in past large floods. About 0.3m of silt from the Namu flood caps the section (Fig. 13). Charcoal, collected from within the soil beneath the second highest silt layer, has a radiocarbon date of 1 220±130 years B. P. (old half-life). This indicates that the last major flood in the Matepono before Cyclone N amu occurred over 1 000 years ago. This suggests that the annual probability of such large floods may be about 0.1 %.

Given these pieces of evidence, and the difficulty in judging how applicable the estimate of flood frequency in the Lungga is to other rivers and the uncertainty in the estimate from the Lungga, we have used a value of about 1 % for the annual probability of Namu-sized flooding, although we realise the actual probability could be smaller.

Figure 13. Layers of river deposits and buried soils in west bank of Matepono River approximately 200m above road bridge. The top silt was deposited in Cyclone Namu. At least five other alternations of silt and buried soils are present. These represent deposition in large floods. Charcoal, from the top of the soil buried by silt from the last large flood prior to Namu, has a radiocarbon age of I 220±130 years. A complete description of the section is given in Appendix 1.

Figure 14. Terrace riser (approximately 8m high) in upper Sutakama watershed. showing large boulders and unsorted nature of deposits. Terrace pre-dates Cyclone Namu. Partly revegetated deposits from Cyclone Namu are visible in foreground.

10.0 RELIABILITY OF LANDSLIDE HAZARD ASSESSMENT

The hazard mapping presented in this report was compiled on 1 :25 000 scale aerial photographs. It is presented here in map form at twice this scale. The maps are suitable for broad planning. They are not a substitute for detailed site investigation or detailed zoning. Landslide hazard units are generally larger and more heterogeneous than flood hazard units making the frequency of landsliding variable with in any landslide hazard unit. Estimates of landslide frequency are based on qualitative information and are relative assessments only.

10.1 Position of boundaries

Boundaries between landslide-hazard units are generally sharp. They were located, by stereoscopic interpretation of aerial photographs, on the basis of slope and relief (i e. landform), and erosion severity. Most are located where slope angle changes, as between rolling mountain tops ("moderate" landslide hazard category) and very steep mountain sides ("very high" hazard), or between terrace treads ("safe") and steep terrace scarps ("low" hazard). Occasionally the boundary between "very high" and "high" was located on the basis of erosion severity. Altitude and physiographic zones also were occasionally used as a basis for locating boundaries as between "very high" or "high" and "low" categories. In general, however, hazard categories were distinguished on the basis of landform.: For example, areas designated "very high" hazard correspond to long steep slopes in the mountains. These areas consistently show the most severe landsliding.

10.2 Variation within landslide hazard units

Individual landslide hazard units generally include a range of landforms with differing susceptibility to landsliding. For example, within an area of predominantly "high"-hazard steep mountain slopes, there are often small areas of rolling tops, gentle lower slopes, or high terraces that have "low" landslide hazard. As a consequence, the probability of landsliding is highly variable within any landslide hazard unit. This variability in probability of landsliding is a major difference between landslide hazard and flood hazard units. The latter tend to comprise only one or a few landforms and hence are more homogeneous with respect to probability of flooding.

It is possible to delineate different landforms with differing landslide susceptibility within hazard units but not at the 1: 50 000 scale mapping presented here. Generally, however, the land facets identified within the land systems of Hansell and Wall (1974) provide a suitable subdivision of the hazard units into areas that have similar likelihood of landsliding (Table 5). Land facets may be used as a first approximation to landslide hazard if more detailed delineation is required.

10.3 Frequency of landsliding

We have not assigned probability of landsliding to the landslide hazard categories as we have for flood hazard categories. The frequency, magnitude and density of landsliding are relative between categories. They are based on a variety of qualitative information:

- visual evidence. Aerial photographs taken after Cyclone Namu show a very large number of landslides (Stephens *et al.,* 1986). Landslide damage was greater in Cyclone Namu than in at least the previous two decades, as 1962 aerial photographs show few areas actively eroding.

they show generally well vegetated slopes and narrow river channels in the mountains. However, scattered landslide scars are visible on 1962 aerial photographs and we observed some fresh scars (i.e. post Namu) during our aerial reconnaissance. Landsliding appears frequent in the mountains.

- vegetation pattern. Vegetation patterns in the upper watersheds show evidence of frequent disturbance. Landslides revegetate rapidly, with an initial cover of ferns and grasses, covering shallow landslide scars within a year or so. This vegetation is quickly replaced by small shrubs, tree ferns and trees. After about 30 years, larger trees appear and gradually become dominant. Thus, landsliding is recorded in the vegetation pattern for many decades as relatively open canopied vegetation that has lower and smaller trees than the surrounding forest. However, a similar vegetation recovery patterns occurs in old garden areas (Hansell and Wall, 1976), complicating the use of vegetation in assessing landslide frequency.

- frequency of landslide triggering events. Landslides are triggered by cyclones and earthquakes. Six major cyclones have affected Guadalcanal in the last 35 years (Fig. 3). Earthquakes also are frequent. Villagers in the Sutakama watershed indicate that landsliding occurred in an earthquake in 1977 and in a cyclone in 1966 or 1967. However, the land sliding that occurred in Cyclone Namu is the greatest within living memory, although one elderly resident of Nanala village had heard a story of a big flood a "long time ago". Rendel Palmer and Tritton (1986) indicate that minor landslides occurred at Lees Lake in 1937, 1966 and 1977.

- occurrence of high terraces in mountain valleys. Terraces are preserved up to 14m above the level of terraces formed in Cyclone Namu in the upper Mbalisuna watershed (Fig. 14). These represent massive deposition in previous large floods.

In combination, these lines of evidence indicate that landsliding occurs frequently in some areas of the mountains but that damage as extensive as that which occurred in Cyclone Namu only occurs on average every few centuries.

11.0 HAZARD MANAGEMENT AND PLANNING

Flooding of rivers and landsliding on slopes are natural, recurring but unpredictable phenomena. This fact needs to be understood by those living on or responsible for management of areas subject to landsliding or flooding.

11.1 The location of future development on the Plains

In many countries the continued development of flood-prone land has resulted in numerous situations where large scale damage and community disruption results when large floods occur. With the advantage of hindsight, it appears that a number of these developments were poorly sited. Learning from these experiences, it is evident that zoning regulations and development conditions are the best long term means of firstly, planning land use to reduce flood hazard, and secondly, of limiting the future growth in flood damage. For these reasons, new developments on flood-prone land on the Plains should be subject to zoning and building controls. The purpose of these controls is to ensure that developments are sited and subject to conditions appropriate to the flood hazard.

New oil palm refineries, schools, villages, industrial developments, or any other major developments that are anticipated to have a life of more than about

20 years, should be sited in areas mapped as "low flood hazard" or "safe". If the structures are sited in other areas then there is a high probability of damage to the structure and loss of life from flooding during the design-life. Developments may be located in such areas, however, if the hazard can be mitigated or if the consequence of flooding is deemed acceptable.

11.2 Managing hazard to existing developments on the Plains

Given future flooding of the magnitude of that in Cyclone Namu it is inevitable that internal transport will be disrupted. Floodwater will cover the main road in many places. This is unavoidable unless the road were to be raised, an expensive option. Floodwater is likely to cover the road, perhaps for as long as five days although large trucks may be able to negotiate the road sooner than this. This assumes, however, that bridges are not destroyed. It is important that bridges are designed to cope with very large flows and the debris carried in such floods. However, this may not be possible or economic. Consequently, it is likely that internal road communication would be disrupted in a future Namu-sized cyclone.

In Cyclone Namu, Henderson Airfield, the only airfield in the Solomon Islands suitable for large aeroplanes, was covered with a metre of floodwater (National Disaster Council, 1986b). While the water only remained for about three hours, international relief could not be supplied until at least one day after the cyclone had passed. Future cyclones as large as Namu also will flood and close the airfield unless engineering works are carried out to protect it. Stopbanks are needed to prevent floodwaters from an overflow channel of Lungga River flooding the airport. A detailed study is required to design adequate flood protection for Henderson Airfield.

To ensure that external communications are maintained in future cyclones, t he adequacy of the present flood way under the Lungga Bridge also should be addressed when the present bridge is replaced. In Cyclone Namu floodwater reached to within 0.6m of the decking and logs carried by the water hit the underside of the decking. If part of the peak flow had not overflowed through Henderson Airfield it is likely that the Lungga bridge may have been overtopped and damaged. In any civil defence emergency the Lungga bridge is an essential link between Honiara and Henderson Airfield.

Selwyn College was flooded with over a metre of water in Namu. Many trees were carried through the school. People caught in the flood report that they were carried upstream by the floodwater. This occurred because the flooding at Selwyn College and at the SIPL settlement on the east bank of Ngalimbiu River resulted from water damming behind the wall of logs that jammed the river at the highway bridge. At Selwyn College floodwater remained for about three hours then drained quickly when the dam at the bridge burst as the bridge approaches were washed away. Since the cyclone a new bridge with only one pier has been. Logs are less likely to jam behind the new bridge and consequently a dam of logs like the one that flooded Selwyn College is much less likely to occur However, at present, the old bridge piers are still standing and a dam could easily form behind them. The piers of the old bridge should be removed before the next wet season. Once this is done the long term hazard (i.e. when the river downcuts again) at Selwyn College will be reduced. With well-designed stopbank and drainage Selwyn College could be made safe from all but the most extreme floods.

11.3 Land use planning for agricultural development

Irregular flooding leading to deposition of silt makes the soils on lower terraces close to the major rivers generally more fertile than those on topographically higher terraces (Hansell and Wall, 1974). However, on these lower terraces flooding is more likely to damage crops. Thus, a trade-off must be made, between fertility and frequency of damage from floods. Land use should reflect this, with annual, high yielding crops, such as vegetables, being grown on lower areas, and slower-growing cash crops on higher areas. As outlined above, however, it is important that processing plants and villages to service these agricultural areas are located in topographically high areas, rather than adjacent to the higher fertility, but more frequently flooded, low terraces.

In the mountains and hills a similar trade-off occurs between safety and fertility. Areas that are not landslide-prone generally have thick relatively infertile soils unsuited for agriculture. While landslide-prone areas have thin, fertile soils more suited for yams, taro and other food crops (Wall *et al.,* 1979). The pattern of agriculture and settlement in the hills reflects these differences in stability and fertility in different parts of the landscape. Villages are located on "safe" stable ridge crests and are the centre for far-ranging shifting cultivation of the steep landslide-prone slopes.

We have mapped areas that flood frequently but only from surface water. Many swampy areas, if drained, may be suitable for agricultural development. We do not know, however, the effects of drainage on soil fertility. The present high water tables reduce leaching and so, to some extent, reduce the loss of nutrients. It also must be noted that some of these presently swampy areas would be flooded when rivers overflow their banks in very large floods.

Hansell and Wall (1976) stress that the agricultural potential of the Plains is grossly under-utilized. Over a decade later, while some land-use intensification has occurred, it is still well below its potential. To feed and support the rapidly growing population of Honiara it is important that further intensification occurs in a planned manner so that land use is matched to agricultural potential. The Plains are the only area in the Solomon Islands with the added advantage of a dry season making crop diversification and large-scale arable cultivation possible.

We hope that this report will act as a catalyst to integrate future planning of development of the Guadalcanal Plains. However, flood hazard is only one of the many factors that need to be considered in planning land use and development. Economics, fertility, crop suitability, land tenure, availability of water, and so on, also must be considered. It is important that planning decisions consider all these factors. Consequently planning must be done by multi-disciplinary and inter-Departmental teams or committees.

11.4 Safe location of developments in the mountains

The hazard maps provide an indication of areas suitable for development, but are not useful for detailed planning of where to site developments in the mountains and hills. However, in general, areas mapped as "very high" and "moderate" landslide-hazard comprise steep slopes or high altitude areas in the mountains with few sites suitable for villages or extensive gardens. By contrast, areas of "high" landslide hazard, because of their greater topographic variability, usually have some safe sites for villages and some sites suitable for gardens. In the intermediate zone, areas mapped as "low" landslide hazard generally comprise steep slopes that have few safe sites for villages although there are large areas suitable for gardens. While "safe" areas are predominantly wide ridges and old terraces that are suitable village sites, but soils lack fertility and are not suitable for gardens.

Our observations during aerial reconnaissance of all the upper watersheds and field study in the Sutakama River, a tributary of Mbalisuna River, indicate that ridge crests are generally the safest sites. Most villages are presently sited in such locations. Ridges in the foothills are usually wider and less at risk from landsliding than those in the mountains. Frequent landsliding makes many mountain slopes unsuitable for development. River beds are unstable and subject to frequent flood and, in some places, debris flows. Even terraces ten or more metres above river level may be flooded in large events. They also may be covered in landslide debris from the slopes above. Consequently all but the highest terraces should not be considered as safe village sites.

11.5 Disaster relief planning

The hazard maps identify areas on the Guadalcanal plains that should be safe from flooding in large floods as occurred in Namu. These localities are logical sites for evacuation centres and for locations from which to distribute relief supplies in future floods.

The maps, by identifying areas that are likely to be flooded in different magnitude events, are useful for planning civil defence strategies. They indicate what areas will be flooded first and what areas are likely to be worst affected. In Namu peak flood levels on the plains occurred in daylight hours. Loss of life would have been much greater had the flood peak occurred at night and evacuation that much more difficult. Civil Defence plans, however, must be made that consider how to minimize loss of life in a large flood that peaks in the hours of darkness.

The maps also highlight the enormity of the hazard. They will be important, as time passes and memories fade, as records of the extent of flooding in Cyclone Namu.

11. 6 How best to disseminate information on hazards

It is important to indicate to developers, planners and the people living on the plains, the consequences of flooding in different areas. Then they can choose what to do about it. Many groups are involved, including central and provincial government planners, financial institutions that fund development projects, private developers and the land owners and villagers themselves (Appendix 2) These groups should have access to this report and maps if this project is to fulfil its goal of developing rational strategies for land use and development on Guadalcanal.

This report is too technical to be used to persuade villagers, extension workers, or developers to avoid areas that have a high risk of flooding or landsliding. Yet there is a need to widely disseminate the information contained in the maps and some of the strategies that can be used to minimize hazards. Where not to put houses or developments, where to go to in a big flood, and the advantages of building houses on stilts, should be publicized. This may be best done with simple cartoon handouts or through discussions with villagers and developers. It is important to involve the local landowners so that they participate in the planning and hazard management process rather than having a government decree forced on them. We lack the language skill to disseminate the information in our report to the local people but would welcome the opportunity to provide technical input to assist others to do so. An indication of the messages that should be conveyed in a handout is provided in Appendix 3. It is important that information is disseminated quickly. Development on the Plains is intensifying, memories of Namu are fading and new people are settling on the Plains who did not experience Namu. We believe the Physical Planning Division and their provincial counterparts, and the National Disaster Council, in conjuction with the Solomon Island Higher School of Education, are the appropriate organizations to prepare the handout. The latter, through its Department of Natural Resources, is involved in training planners and is an excellent vehicle for disseminating information into the community.

11.7 A floodplain management plan

Most of the Guadalcanal Plain is at risk from flooding. A flood management plan for the Plains would help ensure that:

- the use of flood-prone land is planned and managed in a manner compatible with assessed frequency and severity of flooding;
- information on the nature of possible future flooding is available to the public;
- all reasonable measures are taken to alleviate hazard and danger from flooding;
- there is no significant growth in hazard and damage potential resulting from development;
- appropriate and effective warning systems exist, and emergency services are available for future flooding.

The development of such a plan takes into account hydrologic and hydraulic analysis, economic analysis, social and environmental impact analysis, and local planning factors. Given the complexity and range of issues involved in developing a floodplain management plan it is unreasonable to expect anyone agency to have a high level of expertise in all of these fields. Consequently a floodplain management working group, comprising staff from various Ministries, provincial government and the local community should be formed and have the task of coordinating the preparation of a flood hazard management plan for Guadalcanal Plains. Technical expertise from outside of Solomon Islands may be necessary to assist this group in carrying cut this task.

12.0 DISCUSSION

12.1 Climate change

Global warming from the "greenhouse effect" may lead to sea level rise. This will increase the risk of flooding in low-lying coastal areas but will not alter the flood hazard over most of the Plains. Coastline retreat will occur in some areas but progradation of the deltas of the major rivers is likely to maintain the present position of the coast in many areas.

12.2 Long-term floodplain evolution

The Plains are made up of a series of coalescing fans built by the rivers draining the mountains of northern Guadalcanal. On all fans rivers tend to abruptly shift their courses as deposition in the channel raises the river level above that of the adjacent fan. Thus, in large floods, a river may break its banks and create a new channel or re-occupy an old channel where it has flowed in the past. The major rivers on the plains are perched above the surrounding land. Eventually, in some large flood, the rivers will change course and flow in a new channel cut in the lower part of the fan. The flooding in Cyclone Namu suggests that the break out will occur near the upper part of the plains and that any new river course is most likely to be down the topographically low area where adjacent fans meet. However, the probability of river course changes is unknown. There are no prominent old channels on the plains, suggesting that course changes are infrequent.

More frequent river changes occur through the migration of meanders and the formation of cut-off channels. The first arises through scour on the outside of bends and makes the rivers more sinuous. The latter occurs when meanders are cut-off during floods and a new channel cut, shortening the channel. The migration of the meanders and the formation of cut-off occurs over decades (Figs. 15 and 16) and implies that all of the river channel between the terraces that confine the meanders must be considered as potentially active channel over a twenty to fifty year period.

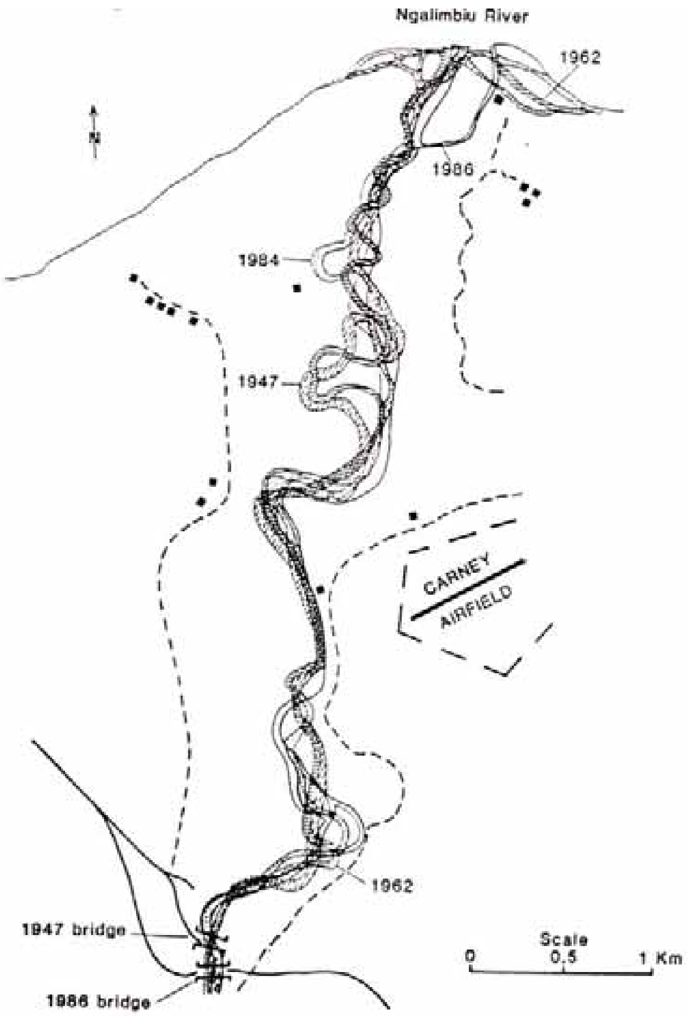

Figure 15. Changes in Ngalimbiu River 1947 to 1986 from aerial photographs taken 3.6.1947, 8.7.1962, 4.7.1979 and 2.8.1986 (post -Namu). Flood flows during Namu straightened the course. Prior to this, changes were predominantly related to migration of meanders and the formation of meander cut-offs. Rapid coastal progradation is occurring at the river mouth.

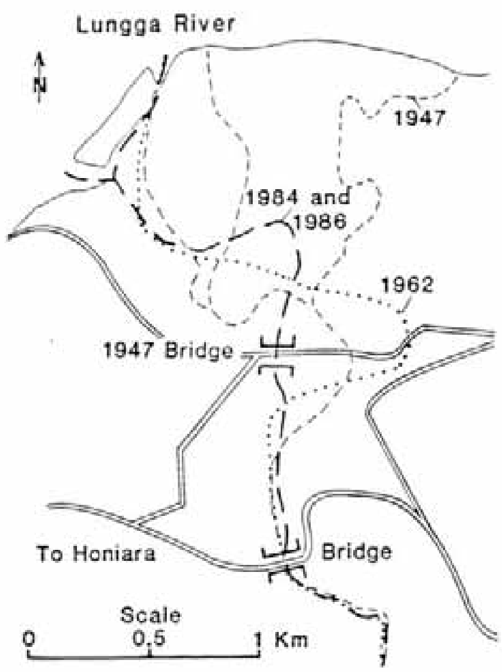

Figure 16. Changes in course of Lungga River 1947 to 1986 as shown on aerial photographs. Such changes make much of the delta vulnerable to flooding. Little change occurred in the flood flows during Cyclone Namu.

12.3 Value of post-Namu aerial photographs

This hazard mapping project would have been much more difficult if the postNamu aerial photographs had not been available. We commend the acquisition of these photographs after Namu. They are a valuable resource, not only to record the enormity of the damage in cyclone Namu, but also for planning ways to cope better with future disasters. We believe that such photography should be an integral part of any disaster relief aid.

13.0 ACKNOWLEDGEMENTS

Our work and stay in Guadalcanal was made possible through the support and assistance from Stephen Danitofea, Permanent Secretary, Ministry of Natural Resources and his staff. In particular, we thank Donn Tolia for logistic help, local knowledge and his willingness to help on all occasions, and Dereck De Pledge for hospitality, hydrological information and encouragement. We thank Bob Curry for initiatives in promoting the concept of hazard mapping. Sam Santalau and Primo Arnusea assisted with the field work in the mountains. We thank Peter Hadwen for support in implementing the project. Peter Newsome, Pam Woodruffe and Donna Foot-McGarvey produced the maps that accompany this report.

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APPENDIX 1

Description of sampled section on Matepono River

Location: western bank of Matepono River, 100m south of road bridge (see Fig. 13)
Sampled: 14 June 1989 by N. A. Trustrum and P. M. Blaschke.

Depth (cm)		Description
0	river silt from Cyclone Namu	Light brownish grey (7.5 YR 7/2)) silt, structureless, distinct wavy boundary.
30	buried soil 1	Dark greyish brown (7.5 YR 4(2) loamy sand, firm, moderately developed coarse nut grading to coarse blocky structure, indistinct irregular boundary.
80	river sand	Medium brown (10 YR 4/4) loamy sand, friable, moderately developed coarse blocky structure, distinct smooth boundary.
110	buried soil 2	Brownish black (10 YR 4/4) loamy sand, very firm, well developed coarse blocky structure, indistinct smooth boundary. Charcoal sampled for radiocarbon dating. (Sample WK 1491; 1220 ± ISO years old, old half life)
140	river sand	Light brown (10 YR S/6) sand, structureless, distinct wavy boundary.
180	buried soil 3	Dark brown (10 YR 3/3) clay loam, firm, moderately developed fine crumb structure, indistinct wavy boundary.
220		Reddish grey (S YR %/2) silty clay, firm, moderately developed fine crumb structure, diffuse irregular boundary.
280	river silt	Dark reddish brown (S YR 3/2) silty clay loam, friable to firm, moderately developed fme blocky structure, distinct wavy boundary.
340	buried soil 4	Dark brown (7.S YR 3/2) with reddish brown (S YR 4/3) mottles, silty clay, firm, moderately developed coarse nut structure, indistinct wavy boundary.
380		Dark brown (7.S YR 4/3) silty clay, firm, moderately developed fine nut structure, indistinct wavy boundary.
400	river deposit	Dark greyish brown (7.S YR 4(2) sandy loam, friable, weakly developed fine nut structure, indistinct smooth boundary.
430	buried soil S	Dark greyish brown (10 YR 4(2) with reddish yellow (S YR 6/8) mottles, silty clay, very firm, well developed fine nut structure, nuts are clay coated.
480	river silt	Pale brown (10 YR 6/3) silty clay, firm, moderately developed fine nut structure
S20		Section disturbed by erosion and slumping. At least one buried soil present in this zone.
630	river level	

APPENDIX 2

Agencies who we suggest should receive copies of this report and maps:

Development, land use and evacuation strategies should be compatible with assessed frequency and severity of flooding and landsliding. To encourage the use of information available in this report for planning we suggest that copies of it and the accompanying maps are sent to:

- Mr Stephen Danitofea
  Permanent Secretary
  Ministry of Natural Resources
  Honiara

- Mr Joseph Hasiau
  Secretary
  National Disaster Council
  Honiara

- Mr Steven Likaveke
  Chief Physical Planner
  Physical Planning Division
  Honiara

- Mr Brian Neilson
  Development Bank of Solomon Islands
  Honiara

- Permanent Secretary
  Ministry of Transport, Works and Utilities
  Honiara

- Permanent Secretary
  Ministry of Agriculture and Lands
  Honiara

- Mr S. Kateha Physical
  Planner Guadalcanal
  Province Honiara

APPENDIX 3

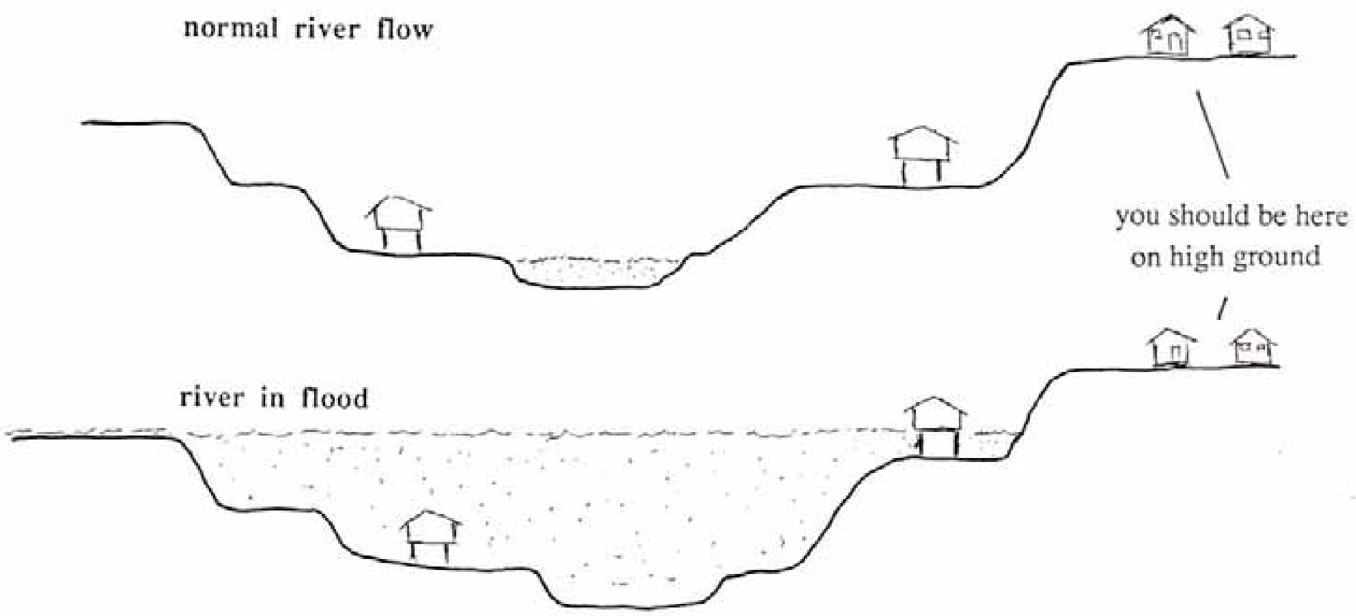
Brochure on flood hazard on Guadalcanal Plains

We suggest that the following messages should be conveyed to all people living on the Plains, and to developers and planners responsible for land use zoning on the Plains. A simple brochure, with the following messages, supported by cartoons and oblique photographs indicating flood hazard (see Figs. 8 and 9) should be prepared.

KEY MESSAGES:

1. Remember Namu. Massive flooding occurred in 1986, there are very few places that will not flood again sometime.
2. Identify where the safe areas are. Go there when lots of rain falls, and before the rivers rise.
3. If planning development or building houses be aware of the consequences of flooding.
4. Reduce the likelihood of damage by building houses on stilts.

POSSIBLE CARTOON

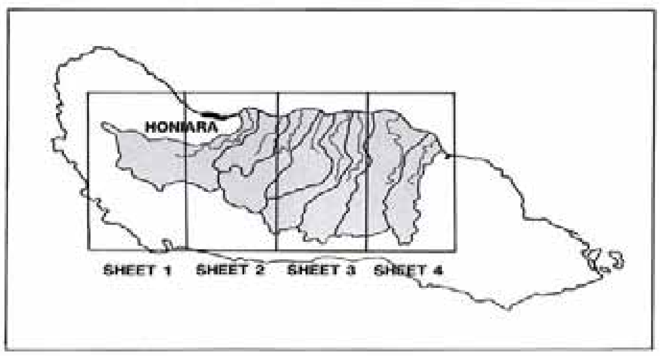


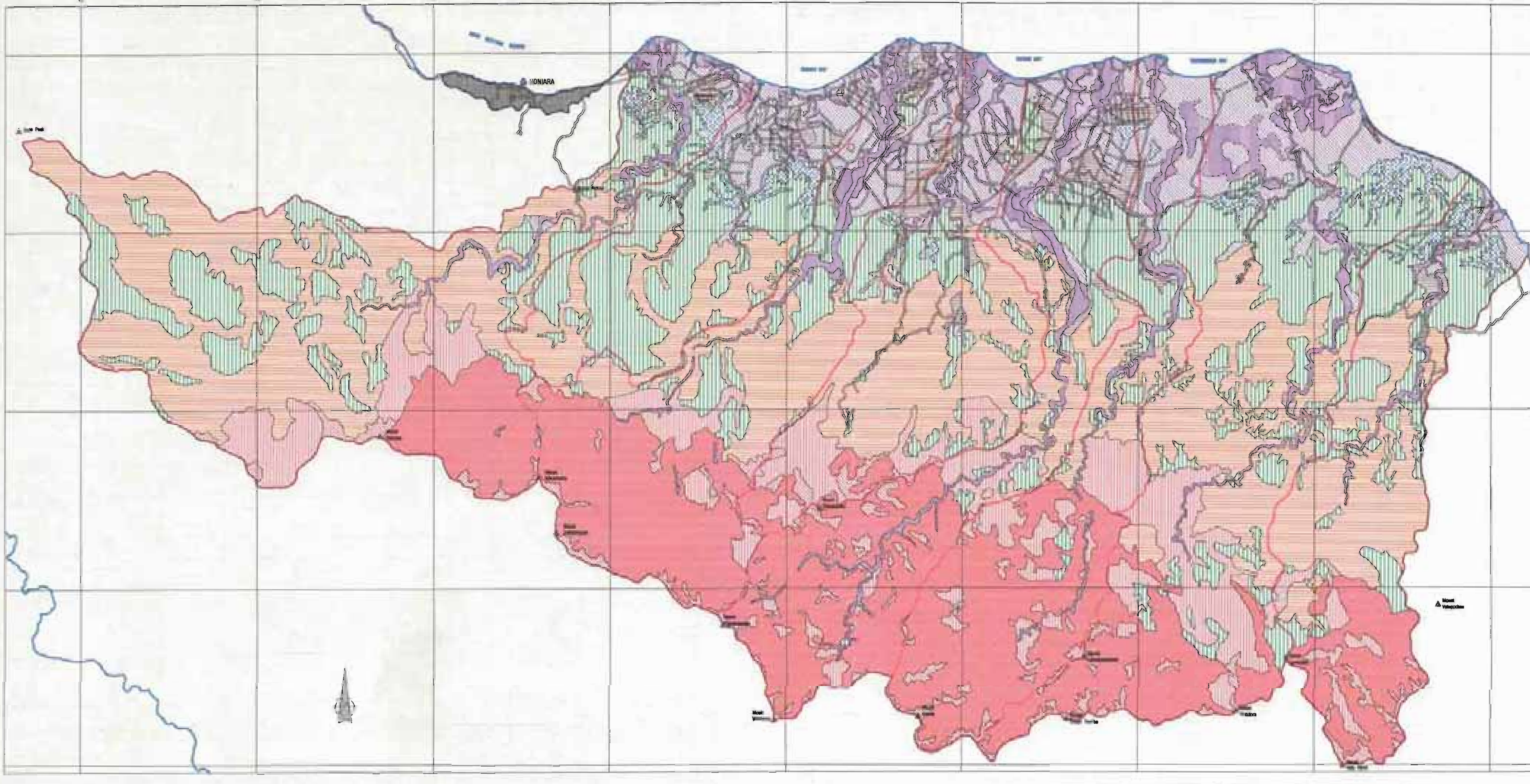
FLOOD AND LANDSLIDE HAZARD
NORTHERN GUADALCANAL
SOLOMON ISLANDS

MAPS TO ACCOMPANY
DLS CONTRACT REPORT 89/07
JULY 1989.
Division of Land and Soil Sciences
Department of Scientific and Industrial Research
Private Bag
Palmerston North
New Zealand.

THIS FOLDER CONTAINS

Summary Sheet 1 : 150 000
Sheet 1 1 : 50 000
Sheet 2 1 : 50 000
Sheet 3 1 : 50 000
Sheet 4 1 : 50 000





FLOOD AND LANDSLIDE HAZARD
GUADALCANAL, SOLOMON ISLANDS

LEGEND

FLOOD HAZARD	LANDSLIDE HAZARD	TOPOGRAPHIC REFERENCE
VERY HIGH	VERY HIGH	ROAD
HIGH	HIGH	AIRFIELD
MODERATE	MODERATE	WATERSHED
LOW	LOW	▲ MOUNTAIN PEAK
SWAMP	SAFE AREAS	

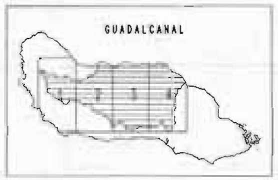
This map has been compiled from aerial photographs, supplemented by fieldwork. IT IS NOT A SUBSTITUTE FOR DETAILED SITE INVESTIGATION. Flooding from surface water ponding because of impeded drainage, occurs on most of the floodplain on average every 5 years or less.

SCALE 1:150,000

3 0 3 6 9 12 15 KM

This map accompanies: "Flood and landslide hazard, northern Guadalcanal, Solomon Islands." DLS Contract Report 89/07, Division of Land & Soil Sciences D.S.I.R., New Zealand.

LOCATION



Produced by: Division Land & Soil Sciences
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Palmerston North
New Zealand

For: UNITED NATIONS DEPARTMENT OF TECHNICAL COOPERATION FOR DEVELOPMENT
(UNTCD Contract 6/89-SOI/87/001)

Mapped and Compiled by:
M.A. Trustrum, I.E. Whitehouse,
P.W. Blaschke
July 1989

Map produced by:
P.F. Newsome, P.J. Woodruffe,
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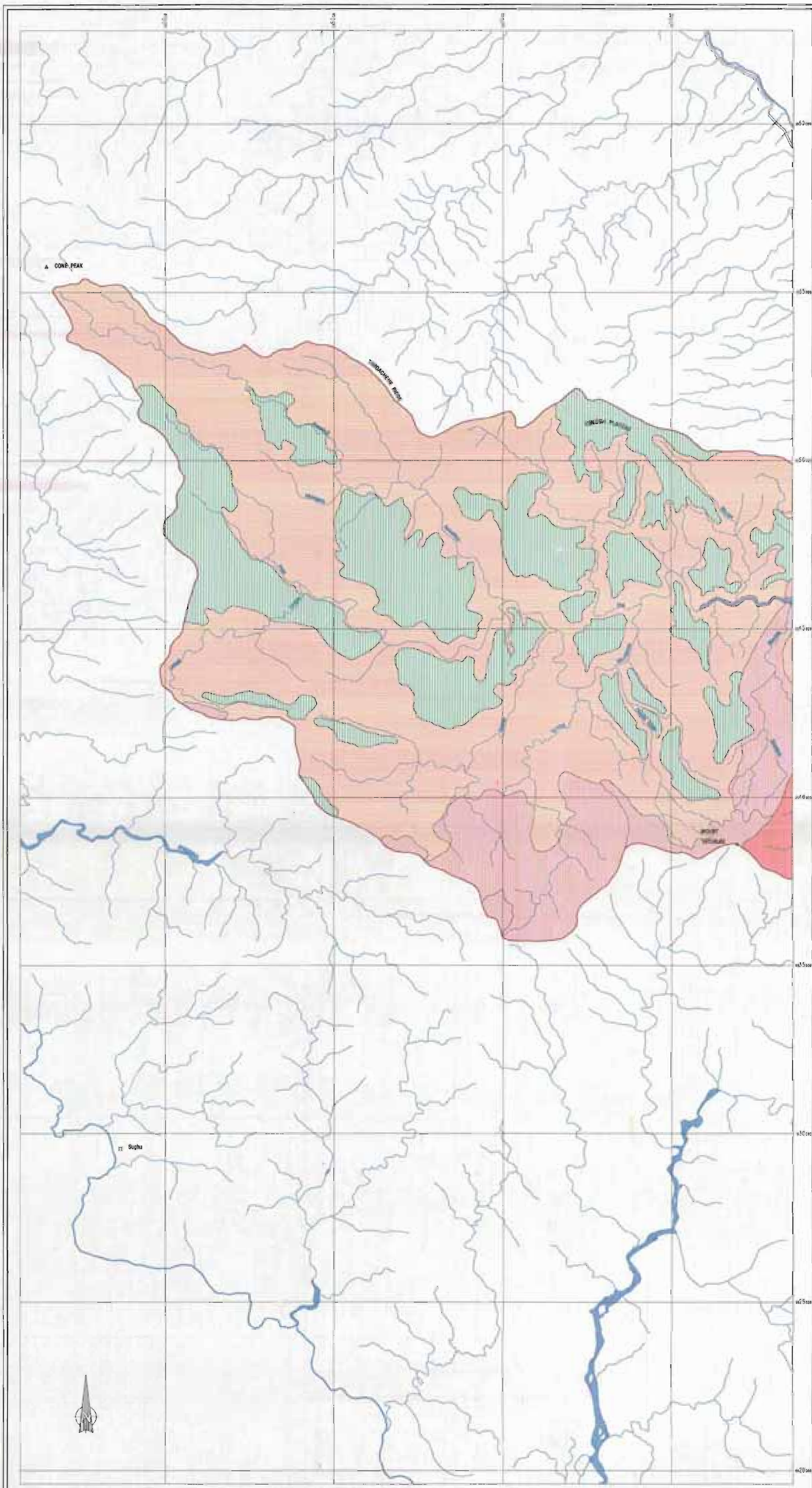
DSIR



FLOOD AND LANDSLIDE HAZARD GUADALCANAL SOLOMON ISLANDS

Sheet 1

LEGEND

FLOOD HAZARD

Annual probability of flooding

VERY HIGH	greater than 20%
HIGH	about 5 - 20%
MODERATE	about 1 - 5%
LOW	less than about 1%

LANDSLIDE HAZARD

VERY HIGH	Frequent shallow and deep landslides
HIGH	Frequent shallow and infrequent deep landslides
MODERATE	Infrequent shallow and deep landslides
LOW	Infrequent shallow landslides

SAFE AREAS

No significant landslide or flood hazard. Not flooded in cyclone Namu.

SWAMP

Large areas of permanently wet or very frequently wet land.

TOPOGRAPHIC REFERENCE

- WATERCOURSE
- ROAD
- TRACK
- AIRFIELD
- WATERSHED
- VILLAGE
- MOUNTAIN PEAK

SCALE 1 50,000

1 0 1 2 3 4 KM

CAUTION

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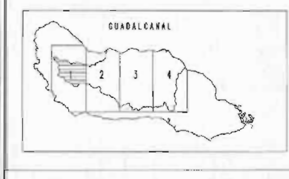

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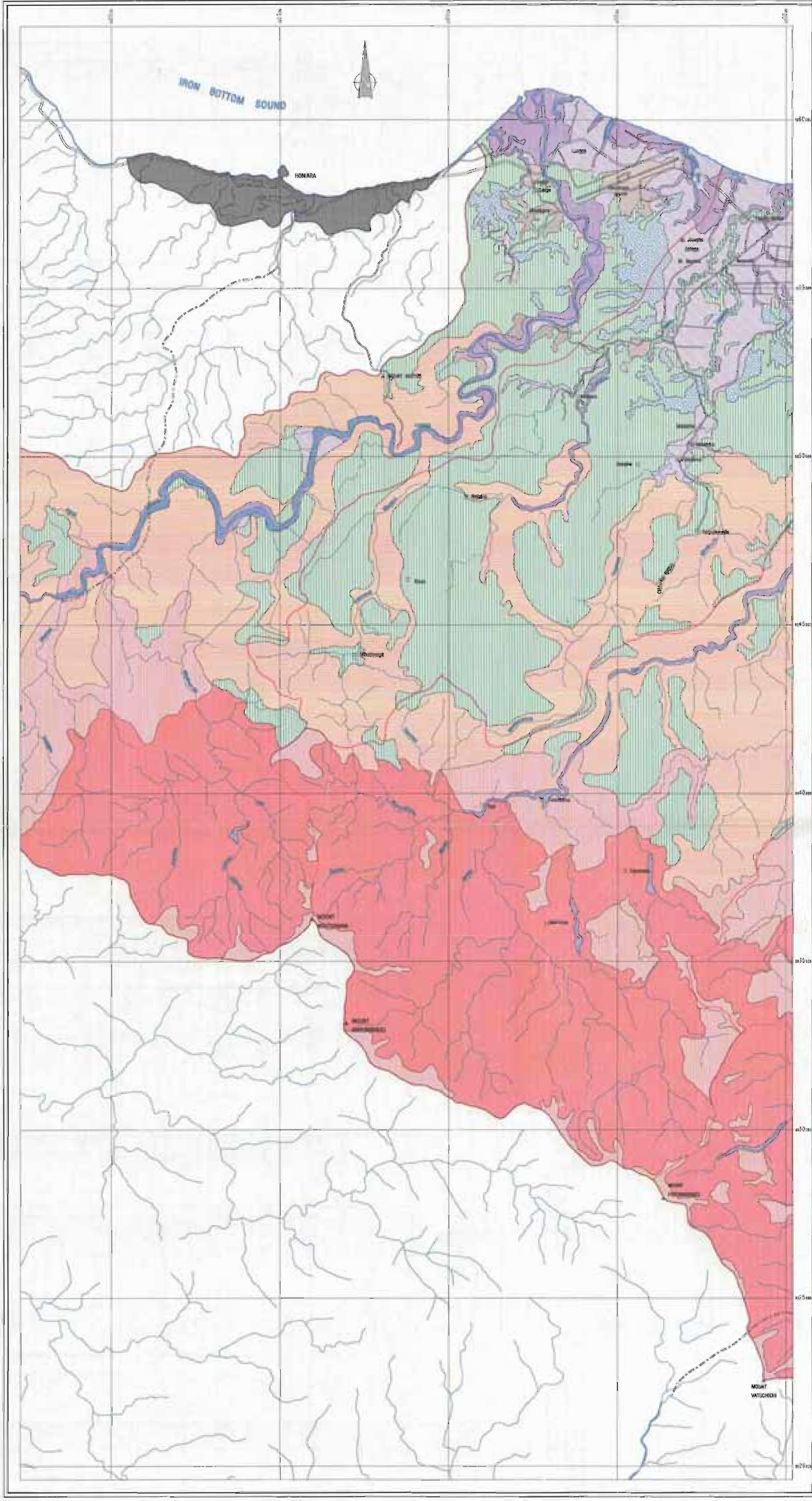

FLOOD AND LANDSLIDE HAZARD
GUADALCANAL SOLOMON ISLANDS
Sheet 2

LEGEND

FLOOD HAZARD

Annual probability of flooding

VERY HIGH	greater than 20%
HIGH	about 5 - 20%
MODERATE	about 1 - 5%
LOW	less than about 1%

LANDSLIDE HAZARD

VERY HIGH	Frequent shallow and deep landslides
HIGH	Frequent shallow and infrequent deep landslides
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LOW	Infrequent shallow landslides

SAFE AREAS

No significant landslide or flood hazard. Not flooded in cyclone Namu.

SWAMP

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1 2 3 4 KM

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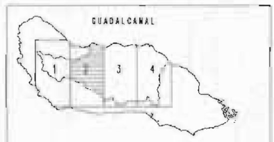

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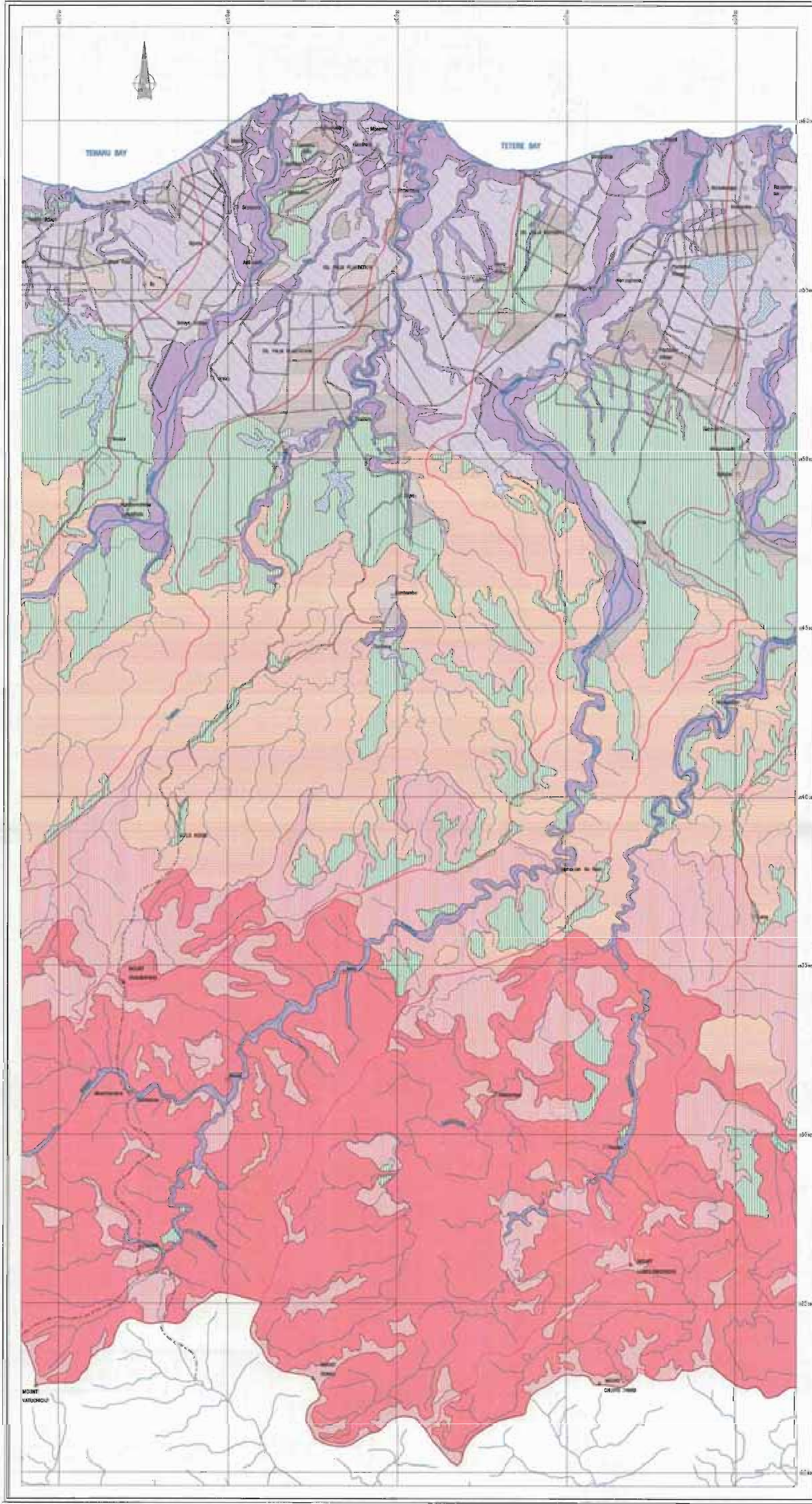

FLOOD AND LANDSLIDE HAZARD GUADALCANAL SOLOMON ISLANDS

Sheet 3

LEGEND

FLOOD HAZARD

	Annual probability of flooding
VERY HIGH	greater than 20%
HIGH	about 5 - 20%
MODERATE	about 1 - 5%
LOW	less than about 1%

LANDSLIDE HAZARD

VERY HIGH	Frequent shallow and deep landslides
HIGH	Frequent shallow and infrequent deep landslides
MODERATE	Infrequent shallow and deep landslides
LOW	Infrequent shallow landslides

SAFE AREAS

No significant landslide or flood hazard. Not flooded in cyclone Namu.

SWAMP

Large areas of permanently wet or very frequently wet land.

TOPOGRAPHIC REFERENCE

- WATERCOURSE
- ROAD
- TRACK
- AIRFIELD
- WATERSHED
- VILLAGE
- MOUNTAIN PEAK

SCALE 1:50,000

0 1 2 3 4 KM

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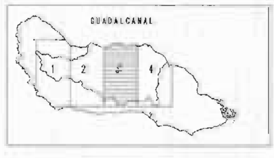

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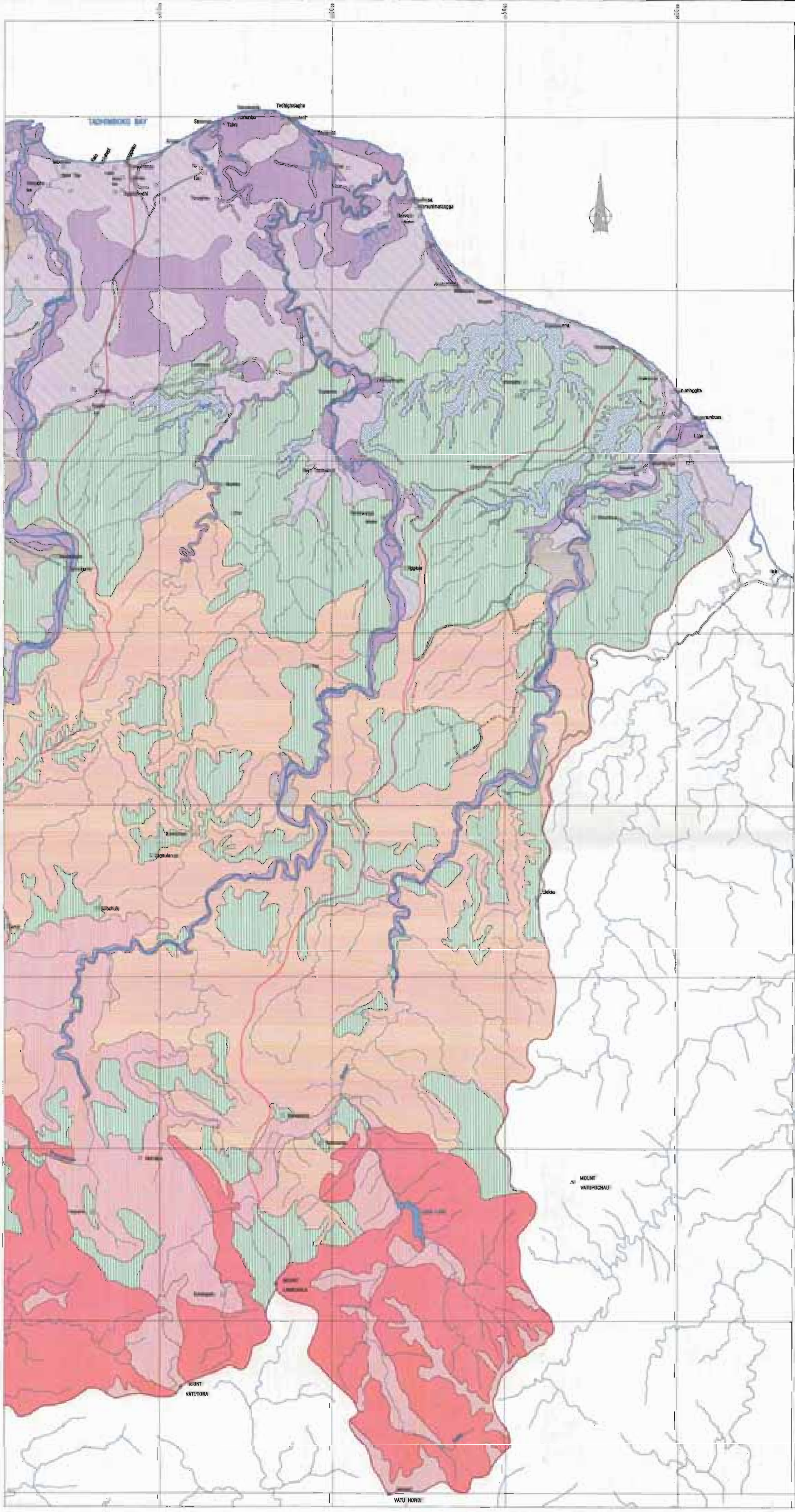

FLOOD AND LANDSLIDE HAZARD

GUADALCANAL SOLOMON ISLANDS

Sheet 4

LEGEND

FLOOD HAZARD

	Annual probability of flooding
VERY HIGH	greater than 20%
HIGH	about 5 - 20%
MODERATE	about 1 - 5%
LOW	less than about 1%

LANDSLIDE HAZARD

VERY HIGH	Frequent shallow and deep landslides
HIGH	Frequent shallow and infrequent deep landslides
MODERATE	Infrequent shallow and deep landslides
LOW	Infrequent shallow landslides

SAFE AREAS

No significant landslide or flood hazard. Not flooded in cyclone Namu.

SWAMP

Large areas of permanently wet or very frequently wet land.

TOPOGRAPHIC REFERENCE

- WATERCOURSE
- ROAD
- TRACK
- AIRFIELD
- WATERSHED
- VILLAGE
- MOUNTAIN PEAK

SCALE 1 : 50,000

0 1 2 3 4 KM

CAUTION

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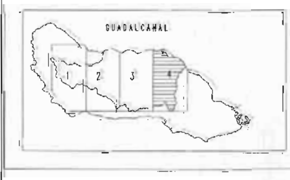

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FLOOD AND LANDSLIDE HAZARD
NORTHERN GUADALCANAL
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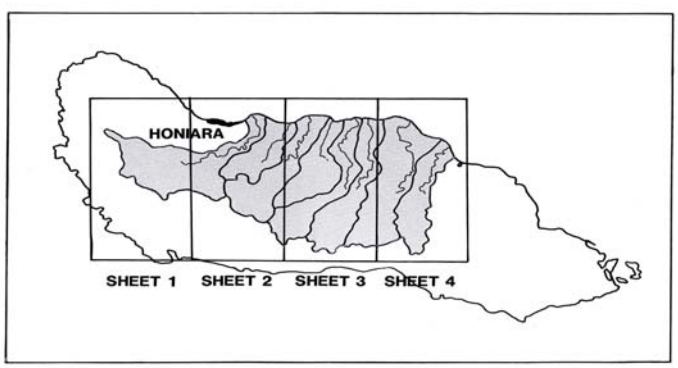

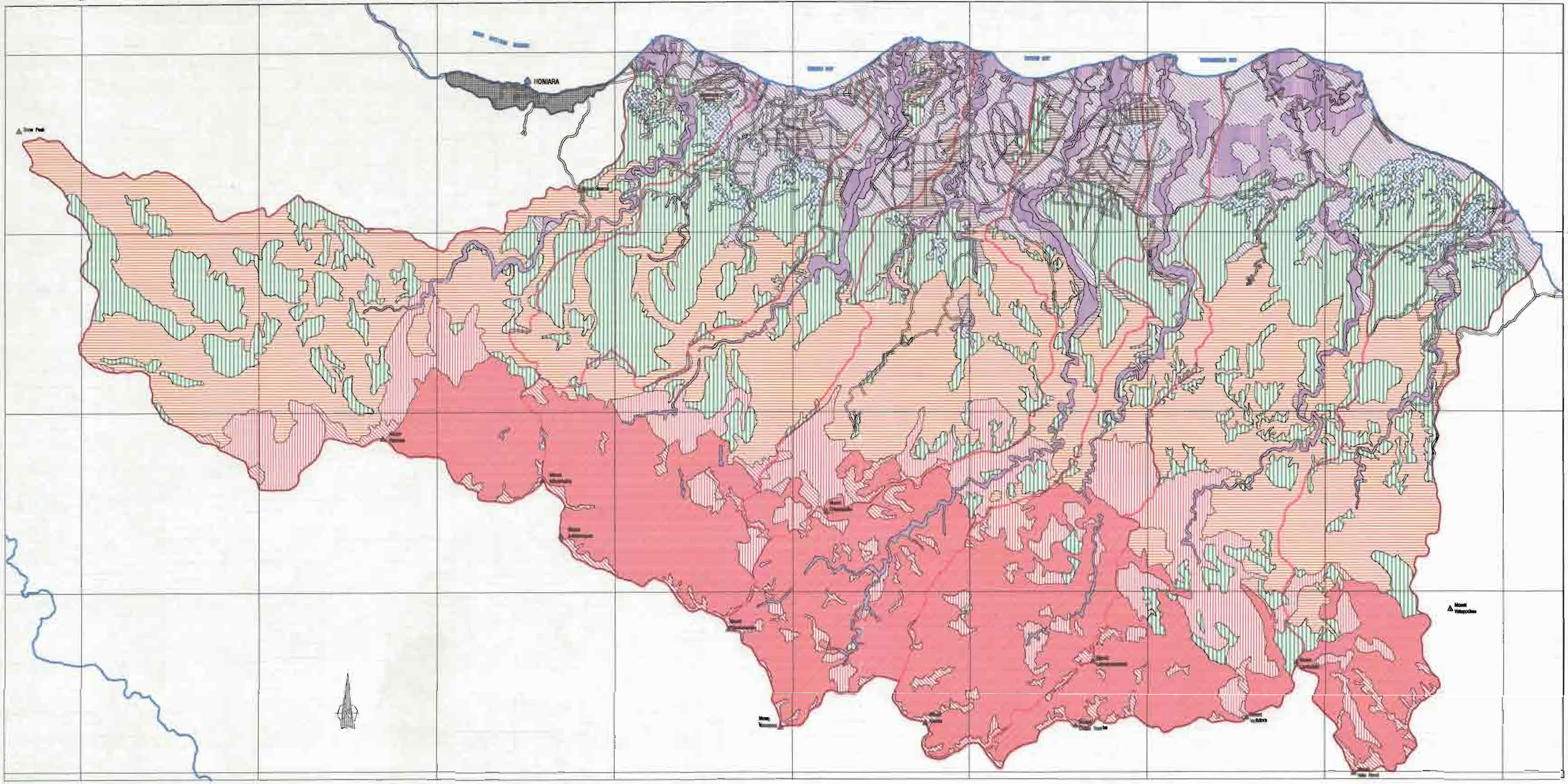

FLOOD AND LANDSLIDE HAZARD
GUADALCANAL, SOLOMON ISLANDS

LEGEND

FLOOD HAZARD
- VERY HIGH
- HIGH
- MODERATE
- LOW
- SWAMP

LANDSLIDE HAZARD
- VERY HIGH
- HIGH
- MODERATE
- LOW
- SAFE AREAS

TOPOGRAPHIC REFERENCE
- ROAD
- AIRFIELD
- WATERSHED
- MOUNTAIN PEAK

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3 0 3 6 9 12 15 KM

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FLOOD AND LANDSLIDE HAZARD

GUADALCANAL SOLOMON ISLANDS

Sheet 1

LEGEND

FLOOD HAZARD

	Annual probability of flooding
VERY HIGH	greater than 20%
HIGH	about 5 - 20%
MODERATE	about 1 - 5%
LOW	less than about 1%

LANDSLIDE HAZARD

VERY HIGH	Frequent shallow and deep landslides
HIGH	Frequent shallow and infrequent deep landslides
MODERATE	Infrequent shallow and deep landslides
LOW	Infrequent shallow landslides

SAFE AREAS

No significant landslide or flood hazard. Not flooded in cyclone Namu.

SWAMP

Large areas of permanently wet or very frequently wet land.

TOPOGRAPHIC REFERENCE

- WATERCOURSE
- ROAD
- TRACK
- AIRFIELD
- WATERSHED
- VILLAGE
- MOUNTAIN PEAK

SCALE 1 50,000

1 0 1 2 3 4 KM

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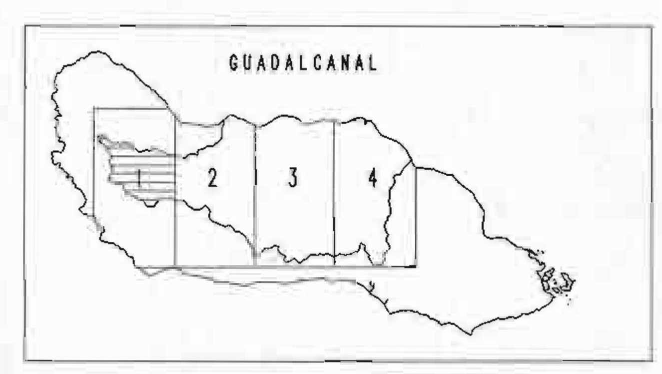

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FLOOD AND LANDSLIDE HAZARD GUADALCANAL SOLOMON ISLANDS

Sheet 2

LEGEND

FLOOD HAZARD

Annual probability of flooding

VERY HIGH	greater than 20%
HIGH	about 5 - 20%
MODERATE	about 1 - 5%
LOW	less than about 1%

LANDSLIDE HAZARD

VERY HIGH	Frequent shallow and deep landslides
HIGH	Frequent shallow and infrequent deep landslides
MODERATE	Infrequent shallow and deep landslides
LOW	Infrequent shallow landslides

SAFE AREAS

No significant landslide or flood hazard. Not flooded in cyclone Namu.

SWAMP

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SCALE 1:50,000

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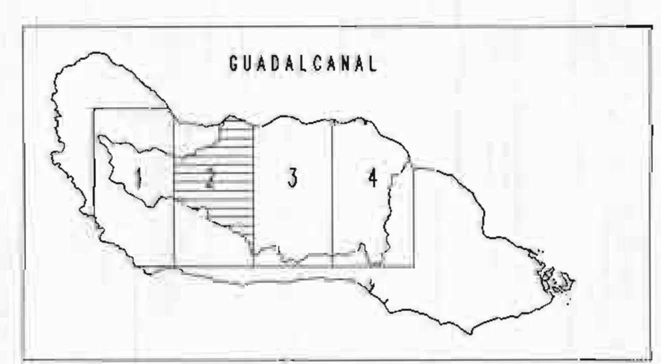

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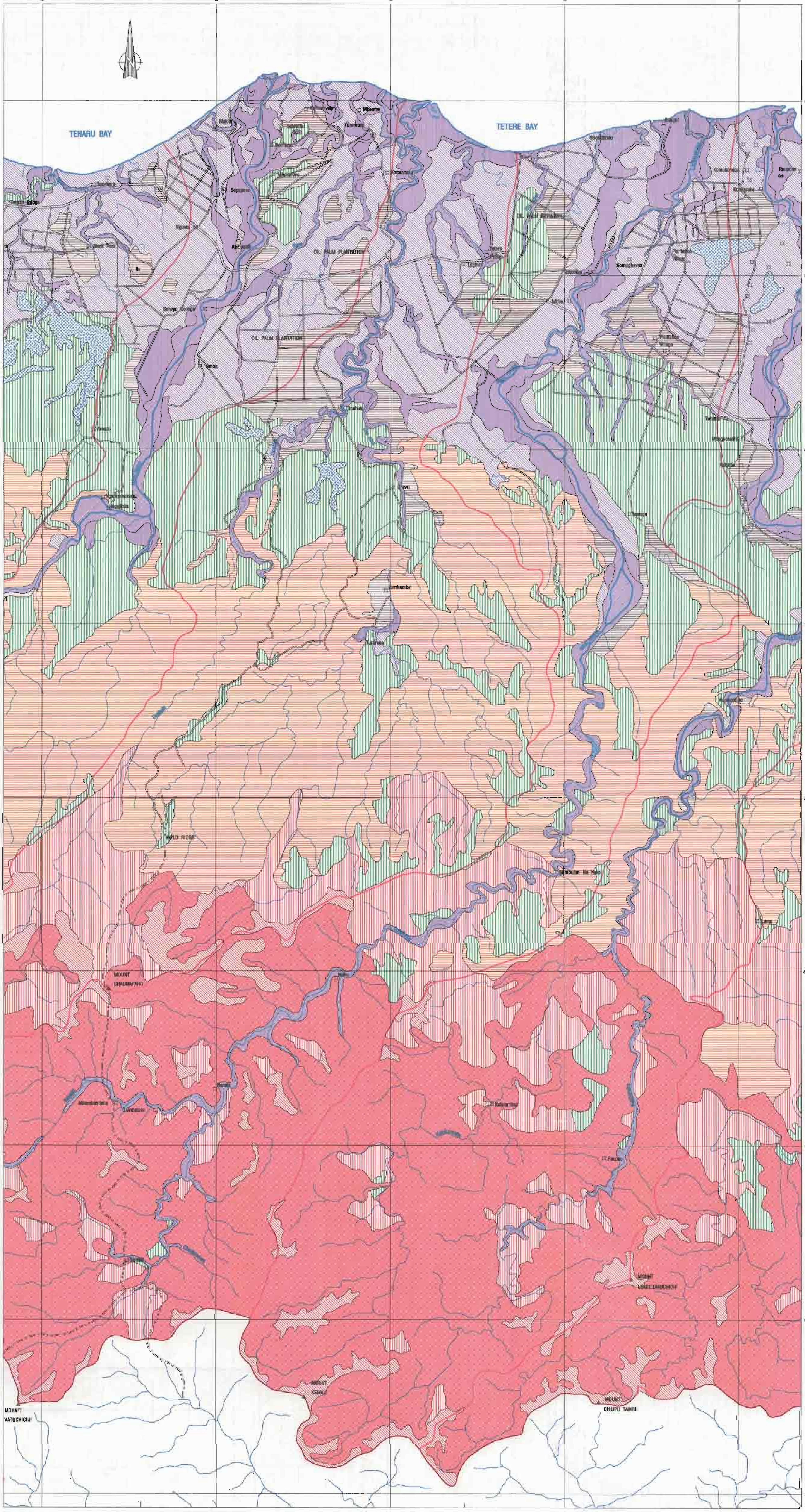

FLOOD AND LANDSLIDE HAZARD GUADALCANAL SOLOMON ISLANDS

Sheet 3

LEGEND

FLOOD HAZARD

	Annual probability of flooding
VERY HIGH	greater than 20%
HIGH	about 5 - 20%
MODERATE	about 1 - 5%
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LANDSLIDE HAZARD

VERY HIGH	Frequent shallow and deep landslides
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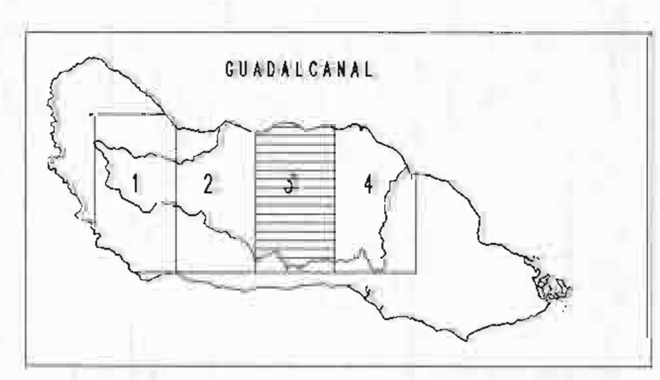

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D.L. Foot-McGarvey

FLOOD AND LANDSLIDE HAZARD GUADALCANAL SOLOMON ISLANDS

Sheet 4

LEGEND

FLOOD HAZARD

Annual probability of flooding

VERY HIGH	greater than 20%
HIGH	about 5 - 20%
MODERATE	about 1 - 5%
LOW	less than about 1%

LANDSLIDE HAZARD

VERY HIGH	Frequent shallow and deep landslides
HIGH	Frequent shallow and infrequent deep landslides
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SAFE AREAS

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- VILLAGE
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SCALE 1 50,000

1 0 1 2 3 4 KM

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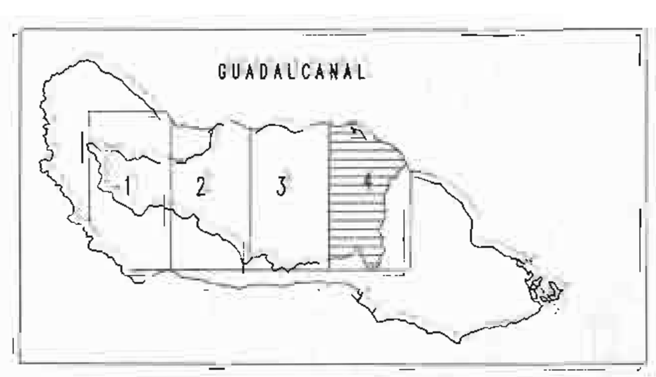

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Division of Land & Soil Sciences
D.S.I.R., New Zealand.

Produced by: Division Land & Soil Sciences
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For: UNITED NATIONS DEPARTMENT OF TECHNICAL COOPERATION FOR DEVELOPMENT
(UNTCD Contract 6/89-S01/87/001)

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July 1989

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