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Cleaning up after Cyclone Namu, Solomon Islands, 1986. Hazard mapping will help identify vulnerable areas.

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ASSESSMENT OF NATURAL HAZARDS IN THE SOLOMON ISLANDS AND IMPLICATIONS FOR OTHER PACIFIC ISLAND COUNTRIES

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Introduction

The emphasis in this study of natural hazards in the Solomon Islands is on the consequences of hazard impact with the aims of identifying the most damaging hazard, the most damaged area, the most deadly hazard and the most deadly area. Whilst damage to all buildings and infrastructure, crops and the environment has been recorded, the mapping project has concentrated on damage to traditional buildings. The project was undertaken with a grant from the Australian International Development Assistance Bureau (AIDAB).

The natural hazards studied include tropical cyclones, earthquakes, volcanic eruptions, tsunami, other storms, floods, and drought. The first four of these hazards have had the greatest impact on the Solomon Islands.

The position of individual islands, in relation to tectonic plates, latitude and longitude as well as their size and topography, determines the incidence to natural hazards. Because of these variabilities, each island and separate geographic areas within the larger islands, have to be studied individually in order to determine their vulnerability. In order to assess the amount of damage within areas of a "reasonable" size, the islands were divided into 146 areas which generally correspond with the wards used in the 1976 population census. This approach was used as fairly accurate population figures, needed to assess the risk from each hazard, were available for each ward.

The Solomon Islands Damage Scale was developed in order to estimate the degree of damage to houses constructed from traditional materials. The scale is constructed in such a way that cumulative damage to traditional buildings can be calculated for any number of hazards or type of event, thereby allowing identification of the most damaged area and the most damaging hazard (Blong et al., 1991).

Various sources provided the data for this project, the most valuable being the personal library of J.C Grover, ex-resident and Chief Geologist of the Solomon Islands as well as natural disaster files maintained by the Natural Hazards Research Group at Macquarie University collected from the **Sydney Morning Herald** and **Pacific Islands Monthly, The British Solomon Islands Protectorate News Sheet**, the British Solomon Islands Reports for the Year, Solomon Islands newspapers, and missionary magazines.

Physical and Social Setting

The Solomon Islands consists of almost 1,000 geologically diverse islands which cover 27,990 km^2 within 800,000 km^2 of ocean. They are located between 5° and 12° south and 155° and 170° east, which places them on the northwestern boundary of one of the most active cyclone regions in the world (Figure 1).

The main group of six islands form a southeast trending double chain of islands which vary in length from 80 to 170 km and 25 to 50 km in width. It is situated in a complex tectonic zone at the boundary of the Pacific and Indo-Australian plates (Cooper et al., 1986). These islands are of volcanic origin overlain by marine sediments and are covered with dense rain forest in the mountainous interior. Guadalcanal, which contains 18% of the population, has a mountainous interior containing the tallest peak in the islands at 2447 m. These mountains are characterised by steep sided valleys prone to

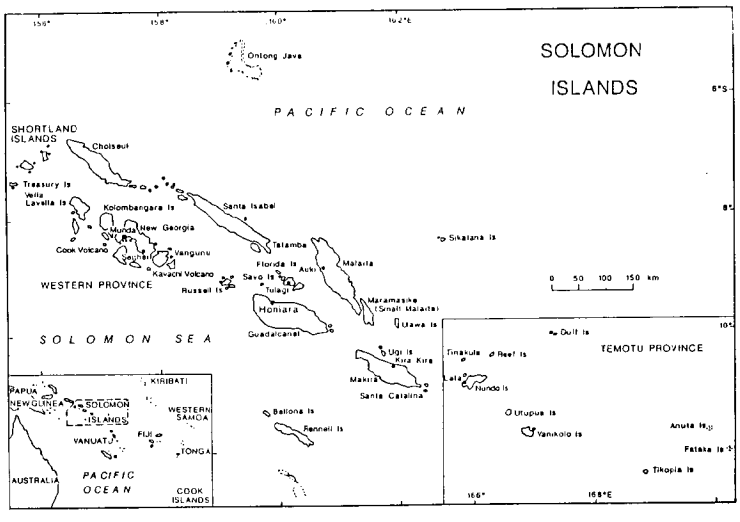

Figure 1 Solomon Islands

landslides and short rivers prone to flash floods. The southern "Weather" coast of Guadalcanal is so called because of the high rainfall and stormy seas experienced in the area.

The Guadalcanal Plains along the northeast coast of the island, 47 km long and up to 10 km wide, is the largest alluvial area and contains the largest agricultural area in the country. Henderson International Airport, is situated on these plains as is a small industrial base and some plantations. The largest town and major business centre in the islands is Honiara which has a population of about 30,000 (10% of the total Solomon Islands population) and is situated on the western border of the Guadalcanal Plains.

Malaita is the most populated island containing 28% of the population. Eight per cent of the population inhabits Makira most of whom live on the north coast away from the swampy highlands. New Georgia (8% population) is a group of islands with a fringing reef. The majority of the population live on the coast. Choiseul (5% population) is the least developed of the main islands. Apart from two highland villages, the entire population are coastal dwellers. Isabel contains 5% of the total population; three quarters of these live in the south east of the island. Thirteen kilometres north of Guadalcanal lies the small, fertile, and thus densely populated, active volcanic island of Savo.

Ontong Java Atoll, on the Ontong Java Plateau, lies 270 km to the north of Isabel, between the latitudes 5°-5.6° South (Figure 1). The atoll consists of 120 vegetated islands of which two are permanently populated; many of the other islands are used as vegetable gardens. The total land area is only 12 km^2, the widest piece of land is 1 km and the highest area is a taro mound only eight metres above sea level.

Temotu Province is geologically separated from the main islands as it is situated on the North New Hebrides Arc. It lies approximately 450 km to the southeast and comprises nine single or groups of small scattered islands. Eight of the nine islands are volcanogenic, Tinakula being the only active volcano. The Reef Islands are biogenic in origin.

About 90% of the Solomon Islands population of approximately 300,000 live in rural areas and are engaged in subsistence agriculture in villages of fewer than 200 people. The main form of communication in the islands is by bush tracks and the main form of inter-island communication is by boat, although most of the larger islands also have airfields.

Meteorological Hazards

Tropical Cyclones - Spatial and Temporal Distribution

The tropical cyclone season in the Solomon Islands is generally considered to extend from November to April. However Cyclone Ida occurred from 30 May - 1 June 1972 and Cyclone Namu from May 16 - 19, 1986.

A total of 45 cyclones have been identified in the Solomon Islands area. The first was recorded in 1568, the second in 1788 and a total of only eight cyclones are known to have occurred before 1900. Six cyclones were reported in the first 50 years of this century and 31 since 1950. The cyclone record is certainly incomplete before 1950. It was not until the early 1950s that cyclones are known to have caused considerable damage in the Solomon Islands. Of the 31 cyclones which have occurred since 1950 at least 21 of them have caused damage.

The number of cyclone and damaging cyclone occurrences since 1950 are listed for each island in Table 1. In terms of the number of damaging cyclones, Guadalcanal has been most affected as 12 of the 16 cyclones have occurred on that island.

Table 1 Cyclone occurence on individual islands since 1950

ISLAND	NUMBER OF CYCLONES	DAMAGING CYCLONES
Guadalcanal	16	12
Makira	12	9
Malaita	9	9
Isabel	4	3
Choiseul	6	4
Shortlands	2	1
New Georgia	7	4
Sikaiana	1	1
Ontong Java	2	2
Anuta	1	1
Duff	1	1
Santa Cruz	7	4
Tikopia	5	5
Utupia	3	3
Vanikolo	2	2

Ontong Java, situated between 5°- 5.6° south, could be considered outside the tropical cyclone belt as cyclones rarely form so close to the Equator, but has experienced two damaging cyclones since 1950. Bayliss-Smith (1988) has suggested that the mean recurrence interval for cyclones on Ontong Java since the early 19th century is 60 years. The return interval for cyclones in the Solomon Islands as a whole since 1950 is one cyclone per year. However the interval varies greatly for each island. For example the return interval on Guadalcanal is 2.5 years, Malaita it is four years and Tikopia it is eight years.

Despite these average recurrence intervals the frequency of cyclones is quite variable. The 1971-1972 cyclone season produced three cyclones which affected the main group of islands. Ursula (December 1971) caused damage on southern Makira. Carlotta (January 1972) affected Guadalcanal, Makira and Malaita. Ida (May 1972) affected all six of the main islands. Similarly, between

1951 and 1953, Tikopia in the Eastern Islands suffered cyclones in December 1951, January 1952 and March 1953.

Tropical Cyclone Damage

Cumulative cyclone damage for the 20th century estimated using the Solomon Islands Damage Scale is most severe on the larger islands of Guadalcanal, Malaita and Makira (Figure 2). The more northeastern of the main islands have been less affected. The islands in Temotu Province have suffered little damage except for the most southerly island of Tikopia (Blong et al., 1991). Undoubtedly, Cyclone Namu, 1986, was the worst cyclone in the memory of Solomon Islanders and the social and economic effects of that cyclone have been well documented. Ninety thousand people, almost one third of the total population, were made homeless and damage was estimated at A$25 million.

As this cyclone affected a number of islands it illustrates the type of damage cyclones cause to various areas. Incessant rainfall for four days was the main cause of the damage on Guadalcanal where 22% of houses and 70% of food gardens were destroyed or damaged. Floods and landslides in central Guadalcanal washed away or buried villages, whilst flooding rivers covered parts of the Guadalcanal Plains with at least one metre of mud and silt. Houses, food gardens, commercial property, plantations and Henderson Airport were similarly affected. On the Weather coast, many villages were damaged by wind, rain and landslides.

In Honiara high winds knocked down power and telephone lines. Water was cut off as the water pipe was swept away and bridges were damaged; the flooding and damage to Henderson Airport closed it for five days before re-opening for emergency operations. On Malaita and Guadalcanal, rivers brought tonnes of mud, silt and trees into lowland areas. Storm surge damage was also apparent in coastal areas but difficult to distinguish from the effects of surface runoff and riverine flooding. On Makira, it was the wind which caused most damage to plantations and crops, particularly on the coastal areas.

On Sikaiana atoll, which has a total land area of 2 km^2, 80% of the houses were destroyed by wind and the water supply from wells and tanks was contaminated by debris and salt spray. The alternative to water, coconuts, were all destroyed as the palms were downed in the wind.

Most of the damage to the southern islands of Ontong Java during Cyclone Annie (1967) was from a storm surge which washed over the island destroying a village and many of the gardens and coconut trees.

Tropical Cyclone Deaths

Of the 45 cyclones in the record, only 11 are known to have caused deaths. One hundred and fifty-four fatalities have been recorded from cyclones and 111 of these, that is 70%, occurred during cyclone Namu. Only 24 people are known to have been killed in other cyclones this century, though this is probably an underestimate (Blong and Radford, in press).

Of the 154 fatalities it is possible to say how 94 occurred. Sixty-one (64%) were due to landslides during cyclone Namu. Three drowned in rivers, three were hit by falling trees and 23 drowned in the ocean when ships sank.

One hundred and two of the total deaths occurred on Guadalcanal, 28 in the eastern islands and 15 on Malaita and four on Makira. One death occurred on each of Bellona, Florida and Santa Catalina. No deaths from cyclones have been recorded from Ontong Java, Isabel or the Western Province, including the Shortland and Treasury Islands, New Georgia and Choiseul. In Temotu Province, deaths are recorded from the Reef Islands, Utupia, Vanikolo and Nendo (Table 2).

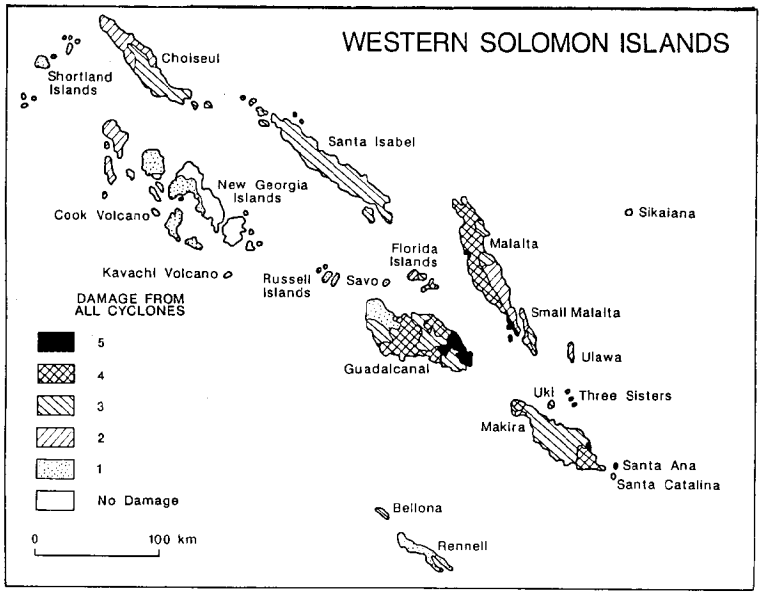

Figure 2 Damage from cyclones derived from Solomon Islands Damage Scale

Cyclone Namu dominates the record for deaths from cyclones. Ninety-seven occurred in the highlands of Guadalcanal where 61 people are known to have been buried in landslides. It is possible that some of the 36 deaths where the cause is not known were also the result of landslides.

Storms

There are only nine storms in the Solomon Islands natural hazards database. While this is almost certainly an underestimate it is worthwhile documenting. All damaging storms are reported from the islands of Florida, Malaita, Ghizo, and Guadalcanal. The first storm reported occurred in 1888 but the first report of damage was in 1936 when riverine flooding occurred. The third storm reported was nineteen years later in 1965 when a ship was badly damaged. Between 1968 and 1984, six more storms occurred, five of which caused wind or rain damage. All of the damage is reported from coastal areas where rivers flooded from excessive rain or high winds uprooted trees and disrupted power and telephone services.

Table 2 Place of death from cyclones

	NUMBER OF DEATHS
Guadalcanal	102
Malaita	15
Makira	4
Florida	1
Santa Catalina	1
Bellona	1
Vanikola	20
Reef	5
Nendo	2
Utupia	1
unknown	2
Total	154

The earliest record of deaths due to a storm was in 1595 when one of Mendaña's exploratory ships disappeared off the island of Tinakula in what was described as a squall. An estimated 20 crew drowned.

Seven people drowned when a canoe sank during a storm in 1888 and in 1984 13 people drowned off the coast of Ontong Java when their canoe capsized. It is probable that many more similar drownings have gone unrecorded.

Floods

Only 10 riverine floods are in the record, the first in 1961. Localised damage has been reported from six of the floods. A total of three children died in two floods. Damage has been reported on the island of Guadalcanal five times, and once on each of the islands of Isabel, Malaita, Makira and Savo. Heavy rain which caused floods and landslides on Savo on 1964 resulted in resettlement of some villages as food gardens were badly damaged. Food aid had to be supplied to about one quarter of the Savo population for three months.

Drought

There are four droughts in the database, only one of which caused famine. This occurred in between the cyclones of 1952 and 1953 on the island of Tikopia. Seventeen people died as a result of the famine. Food relief arrived in time to prevent further deaths.

Geologic Hazards

Seismic activity in the Solomon Islands is generally due to the underthrusting of the Solomon Sea Plate (between the Solomons and Papua New Guinea) beneath the north western islands of the Solomons, but the tectonic system is complex and the distribution and intensity of earthquakes is varied. From Bougainville to Makira the tectonic trench is well developed and seismicity is high along the southern side of the island arc. Between Makira and the eastern islands in Temotu Province the area is of lower seismicity.

Earthquake Damage

Damage has been recorded for about half of the 60 earthquakes reported this century. The most damage from earthquakes has occurred in the larger, most populated islands of Malaita, Makira, Guadalcanal and Santa Isabel, with the southern parts of Guadalcanal and Makira having the greatest risk. No earthquakes or earthquake damage have been recorded in Ontong Java (Figure 3) (Blong et al., 1991).

The most damaging earthquake recorded in the Solomon Islands occurred in October 1931 and had a Richter magnitude of 8.1. Malaita and Makira suffered extensively. On Makira, two villages were destroyed by ground shaking, 18 villages were swept away by a tsunami which rose 6-10 m above high tide and hundreds of landslides buried gardens. On Malaita, landslides dammed rivers which changed course, burst through their banks and flooded downstream.

The 1939 earthquake on Guadalcanal caused a tsunami which was also reported to be 6-10m in some areas. This destroyed most of the houses along the north and south west coast of the island. On the south west coast of Isabel and in the New Georgia islands, houses and crops were also damaged by a tsunami.

The earthquake of 21 April 1977 was 7.5 on the Richter scale. Extensive damage occurred in central Guadalcanal where landslides buried villages in a mountainous area where narrow ridges are divided by narrow and steep ravines. The landslides muddied streams and deprived villagers of a source of water.

Damage also occurred on Isabel, Malaita and Makira but reports indicate that it was minor. A small tsunami occurred on the south coast of Makira but no damage

was reported. In Honiara, the damage to poorly constructed buildings from ground shaking was considerable but minimal to sound buildings. During the five weeks following the earthquake three or four aftershocks occurred each day causing fresh landslides in the interior of Guadalcanal.

As vegetable gardens had been destroyed in the landslides and floods, food was provided for 10,000 people for eight months. Thirteen distribution points were set up but at times it was not possible for some villagers to reach these areas due to continuing bad weather. Food drops and the evacuation of people from the south coast of Guadalcanal by ship was delayed due to heavy rain and rough seas.

Earthquake Deaths

Of the 30 damaging earthquakes in the record only four of them have caused a total of 104 deaths. Fifty-Four of them occurred on Guadalcanal, five on Malaita and 50 on Makira. Of the 78 fatalities for which the cause of death is known, 62 died in tsunami, 15 in landslides and one was killed by a falling rock.

Tsunami

Tsunami may be caused by distant or local earthquakes. Since 1952, three tsunami generated at large distances have been recorded in the Solomon Islands but none have caused serious damage or deaths. The 1960 tsunami caused by the Chilean Earthquake did cause some damage to wharfs and inundated a village in Santa Isabel but the damage was minimal as the houses were raised on posts. It is tsunami generated by the local earthquakes noted above that have caused major damage and deaths.

Volcanic Eruptions

There are four active volcanoes listed in the *Catalogue of the Active Volcanoes of the World* (Fisher, 1957). These are Savo, Kavachi, Cook and Tinakula. Damage and deaths have been confined to Tinakula and Savo and on the two occasions where the impact of eruptions has been documented, it was the inability to flee the islands which apparently caused the majority of deaths.

In approximately 1827, a nuée ardente eruption, accompanied by an earthquake and tsunami occurred on the island of Tinakula. The inhabitants rushed to the coast so they could escape the effects of the eruption by going to sea, but a tsunami made it impossible to launch canoes which were the only means of escape. Consequently, the entire population was killed.

In the 1840s Savo erupted and an estimated 500 people died. As was the case on Tinakula, the only escape route was by sea. Reportedly, many people died as there were not enough canoes to escape from the island.

Kavachi, a submarine volcano in the New Georgia group, was first noted to have built above sea level in 1952. During subsequent eruptions it built above sea level in 1969, 1970 and 1976, but was soon eroded down to below sea level. In 1951 a minor tsunami occurred during the eruption. The Cook volcano has not built up above sea level and its identification is questionable according to Exon and Johnson, (1986) who think it may be a deep water vent.

The two volcanic eruptions which occurred in the first half of the 19th century caused an estimated 600 deaths, dominating the death record.

Indirect Health Effects of Hazards

The number of indirect deaths which have occurred following a number of the natural disasters have not been accounted for in this study as figures are not available; however, they may well exceed the number of direct deaths.

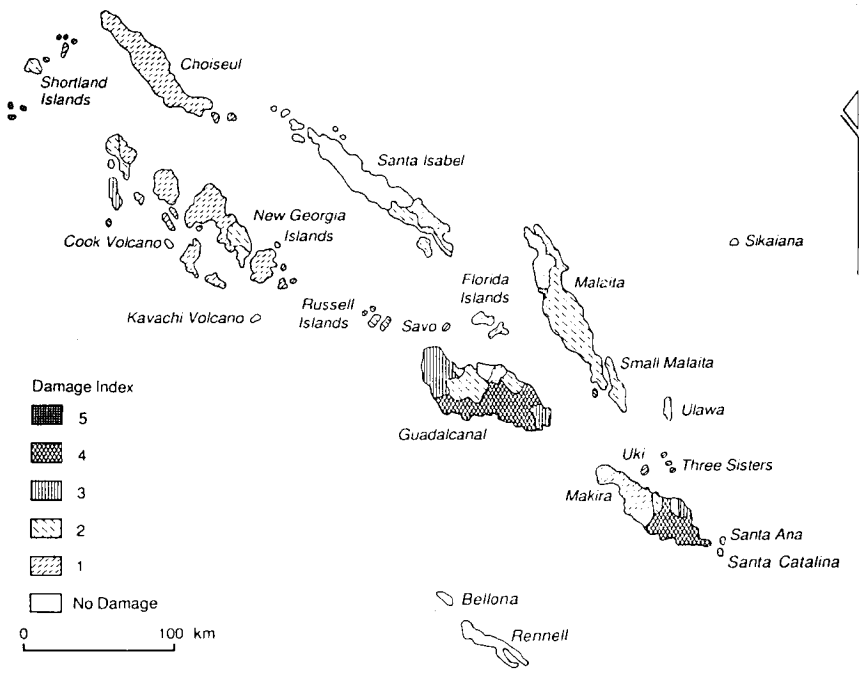

Figure 3 Earthquake damage 1900 - 1990

Five months after Cyclone Kerry struck (1979), an outbreak of malaria occurred, evidently because mosquito breeding places had not been sprayed following the cyclone. Following Cyclone Namu, severe exposure to flood conditions and an outbreak of malaria and diarrhoea caused the death of many children.

Survivors of the 1931 earthquake suffered further casualties as they had no shelter and an epidemic of influenza and pneumonia occurred. Six months after the 1977 earthquake, five children and an elderly man died in a village to which people had been evacuated, the cause being poor sanitation.

Hazard Pairing - Exacerbation of Effects

Hazards occurring together or in close temporal proximity may have a multiplying effect. Between 1951 and 1953, Tikopia in Temotu Province suffered cyclones in December 1951, January 1952 and March 1953. Between the 1952 and 1953 cyclones a drought occurred. The recovery of crops following the 1951 and 1952 cyclones was delayed by the drought; the effect of the drought was exacerbated by the cyclones and a famine resulted.

Geological hazards may occur in combination with meteorological hazards. The heavy rain and rough seas along the southern coast of Guadalcanal following the 1977 earthquake stopped a food relief ship from delivering its supplies. The amount of rain which fell both before and after the earthquake exacerbated landsliding. The rain prior to the earthquake helped to cause landslides during the earthquake; the rain following the disaster, when 760 mm (30 inches) fell in the first two days of July, caused more landslides, hampered overland rescue attempts and made temporary shelter difficult to find.

Impact of Extreme Events on the Record

Although 31 cyclones have occurred in the Solomon Islands since 1950, the cyclone damage and death record has been dominated by Cyclone Namu (1986) which caused extensive damage on a number of islands.

A similar pattern of domination by a small number of events is seen in the earthquake record where a total of 63 earthquakes have been documented but only three, occurring in 1931, 1939 and 1977, are known to have led to serious damage and deaths.

Destructive volcanic eruptions occur less frequently than the other hazards, but when they do occur they are more devastating in terms of number of deaths. However, due to their infrequency they may not be taken into account when threats from natural disasters are considered. It is now almost 150 years since any deaths resulted from volcanic eruptions in the Solomon Islands.

Overview of Natural Disasters in the Solomon Islands

The geography, topography and social nature of the Solomon Islands leads to specific problems caused by natural hazards. Reliance on subsistence agriculture means food aid often has to be given for some months following the disaster until gardens have been replanted and regrown. Because of the isolation of many of the islands, in terms of distance, limited communication, or lack of infrastructure within the islands, rapid response to disaster is often not possible. Cyclone Anne (1988) caused extensive damage in the Reef Island, Anuta, Duff and Utupua. However, lack of boats or aircraft and the remoteness of the islands meant that early assessment of the damage or prompt relief measures were not carried out.

As the country is composed of many islands there is a relatively large coastal area which is susceptible to tsunami. As a large per cent of the population lives on the coast, the risk of death and damage from tsunami is relatively high. The lack of a clean water supply in some rural areas and the interruption of health protection procedures following cyclones and earthquakes leads to outbreaks of disease and subsequent deaths.

Economic losses from natural disasters in an economy such as the Solomon Islands can be enormous. Because the country is heavily dependent on the export of primary products such as copra, cocoa, palm and wood products, which are particularly susceptible to damage in cyclones, interruption to these industries causes a significant decline in exports. Thus, the recovery from a disaster has to be met with a reduced income and reliance on overseas aid.

Hazard Severity and Future Risks

The severity of a natural hazard cannot necessarily be judged from its physical characteristics. The relatively moderate intensity of Cyclone Namu, 2-3 on the Cyclone Severity Scale, would not, of itself, indicate the amount of damage incurred. Its slow movement over the islands and the excessive rainfall were the main causes of damage from Cyclone Namu. As coastal development increases from population and industrial expansion in areas such as the Guadalcanal Plains, the risk of damage from cyclones and earthquakes will also increase. Cyclones of similar or greater magnitude than Namu can be expected in the future.

The 1977 earthquake magnitude does not take into account the effect of the rainfall or the effect of smaller aftershocks occurring in subsequent weeks. If the weather had been dry prior to the earthquake, many of the landslides in the highlands may not have occurred. The 1931 earthquake had a Richter magnitude of 8.1, and although it caused a great deal of damage and deaths,

it did not greatly affect what is now the most urbanised and agriculturally important area in the Solomon Islands. An earthquake of that magnitude affecting the north coast of Guadalcanal today would cause considerably more disruption and damage.

Eruptions of Savo or Tinakula will occur again, but it is not possible to predict when. The magnitudes of the next eruptions are also impossible to predict but may well be greater than those of the 19th century eruptions. Kavachi and possibly Cook Volcano in the Western Province could be the area producing more explosive eruptions and damaging tsunami in the future.

Conclusion and Implications for Other Pacific Island Countries

Examination of the phenomena associated with different hazard, indicates the characteristics of the damage which may be expected on the different types of islands. A number of countries in the Pacific Islands consist of at least one of the island types found in the Solomon Islands and are therefore vulnerable to the same hazards. Drought, floods, cold weather and distance generated tsunami which have either not been significant in the Solomon Islands, or their occurrence has not been documented, may have more impact in other Pacific Island countries.

It is essential to consider the diverse effects of hazard impacts on each island. It is not only the position of the islands in relation to seismic and meteorological activity which determines vulnerability to natural hazards but also the very nature of the islands; large coastal areas susceptible to tsunami; small low atoll islands susceptible to wind and storm surge; active volcanic islands; steep, landslide prone mountains and short, swift flowing, flood prone rivers.

The nature of the society increases the vulnerability to hazard recovery. All of the population in some areas rely on food and shelter from local gardens and lagoons. Inundation by salt water pollutes drinking water and retards plant regrowth; the loss of trees by wind damage causes loss of food and materials for shelter; soil erosion and burial of gardens in landslides means that there is a heavy reliance on food aid and raw materials for rebuilding for many months. Some villages and gardens have to be abandoned. The propensity to live in "hazardous" parts of the islands also increases risk.

Due to the inaccessibility of some of the more remote areas in the Solomon Islands, it can take some time to reach disrupted communities following a disaster. Similar problems occur in other Pacific island nations. Assistance may take some days to reach these areas, thus increasing the risk of post-disaster ill-health and deaths.

The vulnerability to cyclones depends on the latitude and longitude of the country and the majority of the Pacific Islands lie within the tropical cyclone zone. Storm surges and strong winds associated with cyclones are a major cause of deaths.

Views of the most damaged and deadly areas and the most damaging and deadly hazard change according to the length of the hazard record considered. It is evident that cyclones dominate the short (40 year) record and earthquakes become important in the longer, 80 year record. In the much longer record of about 200 years, volcanic eruptions are the major cause of deaths but cause damage to smaller areas than earthquakes or cyclones. The effects that a few events have on the number of deaths and/or damage in the record of natural hazards highlights the importance of extreme events in the Solomon islands. Thus, the longer the record, a more accurate picture of the impact of all natural hazards is obtained.

The study of natural hazards in the Solomon Islands has produced useful and surprising results. The identification of island and area specific effects of the varying hazard phenomena allows a more considered approach to be taken towards hazard mitigation and a more efficient targeting of aid. Studies in other Pacific Island countries could take a similar approach by considering the effect of all hazards together rather than individual hazards, and thereby building a regional view of all natural hazards in the Pacific Islands.

Acknowledgments

Thanks are extended to Joe Barr for his continued interest in the project and to Neil Flood for his valuable GIS expertise.

An Appeal

In our studies of the natural hazards and disasters in the Pacific we have found accounts in old missionary books, magazines and reports extremely useful. Undoubtedly, we have found only a fraction of this material. We would be most grateful for any information you have. Please write c/-School of Earth Sciences, Macquarie University NSW 2109, phone (02-805 8426) or fax (02-805 8428).

14 DEC 1992

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